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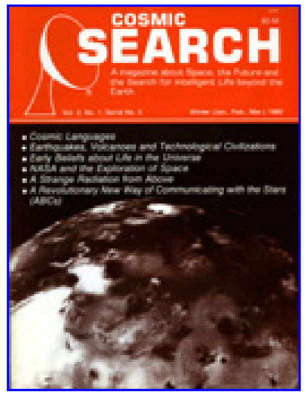

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[All Articles & Miscellaneous Items]

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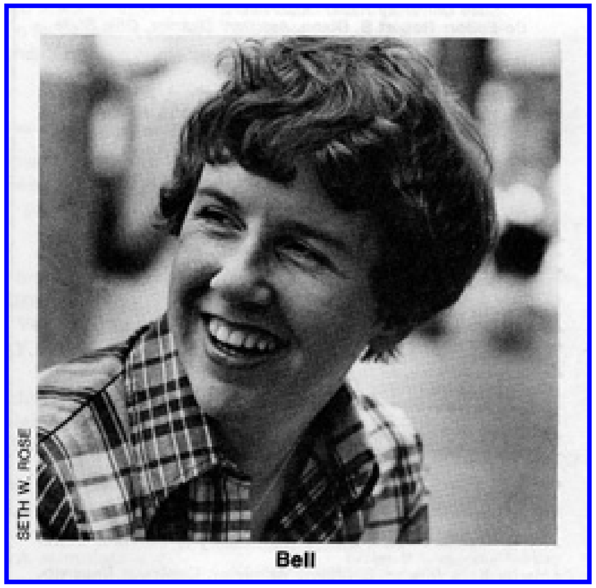
The Grand Analogy:
History of the Idea of Extraterrestrial Life

By: Trudy E. Bell

[Article in magazine started on page 2]



Bell

Is there life on other worlds?

As yet we do not know. On the basis of modern-day knowledge of astronomy and biology, the answer "yes" is strongly suspected: enough that the search for extraterrestrial life has already begun.

The single strongest piece of evidence in favor of the existence of extraterrestrial life is the fact that we exist. From that fact we know that at least once in the history of the universe a system of planets accreted around a warm stable star and that at some moment in prehistory on the surface of one of them life stirred in the primordial ooze. Now, if we are a valid sample of the universe and if planets and life and sentient beings evolved once in one corner of the Milky Way, might they not have evolved elsewhere as well? Indeed, might the event not be quite common? Sum, ergo cogito.

The question "Is their life on other worlds?" is at least as old as human speculation about the possibility of flight. Moreover, the reasoning from analogy with the earth that the answer might be "yes" is equally venerable. In the first century before Christ the honey-tongued Roman philosopher-poet Lucretius declared:

> "It is in the highest degree unlikely that this earth and sky is the only one to have been created ... Nothing in the universe is the only one of its kind, unique and solitary in its birth and growth ... You are bound therefore to acknowledge that in other regions there are other earths and various tribes of men and breeds of beasts."

In the Thirteenth Century a scholar in a totally different civilization, Teng Mu of the Sung Dynasty in China, reached the same conclusion by the same logic:

> "Empty space is like a kingdom, and earth and sky are no more than a single individual person in that kingdom. "Upon one tree there are many fruits, and in one kingdom there are many people. "How unreasonable it would be to

suppose that, besides the earth and the sky which we can see, there are no other skies and no other earths."

Nor are these two philosophers unique in the history of thought.

In order to answer the question "Is there life on other worlds?" (indeed, even in order to be able to ask it) one must operate upon three basic assumptions: that there are other worlds, that those other worlds might bear life, and that we have some means of discovering it. Although the first two assumptions appeared and disappeared at various times over the past two-thousand-plus years, the third one did not begin to appear in the modern sense until the first crude telescope was turned heavenward.

Are There Other Worlds?

For one and a half millenia, until the time of Copernicus, the generally accepted cosmology was a geocentric picture of the universe refined by Aristotle and Ptolemy. According to Aristotle's cosmology, the earth—composed of four gross and corruptible elements earth, air, fire, and water—was believed to be poised in the center of the universe. The rest of the universe, composed of a pure and noble fifth element, the aether, was a large sphere enclosing the earth, its boundary being the sphere of fixed stars. The sun, moon, and planets were embedded in concentric spherical shells between the earth and the stars. They revolved with uniform velocity around the earth by virture of motion imparted to them from a *Primum Mobile*, or prime mover, at the periphery of the sphere of fixed stars—needed because in Aristotelian physics there was no concept of momentum. In the Middle Ages, when the early Christians adopted the Aristotelian world picture, they replaced the unpersonified *Primum Mobile* by God; to them this proved that God was the necessary force in perpetual and direct contact with the universe that kept the stars in their courses and the planets harmoniously executing their silent ballet.

Now, the Aristotelian picture of the universe assumed only one abode for mortal life: the earth. The stars and the planets were simply lights composed of the aether, their brilliance produced by friction between the heavenly spheres. The Christians thus inherited from Aristotelian physics the idea of a unique abode of life—the earth—which accorded very well with the Biblical account of the special creation of man by God and with the story of Salvation by God's only begotten son. Such a cosmology did not admit of the possibility that other worlds like the earth even existed, much less that such worlds might bear life.

The Aristotelian cosmology seemed illogical to several medieval and early Renaissance thinkers. In 1440 the Cardinal Nicolas Cusanus wrote an essay, *Of Learned Ignorance*, in which he contended that the universe was indefinitely large with neither a center nor a circumference, that there was no essential difference between the nature of terrestrial matter and celestial matter, and that each star was a sun like our own with its own complement of planets, which were probably inhabited. Cusanus was a man before his time, however, and his ideas didn't have their greatest impact for another century and a half.

Copernicus rearranged the components of the universe and moved the sun to the center of the solar system. Earth was therefore delegated to be one of the solar system's planets. Despite these changes, Copernicus retained the idea of an outermost sphere of fixed stars.

From "De Revolutionibus Orbius Coelestium" courtesy Rare Book Division The New York Public Library, Astor, Lenox and Tilden Foundations.

The real pivot in thought about the existence of other worlds came in 1543, with the publication of *De Revolutionibus Orbium Coelestium*. In this work Copernicus commanded the sun to stand still and sent the earth revolving around it, a planet like all others. He halted the 24-hour revolution of the stars around the earth and started the earth spinning on its axis to create the same effect. But this modest canon of Frauenberg was not a heretic nor was he particularly revolutionary: he still kept the universe spherical and finite (although very large indeed), and he still kept the earth and the other planets embedded in their crystalline spheres and revolving with uniform velocity around the sun.

Whether Copernicus intended it or not, however, his sun-centered cosmology undermined the Aristotelian picture. The most crucial feature was that by arresting the diurnal rotation of the sphere of fixed stars around the earth, he deprived it of its primary physical function: to communicate the motion imparted to it by the *Primum Mobile* (or God) to the rest of the universe. Copernicus's intellectual successors were quick to perceive that, and Copernicus had scarcely been in his grave a decent time before they were shattering the crystalline spheres altogether, scattering the stars at various distances throughout infinite space, admitting a vacuum between them, and dreaming of other worlds inhabited by other men in the vast expanses of the solar system.

First, in 1572 Tycho Brahe observed a new star that flared up as brilliant as Venus and remained visible for over a year in the supposedly immutable realm of the fixed stars. Five years later he discovered that a bright comet exhibited no measurable parallax and from that he concluded that the comet had to be a celestial phenomenon traveling between the planets, puncturing their aethereal spheres—had such existed.

Meanwhile, in 1576 the leading Elizabethan mathematician Thomas Digges published *A Perfit Description of the Caelestiall Orbes*, in which he exulted that Copernicus's new concepts for the first time allowed the human mind to contemplate overthrowing the classical belief that the universe was spatially bounded by the sphere of fixed stars; in fact, Digges artfully worded his arguments in such a way that he made the notion of an infinite universe seem as though it were an integral part of the heliocentric hypothesis.

Thomas Digges decided to abandon the notion of a sphere of fixed stars and instead imagined the stars to be scattered throughout the universe to infinity. His diagram of this system was published in 1576 in his book, "A Perfit Description of the Caelestial Orbes."

A Perfit Description was so popular that between 1576 and 1605 it went through no fewer than seven editions. About the time that the third edition was published, in 1583, a renegade monk from Italy named Giordano Bruno came to the court of Queen Elizabeth. Exposed to Digges's thoughts, which supported his own mystically-inspired view of an infinite universe, partially drawn from Lucretius and Cusanus, he wrote several works that advanced the idea that the universe contained an infinite number of suns, each of which was accompanied by its own retinue of inhabited planets.

And indeed, philosophically, the hypotheses of Cusanus, Copernicus, Digges, and Bruno seemed to be confirmed that frosty January eve in 1610 when Galileo first turned his homemade telescope on Jupiter and discovered that the giant planet was orbited by four unmistakable moons.

The concept of a plurality of worlds in space shook the very foundations of Aristotelian Christianity. In the Christianized Aristotelian cosmology, heaven—the abode of God and the angels—lay outside the sphere of fixed stars; if the stars were strewn throughout infinite space, where was heaven? Without the crystalline spheres how could God directly intervene in life on earth? Indeed, in such a universe what was the necessity and role of God? Dangerous, frightening ideas, these—all direct implications from the cosmological model of a devout canon. It was in part for espousing such frightening ideas implicit in the concept of a plurality of worlds that in the early Seventeenth Century Bruno was burned at the stake, *De Revoluntionibus* was put on the Index of forbidden books, and Galileo—feared as a resurrected Bruno—was shown the instruments of torture and put under permanent house arrest.

But ideas, once they have inflamed the imagination, do not die, nor were they everywhere repressed. Telescopes were becoming available so rapidly that in a few short years hosts of philosophers and ordinary citizens began turning their own marveling eyes toward the moon, the planets, the starry Milky Way ... and began asking the inevitable next question.

Are the Worlds Inhabited?

The telescope revealed beyond doubt that the moon was a world much like the earth, with rugged mountains and large dark flat areas smooth as seas; clearly it was a solid opaque body that reflected the light of the sun and had no light of its own. The changing phases of Venus were so much like the moon's that Venus, too, must be a body like the moon. And if these bodies were so much like the earth in some ways, could it be that indeed they were exactly like the earth in all ways?

A number of Seventeenth Century authors explored that question, cautiously speculative. By far the most famous book on the subject was the engaging *Entretiens sur la pluralité des mondes* published in 1686 (the year before Newton's *Principia*) by a 28-year-old playwright named Bernard le Bouvier de Fontenelle. The book is written in the form of a delightful dialogue over half a dozen starlit evenings between Monsieur L---- and a fictitious quick-minded Marchioness of G----. Both the flavor and the essence of the conversations are embodied in one particularly nice passage:

> "I must tell you [says the monsieur], that in love and the mathematics, people reason much alike: allow ever so little to a lover, yet presently after you must grant him more; nay, more and more, which will at last go a great way; in like manner, grant but a mathematician one minute principle, he immediately draws a consequence, to which you must necessarily assent; and from this consequence another, till he leads you so far, whether you will or no, that you have much ado to believe him.... Now this way of arguing have I made use of. The moon, said I, is inhabited, because she is like the earth; and the other planets are inhabited, because they are like the moon; I find the fixed stars to be like our sun, therefore I attribute to them what is proper to him: you are now going too far to be able to retreat, therefore you must go forward with a good grace."

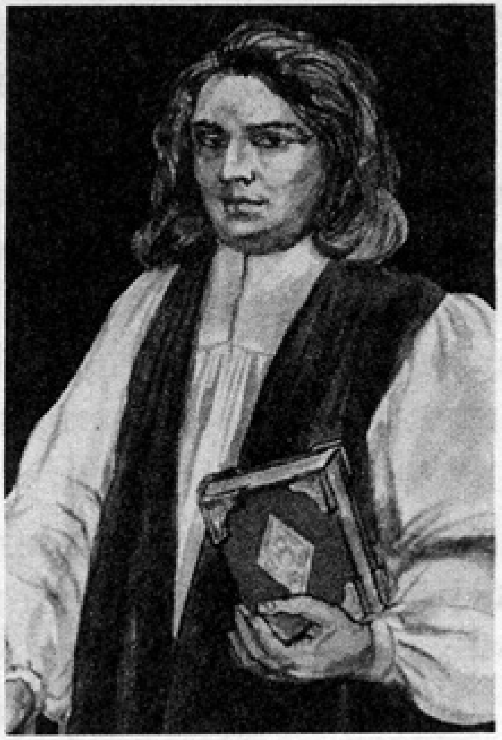
Fontenelle's *Plurality of Words* [sic; "Words" should be "Worlds"], as it was called, was read so avidly that it was translated from French into all the major languages of Europe; it had at least three separate English translations, one of which ran through six editions by 1737. One of its readers was none other than Christian Huygens, who actually felt that Fontenelle did not go far enough in his reasoning. Then in his 60s, Huygens put pen to paper and gave the world *Cosmotheoros* (Latin for "Theory of the Universe") in which he dispassionately and critically examined the possibility of life on other worlds.

Metrodurus (5th cent. B.C.)

Lucretius (1st cent. B.C.)

Teng Mu (13th century)

Bruno (16th century)



Wilkins (17th century)

de Fontenelle (17th century)

Huygens (17th century)

In one of the first attempts at stellar photometry, Huygens tried to determine how far away the stars actually are and concluded from his experiments that if Sirius were the same absolute brightness as the sun, it must by 27,664 times farther away—about a quarter of a light-year in modern terms.* (*In reality Sirius is 8.7 light-years away, but it is some 50 times brighter than the sun; if Sirius were only as bright as the sun, it would have to be seven times closer to the earth in order to have the same apparent magnitude—meaning that Huygens's estimate based on that assumption is impressively close to being correct.) At that distance, he concluded, from the earth no planets would be visible around another star because they would be so close to the star that they would be lost in the glare.

In our own solar system, Huygens methodically reasoned from analogy with the earth that all the planets must have plants and animals and intelligent life, all adapted to the heat or cold of their respective environments. But although the inhabitants must thus be different in some ways from those on the earth, they must also have many similarities: if they are mobile, for example, they must either walk over land or swim through liquid or fly through the atmosphere, meaning that they must have either legs, fins or wings. Huygens extended such arguments of necessity to include the inhabitants' culture, science, and morals. And all through the book he endeavors to show that a plurality of inhabited worlds did not contradict Scripture because

> ... should we allow the Planets nothing but vast Deserts, lifeless, inanimate Stocks and Stones, and deprive them of

> all those Creatures that more plainly speak their Divine Architect, we should sink them below the Earth in Beauty and Dignity; a thing very unreasonable..."

and also very wasteful, completely uncharacteristic of a God who has a purpose for everything.

Huygens's scientific reasoning about the existence of extraterrestrial life seemed to be confirmed by the rapid astronomical discoveries of the Enlightment. Newton's laws of gravity established a physical connection between all the bodies in the universe, and his first law of motion established the existence of inertia and momentum, thus eliminating the last Aristotelian need for a finite universe and *Primum Mobile*. James Bradley's observations of the aberration of starlight conclusively demonstrated that the earth was indeed moving around the sun. Furthermore, William Herschel's observations of double stars revealed that light-years away from the earth, bodies were behaving according to the same laws of gravity and motion that our own solar system was, proving finally that there was no difference between celestial matter and terrestrial matter—the universe was indeed all of a piece.

What powerful tool that was! It implied for once and for all that reasoning about other planetary systems by analogy with our own was indeed a valid approach. Even more exciting, the nebular hypothesis of Immanuel Kant and later Pierre Simon Laplace that the sun and planets condensed out of a spinning cloud of gas and dust, implied that planetary systems were a natural accompaniment to the formation of stars. These discoveries opened the way for a veritable flood of Eighteenth Century writings—ranging from scholarly treatises to cheerful essays in almanacs—setting out to prove the existence of extraterrestrial life and speculate what it was like.

Huygens's theological reasoning also threw open the way for others to demonstrate that—lo and behold!—the existence of a plurality of inhabited worlds actually glorified Scripture. In an influential work entitled *Astro-Theology* published in 1715, William Derham rushed in where Huygens dared not tread, populating all the bodies in the universe, even the sun and comets. "How can we say they are not inhabited?" he asked. "How can we place such limits on the infinitude of God's capabilities?" With such arguments the question of extraterrestrial life began migrating into a highly theological realm, until in the first half of the Nineteenth Century Thomas Dick unconsciously demonstrated the irony of Bruno's death by declaring in his *Sidereal Heavens*: "...though the Scriptures never directly or explicitly treat of this subject, the doctrine of a plurality of worlds *is embodied in many passages of the sacred writings*" (his italics).

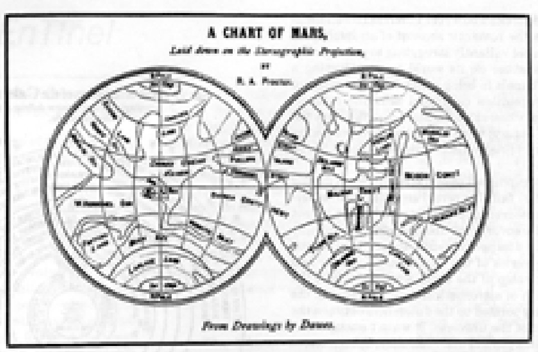
Now, to be sure, not every astronomer felt that the existence of extraterrestrial life was a foregone conclusion. Although by the Nineteenth Century negative views on the subject were prone to attack, there were a minority of dissenters, the most notable of whom was the British philosopher William Whewell. In his *Plurality of Worlds* of 1851 Whewell stated that he was skeptical about the concept of extraterrestrial life on theological grounds because he thought it unnecessary: to him the creation of man was the great event of the universe and he did not think it at all derogatory to divine wisdom to have arranged all the other bodies of the universe to provide an elegant setting for the existence of such a being.

On scientific grounds Whewell did not settle for the assumption of his predecessors that life would arise everywhere and adapt itself to the conditions under which it existed. On the contrary, he felt that certain conditions were necessary for life to arise at all. Neptune, Uranus, Saturn, and Jupiter were simply too far from the sun and too cold and dark for life; moreover, their gravitational fields are so great that at best any life there would not have a skeleton, but would "be cartilaginous and glutinous masses...boneless, watery, pulpy creatures" floating in the liquid environment. On Mars he abstains from commenting: "[We] need not discuss the question whether there are intelligent beings on the surface of Mars...till we have better evidence that there are living things at all." Mercury and Venus he depopulates in a page as being too close to the sun.

> "The earth, alone, is placed at the border where the conditions of life are combined; ground to stand upon; air to breathe; water to nourish vegetables, and thus, animals...; and with this, a due supply of light and heat, and due energy of the force of weight. All these conditions are, in our conception, required for life; that all these conditions meet, elsewhere than in the earth's orbit, we see strong reason to disbelieve...That the earth is inhabited, is not a reason for believing that the other planets are so, but for believing they are not so."

In that passage Whewell distinguishes himself as the first writer to describe what is called the zone of habitability. He also seems to be one of the first to recognize that life on a planet does not necessarily mean intelligent life, an assumption implicit in the writings of his predecessors.

The Nineteenth Century was a bustling, active, exciting era for astronomy. For the first time astronomers possessed big telescopes for gathering light from faint stars and for examining details on planets; for the first time they possessed spectroscopes for sifting the light to determine their chemical constitution. With the advent of tools for probing the physical secrets of the universe, theological arguments about the conditions on the planets began to have less force, and scientific arguments had more.



Richard Proctor compiled the first good map of Mars in 1869. This map, reproduced here from Proctor's "Other Worlds Than Ours", 1871, was in turn based upon drawings of Mars by the keeneyed observer W. R. Dawes. It is notable that Proctor included no canals and no canal-like features. Proctor did believe he was seeing evidence for the presence of continents and oceans on Mars.

The first really good map of Mars was constructed by the British astronomer Richard A. Proctor in 1869 [graphic on the left], but the map that inflamed the world was the one drawn a decade later by the Italian astronomer Giovanni Schiaparelli, showing that the ruddy surface of Mars appeared to be crossed and recrossed by a delicate tracery of dark lines that appeared to be channels, "canali" in his native Italian. In English, however, the word was rendered "canals", implying an artificial origin. Subsequent observations of seasonal changes on Mars by a number of astronomers, and compelling books by the American observer Percival Lowell thrilled the world with the romantic account of an intelligent race on a dying planet valiantly struggling to preserve the last remaining moisture on its world by constructing a heroic network of canals to bring water from the polar ice caps to nourish vegetation cultivated near the equator. Speculation and excitement about Mars ran high into the early Twentieth Century: were we on the threshold, after all these centuries, of finally discovering intelligent life on a neighboring world?

When the photographs and observations of Mars during its opposition in 1907 failed to reveal anything new, different, or exciting, however, popular interest in the planet began to wane. Moreover, that disappointment was only one in a series of disappointments about the planets. Whereas the discoveries of the Eighteenth Century had emphasized the kinship of the earth with the rest of the universe the wealth of astronomical data gathered in the Nineteenth Century pointed up the differences between the earth and the rest of the universe. It wasn't enough that they shared the same physics and chemistry. Spectroscopic observations indicated that Mars was a frigid desert, populated at most by lichens. Venus seemed to be a swamp, at best roamed by dinosaurs as in the earth's own past. The rest of the solar system was totally inhospitable: the moon was airless, Mercury was a heap of slag, Jupiter and the other giant planets were bloated balls of poisonous gases.

Even more disheartening, the prospects outside the solar system also looked grim. By the mid-1800s it had been observed that the sun, which contains the overwhelming majority of the mass in the solar system, has only a small fraction of the angular momentum; the rest was possessed by the planets. Since no way was known for the sun to get rid of angular momentum, that disparity constituted a real objection to the nebular hypothesis. To explain the fact, various catastrophic theories of planetary formation were proposed. One of the most popular was the Chamberlin-Moulton theory, which hypothesized that the planets condensed from material pulled out from the sun by the gravitational attraction of a star passing close by. The implication of all the catastrophic theories, however, was that the formation of a solar system was an exceedingly rare event. How much rarer must be life.

The result of such disappointments was that during the first half of the Twentieth Century the books and articles discussing the possibility of intelligent life in the universe were noticeably less exuberant—some cautious to the point of pessimism.

It is intriguing to note, however, that this pessimism in science coincided with the birth of the lusty, burgeoning genre of early modern science fiction, which had its heroes swashing their buckles in steaming Venusian swamps or on the shifting sands of Mars, rescuing voluptuous damsels in distress from the clutches of green and drooling monsters. Now, science fiction is very old: its roots go back at least to the Seventeenth Century, when the initial speculations about a plurality of inhabited worlds loosed the imaginations of Kepler, Cyrano, and later even Poe. But these older science fiction works were rather isolated phenomena, because, I suspect, the idea of life on other worlds was so widely accepted that people could satisfy their yearnings and curiosity about extraterrestrial life in books of speculative fact. Only when theological arguments lost weight and scientific arguments seemed to indicate that the probability of extraterrestrial life was slim, did science fiction in the modern sense begin to appear—almost as if thwarted hopes and dreams were channeled into speculative fiction.

In the short run the rise of science fiction had a negative effect on the concept of extraterrestrial life: it became associated with LGMs (Little Green Men) and the extravagant exploits of space opera. Moreover after 1947 with the widely publicized sighting by Kenneth Arnold of an unidentified flying object (UFO), the idea of extraterrestrial life was also co-opted by the flying saucer cults. To serious, conservative investigators, the idea of extraterrestrial life had not only been shelved by science, it had fallen off the shelf into bad company—and I suspect that all these associations were what conspired to make the idea temporarily distasteful.* (*This hypothesis seems to be supported by the fact that today, now that extraterrestrial life is once again a reputable field for speculative fact, science fiction is being incorporated into mainstream literature.)

In spite of the fact that the idea of extraterrestrial life per se languished in the early Twentieth Century, astronomers, biologists, and engineers were independently making contributions that eventually met in powerful combination.

By 1931 the spectroscope revealed the curious fact that although hot, brilliant, massive stars were spinning rapidly on their axes, rotating once in a period of hours or days, there was a fairly sharp dividing line below which smaller, cooler stars were spinning very slowly, rotating perhaps only once per month—exactly like the sun. Where did all their angular momentum go? Might all the myriad of slowly spinning stars in the galaxy also be accompanied by systems of planets—exactly like the sun? Within the following decade or two, astronomers returned to the nebular hypothesis, with newly-discovered principles of magnetohydrodynamics playing a key role in solving the angular momentum problem.

In the early Twentieth Century radio developed, and in the 1930s it was discovered that the universe was alive with radio signals. Radio astronomy was born: astronomers began to "listen" to the stars and the gas and dust between them, penetrating regions blocked to the narrow range of visible light.

Meanwhile, biochemists were hypothesizing that life on the earth began spontaneously in a "hot, thin soup" of amino acids, sugars, proteins, and organic compounds in a lightning-stormy hydrogen-rich atmosphere of the primordial earth. Laboratory experiments seemed to verify this, implying that life might be an intrinsic property of molecules past a certain stage of complexity. And subsequently organic molecules were found deep inside certain meteorites and in clouds of dust in interstellar space, suggesting that carbon compounds tend to form even in hostile environments.

But perhaps most significant of all, on October 4, 1957, a Soviet rocket thundered off its launch pad, split the atmosphere, and injected a beeping satellite the size of a basketball into orbit around the earth, Sputnik. With that one decisive stroke the human race "slipped the surly bonds of earth"—and 12 years later reached up and touched the moon.

The impact of space travel on the idea of extraterrestrial life was dizzyingly profound. Suddenly perspective altered: visiting other bodies in the universe was no longer a fantastic dream but was within the grasp of reality—and so for the first time, was the possibility of finding out first-hand whether there was indeed life on other worlds.

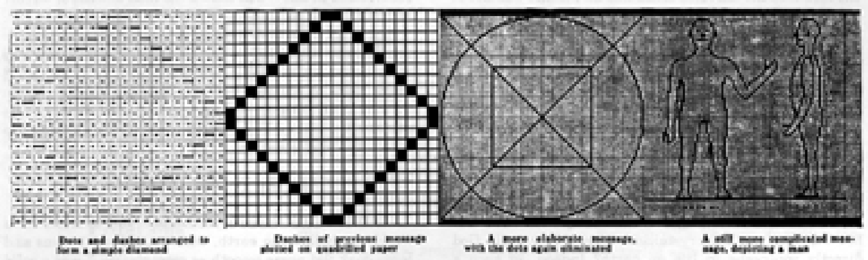
Can We Find Out?

The first human being had not even left the surface of the earth to venture into space when the new hope, the new optimism leapt up to embrace the stars. All the seemingly independent threads of investigation that led to the new optimism were gathered together into one bundle by Harlow Shapley. In 1958, in his delightful book *Of Stars and Men*, Shapley was the first to put numbers to the probability of life on other worlds. Suppose, he estimated, that only one star in a thousand has a planetary system, that only one of those systems in a thousand has a planet in the zone of habitability, that only one of *those* planets in a thousand has the proper chemical composition for life. Why, that meant that one out of a trillion (10^{12}) planets meets all tests for life; and since there are some one hundred million trillion (10^{20}) observable stars in the universe, then that meant there are a minimum of 100 million opportunities for life in the universe. Personally Shapley felt that the estimate was between 1,000 and one million times too *low*.

The effect of Shapley's book was electrifying. In 1959 Giuseppe Cocconi and Phillip Morrison published an article in *Nature* titled "Searching for Interstellar Communications" in which they suggested we listen for intelligent signals from several nearby sun-like stars at the radio wavelength of atomic hydrogen, 21 centimeters. With their last paragraph they threw the question of extraterrestrial life back into scientific repute:

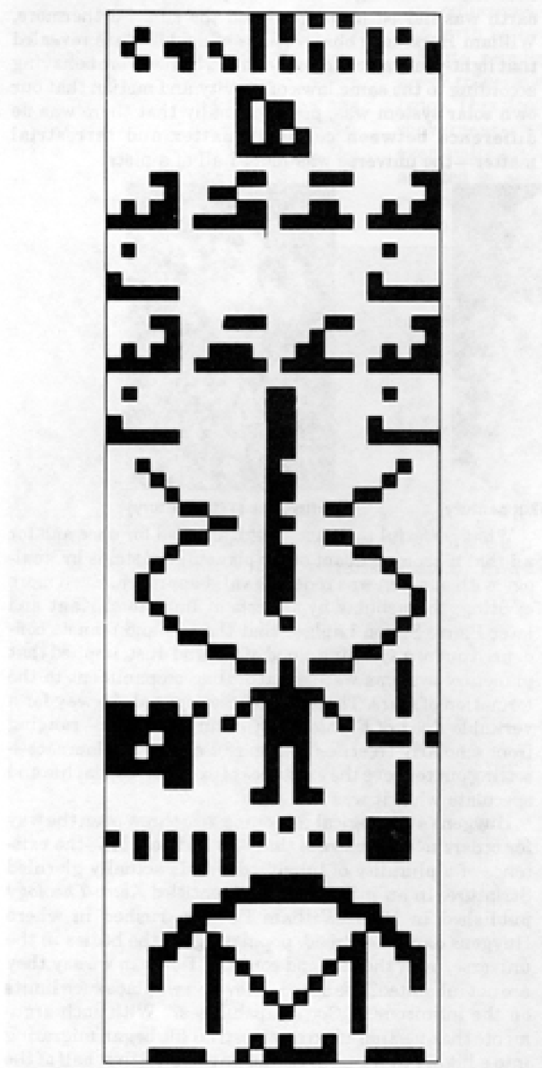
> "The reader may seek to consign these speculations wholly to the domain of science fiction. We submit, rather, that the foregoing line of argument demonstrates that the presence of interstellar signals is entirely consistent with all we now know, and that if signals are present the means of detecting them is now at hand...We therefore feel that a discriminating search for signals deserves a considerable effort. The probability of success is difficult to estimate; but if we never search, the chance of success is zero."

Although the idea of communicating with extraterrestrial beings is not a new one—Gauss, Littrow, and several other Ninteenth Century astronomers entertained various schemes for signalling Mars with light—the suggestions were isolated phenomena until the development of radio in the Twentieth Century.



The Arecibo message was constructed in a way very similar to that proposed by H. W. Nieman and C. Wells Nieman in "Scientific American" 55 years earlier. The Niemans, in their article "What Shall We Say to Mars?" suggested that the signals could be combined to form a picture, which presumably would be understood more easily than language or mathematics by an alien intelligence. Illustration courtesy "Scientific American", March 20, 1920, page 187.

Apparently the earliest discussion of the problem of building up a "lingua cosmica" was an article in 1920 by H. W. and C. Wells Nieman in *Scientific American*, called "What Shall We Say to Mars?" In it they suggested sending a series of signals that could be combined in such a way that it would form a pictorial message [see graphic to the right]—a message remarkably similar in part to the two-and-a-half-minute message sent in 1974 from the Arecibo radio telescope in Puerto Rico toward the globular cluster M13 in Hercules [see graphic below left]. The problem of an interplanetary vocabulary was discussed at greater length by Lancelot Hogben in his article "Astroglossa, or First Steps in Celestial Syntax" in the *Journal of the British Interplanetary Society* in 1952, and by Hans Freudenthal eight years later in his book *Lincos: Design of a Language for Cosmic Intercourse*.



In 1975 the giant radio telescope dish at Arecibo sent a 2½ minute message in the direction of the globular cluster M13 in the constellation of Hercules. This transmission built up its pictorial images in a manner suggested 55 years ago.

From "The Search for Extraterrestrial Intelligence" by Carl Sagan and Frank Drake, *Scientific American*© 1975.

Today the problem is receiving considerable study, because only in the 1960s and 1970s has the technology become available for a serious search for extraterrestrial intelligence. In 1974 Carl Sagan pointed out that if on another planet there were another civilization only as advanced as ours with a radio telescope just like the one we already possess at Arecibo, the two radio telescopes could be essentially anywhere in the Milky Way galaxy and still communicate with each other.

Over the past 10 or 15 years scores of technical conferences, hundreds of books, thousands of articles and innumerable lectures have addressed the question of life on other worlds, ways of detecting it, and the implications—both exhilarating and threatening—that its discovery might have on our science and society. The search for it has begun. One of the principal purposes of the Viking mission to Mars was to search for evidence of microbial life—and the results were tantalizingly ambiguous. The plaques attached to the Pioneer spacecraft and the records of terrestrial sights and sounds included with the Voyager spacecraft are as much greeting cards addressed to "Occupant, Universe" as they are interstellar graffiti: "Homo sapiens was here."

On a very modest scale half a dozen astronomers under Stuart Bowyer at the Hat Creek Radio Observatory of the University of California have begun Project SERENDIP: Search for Extraterrestrial Radio Emissions from Nearby Developed Interstellar Populations.

Searches have also been conducted or are in progress at the National Radio Astronomy Observatory at Green Bank, West Virginia, the National Astronomy and Ionosphere Center at Arecibo, Puerto Rico, the Ohio State-Ohio Wesleyan Radio Observatory, Delaware, Ohio, the National Research Council Observatory at Algonquin Park, Canada, and at several observatories in the U.S.S.R.

The subject of searching for extraterrestrial intelligence has become sufficiently reputable that in the past three years an article on it was published in *Scientific American* and an entire number of the *Proceedings of the Royal Society of London* was occupied with "A Discussion on the Recognition of Alien Life." The sheer tonnage of wood pulp and volume-hours of warm air lavished on the subject can easily lead one to the happy assumption that intelligent extraterrestrial life not only exists but is friendly and eager to see us wave to it across the light-years. (Some uncritical minds even assume it has already contacted us.)

In backlash to such confident press, a number of authors have constructed detailed arguments based on contradictions in internal logic, devoted to showing that we have no reason at all to assume that life developed elsewhere in the universe and that even if it had, the structure of its society or the existence of interstellar travel might preclude us from discovering it or communicating with it at all.

"The difference is that today, we have the capability to stop speculating and find out."

Arguments of this type impress me as being the modern-day equivalent of the medieval debates as to how many angels can dance on the head of a pin. On the basis of exactly zero data, careful mathematical formulae are devised to show how many aliens we cannot hope to detect. Although the arguments are phrased in terms of communicating with extraterrestrial life, however, the real issue being argued is nothing less than *the grand analogy* that forms the philosophical foundation of modern astronomy: the assumption that the laws of physics and chemistry and the mathematical probabilities in the universe are everywhere the same. Without that assumption, astronomy would consist only of gathering data about an infinite number of unrelated special cases. The grand analogy has been a fruitful tool for 350 years. If one truly wants to find out if extraterrestrial life exists—and I suspect that the authors of the negative arguments simply do not—one must begin somewhere, and the grand analogy is all we have. It's even been suggested that the search for extraterrestrial life would be an excellent test of our assumption about the universality of the universe.

On the other hand, the fact remains that we still have exactly zero direct evidence in favor of extraterrestrial life. No planet has ever been seen around another star, no LGM has ever radioed to us: "Mind if I drop in for tea?" Too much flashy overconfidence about the existence of extraterrestrial intelligence could whip up public fervor for a great search, only to create a bitter taste if success is not immediate. After all, if we look at all the wrong stars first, or listen at the wrong wavelengths, a search could take years, even decades.

Nonetheless, we have much circumstantial evidence about the universe that gives us hope that indeed there is a plurality of inhabited worlds, Moreover, that hope is held today for the same reason that it sprang eternal centuries ago: the grand analogy. *The difference is that today, for the first time in human history, we have the capability to stop speculating and to find out.*

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This article appeared previously in the August 1978 issue of the *Griffith Observer* (Los Angeles) being the First Prizewinner in the 1978 Hughes Writing Contest. Reprinted by permission.

Artwork (Metrodurus, Lucretius, etc.) by Lois Cohen.

Bell

Trudy E. Bell is adjunct instructor in history of science at Fordham University and Contributing Editor for Science 80, the new lay science magazine published by the American Association for the Advancement of Science. Born in 1950 in Richland, Washington, she received her bachelor's degree from the University of California at Santa Cruz (1971) and her master's degree from New York University (1978), both in history of science and American intellectual history. Her background includes 6 1/2 years (from 1971 to 1978) on the editorial board of *Scientific American* magazine. She is also Acting Chairman of the New York Section of the American Institute of Aeronautics and Astronautics.

Equally concerned both with original historical research and with the lay understanding of science, Ms. Bell is the author of some 50 articles and book reviews on astronomy, space activities, and history of astronomy, which have appeared in publications ranging from *Journal for the History of Astronomy*, *Sky and Telescope*, to *Travel and Leisure*, and *Family Circle*. She has also written several technical-information booklets for the National Aeronautics and Space Administration (NASA). Currently she is working on books for Harper and Row and Doubleday.

Letters*

By: The Editors

[Letters in magazine started on page 11]

(*Letters are always welcome but owing to the volume it is not possible to acknowledge all of them. Also due to space limitations we reserve the right where necessary to condense or edit the contents. Letters may be addressed to: Editorial Dept., **COSMIC SEARCH**, P.O. Box 293, Delaware, Ohio 43015.)

I would like to congratulate everyone at **COSMIC SEARCH** for a job well done. You have fulfilled a wish for many, including myself, to have a magazine devoted to space, the future and the search for intelligent life beyond the earth.

Stephen Udvardy
Edmonton, Alberta, Canada

I picked up a copy of **COSMIC SEARCH** and started thumbing through it. Before I knew it, I had spent most of my lunch hour engrossed in its contents. **COSMIC SEARCH** is unique and I congratulate you on a great job. I am subscribing immediately.

A. J. LaFazia
Bristol, Rhode Island

Keep up the excellent contribution that **COSMIC SEARCH** is making. I look forward to each issue.

Professor Howard I. Thorsheim
St. Olaf College
Northfield, Minnesota

I hope your magazine will have all the success it certainly deserves. Best wishes and a long life to **COSMIC SEARCH**.

Rudolf Pesek
Chairman, CETI Committee of the International Academy of Astronautics
Prague, Czechoslovakia

Congratulations on your excellent publication. May it prosper and prevail amid today's blizzard of far less worthy magazines.

Trevor James Constable
San Pedro, California

Thanks for a fantastic magazine.

Jerry T. Searcy
Las Vegas, Nevada

I would like to congratulate you on the publication of **COSMIC SEARCH**. I really enjoy reading your magazine and I am looking forward to receiving the next issues.

Chriet Titulaer
Houten, Netherlands

I would like to comment on a section of one your articles in the Summer issue of **COSMIC SEARCH**, "Extraterrestrial Politics" by Michael Michaud.

I was delighted to read, "Only if the intelligent species of the universe work together can they hope to reverse the running down of the cosmos, that we measure as entropy, or its collapse into a new primeval fireball."

It is disconcerting to read time and time again by distinguished scientists as well as by other writers, the gloomy end of the universe predictions that can not be averted.

In a short space of time, cosmically speaking, we have discovered a tremendous amount about the universe we live in. Yet, I think the most important thing we have (or should have) learned is the simple fact that we really know practically nothing. In science we have hardly begun to scratch the surface. What knowledge will be ours in even 10,000 years time?

To answer Michaud's question, I do not think that we have evolved to consciousness only to face a hot or cold death. Either alone or in conjunction with other beings throughout the universe I believe it possible that we can, in the distant future, not only shape solar systems for our benefit, but ultimately the whole physical universe itself.

Fergal MacAlister
Dublin, Ireland

We are very much impressed with the excellence of **COSMIC SEARCH**, the scope of content and the high quality of presentation. In particular, I applaud your success in making the articles readable and mind-stretching for the layman. **COSMIC SEARCH** could be an effective agent in regenerating respect for science by the general public.

Marguerite Jansky Froscher
Fernandina Beach, Florida

Correction

In Louis Berman's article "What It Was Like Before Ozma" in the Fall 1979 issue of **COSMIC SEARCH**, the statement is made that Marconi's experimental communications yacht, "Elettra", was named after his wife.

Dr. George H. Brown, father of color television and formerly Vice President for Research and Engineering of the Radio Corporation of America (RCA), has informed us that this is not correct. Brown, a friend of the Marconi family and a Marconi Centenary Lecturer, writes as follows:

> "Marconi's first wife was Beatrice O'Brien and she helped in the naming of the yacht. The first choice was *Scintilla*, pronounced in Italian as *Shintilla*, meaning *spark*. But Marconi was afraid that English-speaking persons would say *Sintilla*. So *Elettra* was the choice. *Elettro* means *amber*, but since a ship is feminine, he modified the name to *Elettra*. The yacht was purchased and named in 1919.
>
> "Marconi's second wife was Countess Cristina Bezzi-Scali, who gave birth to Marconi's child, named Maria Elettra Elena Anna on July 30, 1930."

COSMIC SEARCH is excellent. Keep up the good work on this first-rate and much needed magazine.

Roger Ptak
Director of Astronomy
Bowling Green State University
Bowling Green, Ohio

Having just obtained my first copy of **COSMIC SEARCH**, I am very excited to find it and read about the research being done.

David L. Dunlap
Salt Lake City, Utah

Congratulations! **COSMIC SEARCH** is the SETI buffs dream: fun to read and not too technical yet responsible and scientific.

It's volunteers like you who are already disseminating messages to their fellow beings that give me so much hope for eventual contact.

Randall B. Black
New York, New York

COSMIC SEARCH is long overdue. It outdoes everything else on SETI. I can hardly wait for the next issue to arrive.

Shelby W. Haukos
Fergus Falls, Minnesota

COSMIC SEARCH is the most exciting new publication in many a moon. It should make people do some thinking.

Dennis G. Brewer
Careysburg, Liberia

I am much impressed with your magazine which should be of interest to many readers. I like the factual presentation, the diversity and excellent make-up of the contents. Thank you for your efforts.

Jurgen Lehmann
Bautzen, East Germany

I have just received your fourth issue and I read it completely before I walked out of the building.

I wish to congratulate all of you at **COSMIC SEARCH** for striking that delicate balance between informing a technical readership and educating a general public.

I am a member of an observatory that is currently doing serious SETI work (see letter from the Director on page 10 of the fall 1979 **COSMIC SEARCH**). As far as we know, we are the only amateurs doing this work at present.

Barry Perlman
Fort Lauderdale, Florida

I enjoyed the last issue of **COSMIC SEARCH** and in particular the article by Roy Basler. I would like to suggest that it may be possible to combine the cost effectiveness of an orbiting antenna search system with the shielding advantages of a far-side-of-the-moon-based search system. This could be done by placing the orbiting search system into lunar orbit. The cost of this system would surely be much less than a far-side-of-the-moon-based system. Set-up time for listening could be done while in view of the earth; actual listening would be done during the out-of-view-of-earth portion of the orbit. A variation of this concept would be to place the orbiting antenna at one of the LaGrange points; a synchronous lunar orbit continuously out-of-view of the earth. If the shielding problems of an earth orbital system proved more bothersome than originally anticipated, then perhaps the already existing system could be boosted into a lunar orbit using continuous, low-thrust booster systems.

Thank you again for this most interesting issue.

Richard A. Moss
New York, New York

Roy Basler comments that the idea of using the moon as an interference shield is a good one and that some of the possibilities for this arrangement are discussed on pages 28 to 32 of the NASA contract report (NAS2-8938, 1976) referred to at the end of his article.

Eds.

I read **COSMIC SEARCH** from cover to cover as soon as I receive each issue. Keep up the good work. Enclosed are two gift subscritions.

James L. Voight
Alaska Highway via Dawson Creek
British Columbia, Canada

Although **COSMIC SEARCH** has not yet proved to me the existence of extraterrestrial intelligence, I must gratefully admit that in every issue it amply proves the existence of terrestrial intelligence.

Arthur J. Morgan
New York, New York

Thank you for such an interesting and informative magazine. Attached is my check to cover a two year renewal to **COSMIC SEARCH** plus a humble $32 contribution towards your work.

Keep up the excellent work you are doing. I was especially pleased to read the article by C.M. Jansky, Jr., about his brother Karl in the Fall 1979 issue, as I knew Mr. Jansky years ago.

A.V. Shaver
Winchester, Virginia

I can't begin to tell you how excited I am to have discovered **COSMIC SEARCH**. I only regret my discovery didn't occur until the Fall 1979 issue! I enclose a two-years subscription and would be infinitely grateful if you could include those issues which I missed. Thank you so much for your excellent creation.

Michael Sullivan
Natick, Massachusetts

Referring to the interview with Dr. Wheeler in the Fall 1979 issue of **COSMIC SEARCH**, I believe he is right when he says, "So, why is the universe as big as it is? Because we're here!"

However, if I were a pessimist I could easily say we're here because the universe is as big as it is. But being an optimist I believe we're here for a definite purpose and when our universe calls upon us in the future I hope we will have taken the necessary steps to acquire the wisdom and capability to justify our existence in our own universe.

G. M. Wannamaker
McChord Air Force Base, Washington

I love **COSMIC SEARCH** so much I am renewing my subscription for another two years and also want to purchase a gift subscription for my sister.

John H. Fadum
Deerfield Beach, Florida

It's a Nice Planet to Visit, but I Wouldn't Want to Live There

By: Virginia Trimble

[Article in magazine started on page 13]

As all dedicated vacationers know, you can stand anything for two weeks. But most of us become more particular when choosing a long-term residence, and downright fussy as we begin to think about where we want to raise our children. The macrocosm of life is rather like this microcosmic example. Terrestrial life in one form or another can survive for at least a while under a much wider range of conditions than those under which it could have evolved. And (we hope that!) human civilization will be able to endure circumstances that would surely have kept our ancestors cowering in their caves, or even wiped them out completely.

Trimble

What, then, must a planet supply for life to be able to develop, survive, and evolve to intelligence on it? Charles Darwin's warm little pond is a good start:

> ".... conceive in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, etc., present, that a protein compound was chemically formed ready to undergo still more complex changes ...."

That is, we seem to need liquid water (constraining both temperature and composition), a high-grade energy source, suitable raw materials (including carbon and hydrogen compounds, but no free oxygen), and lots of time.

Astronomers, looking at stars and the process of star formation from interstellar gas (which is surprisingly rich in a wide variety of carbon compounds) have generally concluded that these essentials should be available in many places; while biochemists have verified with laboratory experiments that the initial stages of the chemistry leading to proteins, nucleic acid, and so forth do actually occur in such a pond. The implications of these observations and experiments for the frequency of life-bearing planets in the galaxy have been frequently, and usually optimistically, explored in this publication and many others. It is usually assumed that time is not really a problem, because the oldest stars in our galaxy are three or four times the age of our sun. The catch is that these stars (hence, perhaps, their planets, if any) have only about 1 percent as much of the chemical goodies needed for life (carbon, nitrogen, phosphorus, etc.) as the sun does. Thus, the oldest chemically suitable stars may not be much older than our 4.6 billion year sun. A closer look at how life probably got started on earth suggests a number of other plausible constraints.

I want here to focus particularly on the extent to which the appearance of intelligent, technological life on earth may have depended on the existence of plate tectonics.

Plate-tectonics-and-continental-drift, which ascended from the realm of crankiness to that of dogma with extraordinary rapidity less than 20 years ago, is a sort of catch-all phrase to describe what most geophysicists now think are the dominant processes happening on the surface of the earth. Of the ideas that make up the dogma, the ones that will concern us here are:

(a) continental rocks (granites) are less dense than ocean basic rocks (basalts) and float upon them,

(b) the earth's surface is broken into a number (about 10 large and a few dozen small) plates of solid rock, typically containing both land and ocean basin, a few miles thick and hundreds to thousands of miles across,

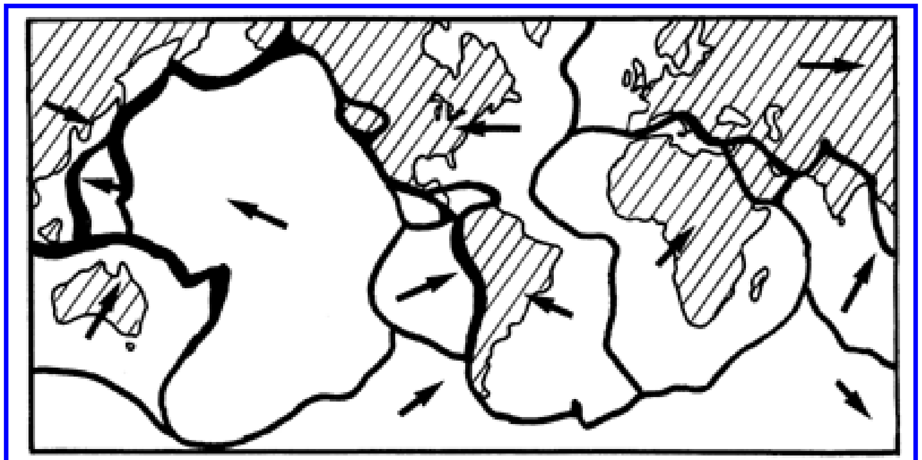
(c) these plates are dragged around on the surface of the earth essentially by the flow of less rigid (but still solid) rocks underneath them in the earth's mantle,

(d) where plates spread apart, molten rock rises and forms new ocean basins (this is happening now in the mid Atlantic and elsewhere),

(e) where plates slide past each other, general unpleasantness occurs (the San Andreas fault of Southern California is the classic example),

(f) where plates crash into one another, continental rock is piled up into mountains (the Andes and Himalayas are regions where this is happening now; the Appalachians and Urals are relics of ancient collisions), while ocean basin rock can be dragged back down into the mantle and remelted, giving rise to volcanoes and considerable chemical reprocessing of the rock (as is now occurring around most of the rim of the Pacific Ocean),

(g) this sort of thing has been going on for most of the age of the earth, breaking apart old continents, forming new ones out of the fragments, and generally messing things up thoroughly, and



Plates of the earth's crust are bordered by zones of earthquake (and volcanic) activity shown by heavy lines, the broader the line the greater the activity. The direction of motion of each plate is indicated by arrows. Land areas are shaded.

Adapted from Judson, Deffeyes and Hargraves, "Physical Geology", Prentice-Hall.

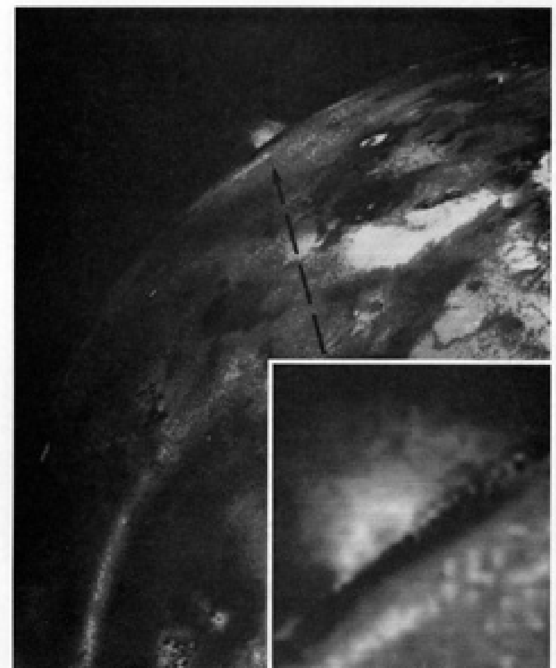
(h) energy to keep this going comes from the interior heat of the earth, which in turn is partly left over from its formation and partly maintained by the decay of radioactive atoms inside. Boundaries of the present plates are marked out by the presence of volcanoes and earthquakes (as shown in the diagram).

Suppose plate tectonic processes were to stop (as must eventually happen when the earth cools off) or had never occurred (as would be the case if the earth had started with a smaller mass, like the moon, or had contained smaller amounts of radioactive elements). Could we continue to live here, could we have evolved to something like our present biological state, and could our civilization (such as it is) ever have developed? The answer to all three questions may well be no. Let's look at three products of plate tectonics that seem to matter. These are (a) the maintainence of the balance between land and water, (b) the provision of a wide range of habitats, and (c) the production of high-grade metallic ores.

If plate tectonics turned off, the first to suffer would be the skiers and climbers, as the taller mountains eroded away over 10 million years or so. After a few hundred million years (this is still short compared to the 4.6 billion year age of the earth) essentially all the land would be eroded below sea level, and eventually the oceans should cover the entire earth's surface to a uniform depth of a few miles (as would always have been the case if there had never been any tectonics). One can imagine a portion of humanity developing under-water cities and surviving this, but it is much harder to conceive of civilization arising under these circumstances. Dolphins, though endowed with impressively large brains in relationship to their body weights, are not tool makers or even (like many primates and other, lower, land animals) tool users. In fact evolution could not have taken anything like its actual course. Though many of our remote ancestors were ocean dwellers, they preferentially inhabited the shallow continental shelf regions, not the ocean deeps, as do the vast majority of marine organisms to this day. Even the chemical reactions that were, in some sense, our earliest ancestors probably require shallow water, with sunlight and muddy bottom not too far apart. Perhaps we should stop here and conclude that plate tectonics is surely essential for life to develop. There may be a way out, though, via a planet on which water is less abundant than on earth (but more so than on Mars today), so that the surface irregularities produced by meteorite impacts are sufficient to keep some areas dry and others wet. Photographs of Mars suggest that it may have been like this not too long ago.

Plate tectonics introduces continuous change into both the number and types of habitats available for living creatures as continents and their shelves emerge, collide, and break apart again. Evolution can surely occur without this, but it will be different. Isolated populations, for instance on tropical islands, tend to be rather fragile, both flora and fauna being likely to succumb before species introduced from a larger, continental environment. In addition the fossil record shows interesting correlations with the positions of the continental plates in the past. When most of the land was in a single continent, diversity of species (both land and shelf dwelling) tended to be small, while existence of several smaller continents is accompanied by a wider range of living creatures. Evidently, when continents collide, species previously free of competition meet, and not all of them survive, producing a wave of extinctions (several of which appear in the fossil record over the past 600 million years). And when continents break apart, new, unoccupied habitats open up, and new species develop through adaptive radiation into the new territory. We are ourselves somewhat the product of such radiation, occurring when the opening of the Atlantic 60 million or so years ago separated the ancestors of the present New World monkeys from those of the Old World monkeys and apes. The result must in general be more rapid evolution than would otherwise occur. Given enough time, this shouldn't matter to the eventual appearance of intelligent life. But, as noted above, recent evidence suggests that there may not be very many stars that are both generously endowed with the elements needed for life and much older than the sun. And it has, after all, taken us the entire age of the solar system to get to where we are now!

Finally, most theories of planet formation suggest that the earth was originally chemically uniform, the iron-nickel core separating from the rockier outer layers as radioactive decay heated and melted the interior. This still leaves the rocky regions more or less well-mixed. The wide range of minerals and ores we find on earth are, to a considerable extent, a direct result of melting, recrystallizing, dissolving and precipitating from water solutions of materials at and near plate boundaries (especially converging ones). Thus nearly pure copper occurs in Cyprus where the African plate is pushing into the European and lead, silver, and molybdenum ores are found in sequence across the western United States, where the East Pacific divergent boundary has disappeared under North America. The development of some aspects of technological civilization would seem to be rather heavily dependent on availability of such ores. The example that comes immediately to mind is the need for good conductors of electricity if one is ever to discover Maxwell's equations of electromagnetism and the technology of radio broadcasting and receiving (the method most often suggested for interstellar communication). There are non-metallic conductors (including salt water and ourselves), but if the typewriter on which this is being written had to be plugged into the salt water line, I think I would just as soon skip the whole thing!


Volcano erupting on Jupiter's moon Io as viewed from Voyager I during its close approach March 4, 1979. The eruption is shown in more detail by the inset. The plume is 160 kilometers high with ejection velocity of 2000 kilometers per hour. Io appears to be far more active volcanically than the earth. Courtesy NASA and Jet Propulsion Laboratory.

Examination of other members of the Solar System tells us that tectonic processes are by no means universal. The moon and Mercury are dead in the tectonic sense, their surface features largely attributable to meteorite impacts. Venus and Mars show what *may* be dead volcanoes and faults, but seem to have little or no activity now. The giant gas planets have no solid surface to be broken into plates. But the earth is not quite unique, either. In spring 1979, Voyager began sending back pictures of Jupiter and its moons. And one of these, Io, had no less than 7 volcanoes in eruption at once (the terrestrial average is more like one). They are not much like our volcanoes, because Io has long since boiled away all its water and similar light compounds (it is much less massive than the earth, so its gravity holds on to things less tightly). But they are volcanoes, suggesting the occurrence of chemical reprocessing (also indicated by apparent sulphur deposits on the surface), motion of surface rocks, and so forth, as on the earth. The energy source is different, too. Io is not massive enough for leftover formation heat and radioactivity to keep its interior warm and fluid. Instead, it is continuously heated by friction of its rocks, which in turn is caused by Jupiter's very strong gravity pushing and pulling tidally on Io as it orbits the planet. The effect is rather like the heating of tires as they get compressed out of round and rub on the road driving at high speed. Thus, evidently, any internal heat source will suffice to keep a planet's (or satellite's) surface active, and plate tectonics need not be confined to planets very much like the earth.

Thus I conclude tentatively that, although we might be willing to visit a planet whose interior is not warm enough to drive tectonic processing, we would probably not want to live there, and almost certainly could not have evolved there, but that such processing may be rather more common than one might at first have guessed. The reader may well want to draw different conclusions, and the foregoing words are meant only as a spur to further thought about the subject, and not as a final answer. Or even a final question.

For further information on earth processes see, for example, "Continents in Motion" by Walter Sullivan, McGraw-Hill (1974).

Trimble

Virginia Trimble has published research papers on white dwarf stars, pulsars, black holes, x-ray stars and supernovas and has written many articles, such as "Cosmology: Man's Place in the Universe", "Are Galaxies Here to Stay?" and "The Origin and Abundances of Chemical Elements".

Born in Los Angeles, California, in 1943, Dr. Trimble received her Bachelor's degree (Phi Beta Kappa) from the University of California at Los Angeles in 1964 and her Master of Science degree in 1965 and Doctor of Philosophy degree in 1968, both from the California Institute of Technology. She also received a Master's degree from the University of Cambridge, England, and held a post-doctoral position there for two years in the Institute of Theoretical Astronomy.

She has been an Alfred P. Sloan Foundation Research Fellow (1972-76), a Phillips Lecturer (1973), a Sigma Xi National Lecturer (1974-77), the Maryland Academy of Sciences' Outstanding Young Scientist for 1976, the Luce Cosmology Lecturer at Mount Holyoke College (1978) and Phi Beta Kappa Visiting Scholar (1979-80).

Virginia Trimble shares appointments with her husband, Joseph Weber, the gravity wave pioneer, at the University of California, Irvine (where she has tenure) and the University of Maryland (where he has tenure).

Dr. Trimble is in frequent demand at professional meetings and conferences where she has delivered invited review papers on galactic structure, gravitational radiation and other subjects and at colleges and laboratories where she has given many popular talks on a wide variety of astronomical topics.

FORUM:
Billingham on NASA and the Exploration of Space

[Article in magazine started on page 17]

Billingham

Space scientist, pioneer SETI organizer and administrator, John Billingham views the future.

*This exclusive interview with John Billingham was made by Robert S. Dixon of **COSMIC SEARCH**.*

COSMIC SEARCH What is NASA's Role in the Search for Extraterrestrial Intelligence (SETI)?

Billingham: I believe it to be central to an American role in SETI. There are three reasons:

> (1) SETI is the type of enterprise which is likely to require a concentrated effort of a type which would probably not be put together by any one organization or society in the U.S.
>
> (2) Also, it is the type of activity which inevitably is going to involve many questions in the international sphere. NASA has considerable experience in cooperative ventures, for example with the Soviets, and this could be put to good use.
>
> (3) I believe NASA is the most suitable national organization to embark on SETI because (a) NASA is charged with a mandate for space exploration and this is space exploration par excellence. (b) The focal point of work on exobiology (non-terrestrial life outside the earth) has been in NASA for more than 15 years. SETI represents a logical extension of the existing work on the search for extraterrestrial life. (c) It is likely that a systematic technology development will be required. NASA has developed the management and engineering expertise to bring this type of endeavor to fruition.

COSMIC SEARCH: What are NASA's short and long range plans for SETI?

Billingham: The short range plan is already well-crystallized. It comprises a two year preparatory phase (Fiscal Years 1980 and

1981) under the cognizance of a SETI Project Development office which has just been established at the NASA-Ames Research Center and which includes scientists and engineers from Ames and the Jet Propulsion Laboratory (JPL), and the universities. Then, we will be submitting a SETI Project Plan for the Fiscal Year 1982 Budget as part of a broader enterprise which we call Life in the Universe. When the SETI Project actually begins, it will be a six-year project involving the use of existing antennas equipped with new and sophisticated data processing systems. The searches are to be carried out under the cognizance of a SETI Project Office and will, of course, include Ames, JPL and cooperating universities and observatories. The average expenditure rate for the six years would be about seven million dollars per year.

Long-term plans are difficult to generate at this time because of our lack of experience at doing a thorough and coordinated SETI program. However, it may be necessary in a few years time to contemplate the possibility of new telescopes, either on the ground or in space.

COSMIC SEARCH: If SETI were an ongoing program, how would it rank in importance among the other things NASA is doing?

Billingham: Recognizing that I am biased, it must rank very high for two reasons:

(1) The agency should always be undertaking new and exciting programs which have both scientific and popular appeal.

(2) Were the search to be successful, the results would constitute one of the great achievements of our own civilization.

COSMIC SEARCH: How many people work on SETI for NASA? Put this in perspective. What do they do?

Billingham: The number of people working on SETI is extremly small because SETI is still in the study phase and is not yet a formally approved NASA program. So there are perhaps some six man-years being devoted to SETI at Ames and probably a comparable amount at JPL. At Ames we carry out extensive studies, and we prepare detailed plans of action to be ready to start the SETI project when funding becomes available. We are also undertaking a few preliminary SETI searches at a very parsimonious funding level, as are our colleagues at different colleges and universities.

Finally, we do spend some considerable time answering the very large number of requests from all over the world for information about SETI. It is very apparent that while a thorough SETI project is not yet underway, the level of interest among people from all walks of life is astonishingly high.

In comparison with the resources being applied to other NASA activities, the SETI enterprise is a very inexpensive program. If we succeed in getting support for the six year project, then it will become somewhat more visible, but it will be still very small in relation to other NASA projects.

COSMIC SEARCH: Can you give some perspective as to the amount of money NASA plans to spend on SETI, in comparison to other NASA programs, or to other things?

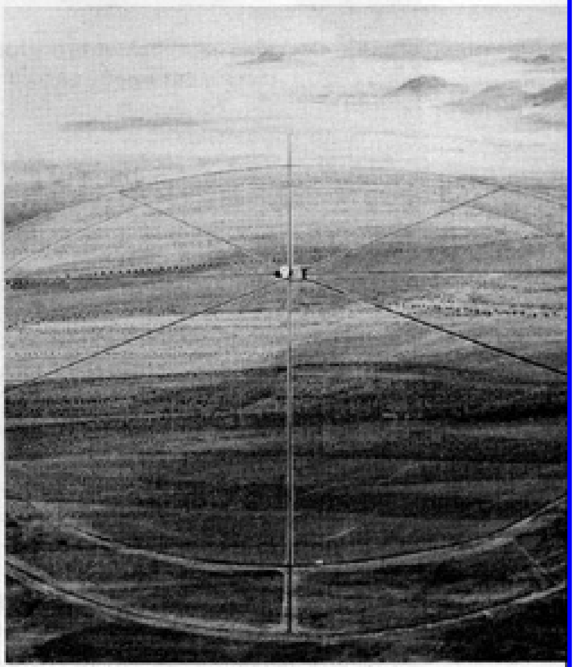
Billingham: The amount of money is very modest by comparison to other NASA programs, and other coordinated projects such as particle accelerators. If NASA is in fact supported by Congress for SETI enterprises, then we would plan to spend a total of some 45 million dollars over a six year period. This represents a sum of just over three cents per year per person distributed across the total American population.

"SETI is space exploration par excellence."

COSMIC SEARCH: Are any other government agencies involved in SETI besides NASA?

Billingham: No.

COSMIC SEARCH: Please tell us about Project Cyclops.



Cyclops could start with a single antenna

Billingham: Project Cyclops was the first major endeavor that the Ames team carried out, with "Barney" Oliver as Director. The idea was simply to ask the question: "What would one actually do if one wished to construct and operate a system for conducting a comprehensive search for other civilizations?"

It was a summer engineering system design study carried out by about 25 faculty persons from various U.S. colleges and universities. It was found to be feasible to construct an expandable system of conventional radio telescopes, phased together and equipped with a very sophisticated data processing system. As the years went by the search would be extended further and further into the galaxy as the number of telescopes, and hence the sensitivity of the system, increased. I would like to clarify a few things about the Cyclops project. First, it was a study only; and second, no one is proposing at this time to implement Cyclops. Third, I would like to correct an unfortunate but widespread impression that Cyclops is necessarily a large system consisting of 1500 antennas of collecting area three square kilometers and costing many billions of dollars. It is in fact not possible to say that Cyclops is of any given size and that its cost would be any given figure. The size and cost are whatever is necessary to detect a signal of extraterrestrial intelligent origin. This could be one telescope, or it could be a large number of telescopes. The strategy is clearly to begin with one telescope in order to be quite sure that we are not missing a strong signal.

COSMIC SEARCH: Tell us about the Science Workshops.

Billingham: The reception given the Cyclops report was of sufficient magnitude to encourage us to pursue SETI further. With the support of NASA Headquarters and under the chairmanship of Phillip Morrison, a series of Science Workshops on SETI were held during 1975 and 1976. The idea was to go back to square one and examine the fundamental scientific rationale for embarking on SETI, to re-examine all possible approaches to the detection of other intelligent life and to explore in more detail any particular approaches that seemed reasonably promising. The workshops came up with four *conclusions* as follows:

(1) It is both timely and feasible to begin a serious search for extraterrestrial intelligence.

(2) A significant SETI program with substantial potential secondary benefits can be undertaken with only modest resources.

(3) Large systems of great capability can be built if needed.

(4) SETI is intrinscially an international endeavor in which the United States can take a lead.

The workshops came up with one *recommendation*, namely that a search for extraterrestrial intelligence be initiated now.

COSMIC SEARCH: Does NASA coordinate any of the ongoing searches? Should they? Should anyone?

Billingham: Since SETI is not yet a formally established and well-organized program, it is not possible to attempt to coordinate at this time. We feel, however, that some form of coordination will be important as soon as SETI is under way. In preparation for this time, the Ames Research Center and JPL have already coordinated their own approaches to SETI and the Ames Research Center has begun to establish a data bank of all existing SETI searches or radio astronomy surveys of any magnitude. Any coordinated program in the future would, of course, involve not only NASA, but universities and observatories interested in carrying out SETI observational projects and those data processing groups in industry and elsewhere who have the capability of developing advanced multi-band spectrum analyzers and signal characterization systems.

COSMIC SEARCH: Is there any international coordination? Should there be?

Billingham: There is no formal regular coordination. However, a meeting between the U.S. and Soviet academies of science was held in 1971 at Byurakhan in Armenia, with attendance also from other countries. The meeting established a small group to maintain liaison and I would guess that a second meeting might well occur in the next few years. Informal exchange of SETI ideas and studies constantly go on through normal scientific channels, particularly at international meetings.

COSMIC SEARCH: How does the JPL program differ from the Ames program?

Billingham: It is not different. It is the same. Ames and JPL are both contributors to a single NASA SETI enterprise.

COSMIC SEARCH: From the standpoint of the typical American taxpayer, how could he expect to benefit from NASA's SETI activities?

Billingham: He should perhaps reflect on the fact that it is an activity which is keeping America in the forefront of new ventures in science and exploration, which is something that very much enhances the image of the United States throughout the world. This is something that is seldom realized. If a contact should be made, there will be the achievement of it having been made by American scientists. There may be things we can learn from other civilizations which could be of great benefit to American taxpayers and indeed to anyone else.

COSMIC SEARCH: What are they?

Billingham: I will mention one and leave the rest to the imagination. The important thing to point out first is that the other civilization is likely to be very much older and therefore more advanced in its culture in general. One thing of some importance is that we will know for the first time that it is possible for a civilization to pass through the sort of troubles that we are experiencing at our present stage of evolution, and live perhaps millions of years into the future under what must be conditions of some stability. This would perhaps give many people (particularly the pessimists), a more positive and hopeful outlook with regard to our own prospects as a civilization.

It is probably up to each one of us to imagine other benefits which might result from the detection of a signal, since all thoughts in this direction can only be speculation.

COSMIC SEARCH: How did you get into SETI, since you're an M.D.?

Billingham: Having been at Ames in the Life Sciences Directorate since 1965, I have been constantly exposed to the exciting research being carried out there in exobiology. In 1969 I read Shklovsky and Sagan's book on intelligent life in the universe and it occurred to me that one crucial question had not been asked. The question was, if one wanted to conduct a serious and thorough search for evidence of the existence of intelligent life outside the earth, how would it be done? I was lucky enough to be able to pursue this question over the next several years, beginning in 1971 with the Ames-Stanford Engineering Systems Design Study, Project Cyclops, directed by "Barney" Oliver, and the latest development being the formulation of NASA ideas on how to approach SETI over the next several years, and with the publication of NASA special publication (SP-419) entitled "SETI" — the results of three years of deliberations by a series of Science Workshops under the chairmanship of Phillip Morrison.

COSMIC SEARCH: Where could readers write to get more information about NASA's activities in general and SETI in particular?

Billingham: For information about SETI, write to me at: SETI Program Office, Mail Stop: 204-2, NASA-Ames Research Center, Moffett Field, California 94035. Copies of Project Cyclops and of the NASA special publication on SETI, SP-419 are available. For information about NASA activities in general, write to the Public Affairs Office, Code LF-6, NASA Headquarters, Washington, DC 20546; or to the Public Affairs Office at any of the NASA field centers.

Billingham

John Billingham was born in 1930 in Worcester, England. He received his M.D. in 1954 from Oxford University Medical School, and subsequently served as Medical Officer of the Royal Air Force Institute of Aviation, specializing in aviation medicine and physiology. In 1963 he came to the United States to join NASA at the Lyndon B. Johnson Space Center in Houston, Texas. There he served as Chief of the Environmental Physiology Branch. In 1965 he moved to the NASA Ames Research Center and became Chief of the Biotechnology Division in 1970. In 1971 he served as co-director of Project CYCLOPS, and since 1975 he has been Chairman of the Annual International Astronautical Congress Review Session on Communication with Extraterrestrial Intelligence.

Since 1976 Dr. Billingham has been Chief of the Extraterrestrial Research Division and Acting Chief of the Program Office for SETI at NASA Ames. He is a Fellow of the Royal Society of Medicine, Senior Member of the American Astronautical Society and Academician of the International Academy of Astronautics. He holds two patents related to temperature-controlled pilot garments. He is author of nearly 70 technical articles ranging from "The Human Aspects of Space Fight" to "A Review of the Theory of Interstellar Communications."

A Strange Radiation from Above

By: John Kraus

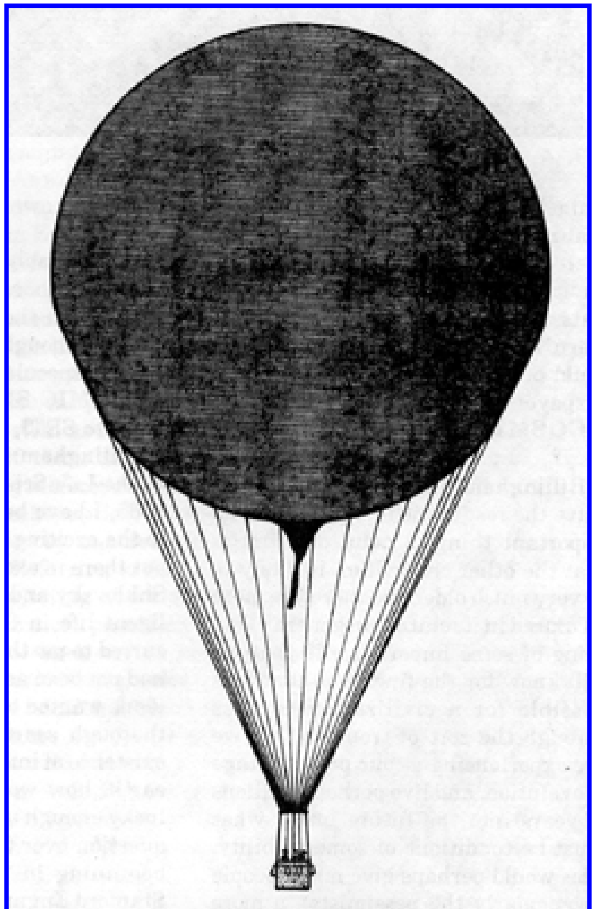
[Article in magazine started on page 20]

The linden and willow-lined meadow near Aussig in northern Bohemia had been active since the earliest light of morning. Nearby the river Elbe flowed northward to the Erz mountains whose azure peaks shimmered in the distance against a cloudless sky. Now a few hours after dawn a huge orange and black balloon towered majestically above the meadow's grassy expanse, the low slanting rays of the sun glinting off its rounded dome. Named the *Böhmen* (German for Bohemia) it towered twelve stories high. Nudged by an almost imperceptible breeze, the big bag tugged impatiently on its ropes. Members of the Austrian Aeroclub moved with a well-practiced efficiency making final preparations for its ascension but one could detect a feeling of excitement in the air for this was no ordinary flight.

It was Wednesday the seventh of August, 1912, and today the *Böhmen*, with its lifting power of two tons, was to carry Herr Doktor Victor Hess and a load of his apparatus on a high altitude flight. Hess, 29, taught physics at an academy of veterinary medicine in Vienna. He was already aboard checking his equipment. The flight meteorologist, Ernst Wolf, was also in the rope-festooned basket adjusting his barometer.

Inflation was complete and the Aeroclub members disconnected hoses from hydrogen tanks on some wagons nearby. Captain Wolfgang Hoffory, the pilot, walked around the outside of the basket inspecting the sand-filled ballast bags hanging from its perimeter. Shouting final orders to the ground crew he swung effortlessly aboard. He was a veteran of many ascensions and had, in fact, piloted Dr. Hess on a number of flights during the previous months. But none went as high as he hoped to rise today.

At twelve minutes past six Captain Hoffory gave the command to cast off and slowly the great rotund *Böhmen* rose gracefully and silently into the sky seeking the source of a strange radiation.



Ascent of the Böhmen

For many years scientists had puzzled over the fact that an electroscope gradually lost its charge even though it was carefully insulated. Electroscopes had come into wide use after the discovery of radioactivity by Antoine Becquerel of France in 1896. A typical electroscope consists of two leaves of gold foil suspended from an insulated electrode or metal rod in a metal container with glass window. When given an electric charge, as from a rubber comb rubbed with a flannel cloth, the leaves spring apart due to the repulsion of their like charges. Radiation from radioactive material brought near the electroscope penetrates the container producing ions or charged particles in the air inside which discharges the leaves and causes them to drop. What the scientists had noted was that even in the absence of any known radioactive material, the leaves would gradually drop, suggesting some unknown radiation. It was suspected, and later confirmed, that the radiation came at least in part from the weak radioactivity of substances present near the surface of the earth.

By measuring the rate at which the leaves collapse one can determine the strength of the ionizing radiation. If the pressure of the air in the container enclosing two leaves is increased, the electroscope becomes more sensitive and these so-called *ionization chambers* were carried to the top of the Eiffel tower and aloft in balloons to determine if the radiation decreased with height above the ground but the results were inconclusive.

Victor Hess had wondered if the unknown radiation might come from outside the earth, perhaps from the sun. With support from the Royal Vienna Academy of Science, he had embarked on a series of balloon ascensions at night, during the day and even one during an eclipse of the sun. From these he concluded that the sun was not the source of the mysterious ionizing radiation.

The flight today was the seventh in a series he had begun in April, 1912, and his aim today was to go much higher than he had before. The previous ascensions indicated that there was a small decrease in ionization going from the ground to heights of a few hundred meters due apparently to a reduced effect of the earth's radioactivity. However, with further increase in height up to 2000 meters the readings did not seem to change.

The *Böhmen* was now rising rapidly and catching a 30 kilometer per hour wind from the south, began to follow the Elbe northward over the Bohemian countryside. Soon clouds appeared ahead. They were scattered, puffy, white cumulus clouds, all at the same altitude. The *Böhmen* climbed though them and now, looking down, they dotted the landscape like balls of cotton all the way to the horizon. Near Peterswalde the balloonists crossed into Saxony and smoke floating up lazily from the factories of Dresden appeared off to the west.

An hour after lift-off they were at 1600 meters and during the next two hours they rose to 3600 meters. The sun climbing in the east warmed the balloon increasing its lift so Captain Hoffory could conserve on the amount of sand ballast he had to release.

At 10:45 they attained 5350 meters, their maximum altitude, and Captain Hoffory pulled a valve to release some gas and start their gradual descent. Above them at about 6000 meters, there was now a thin filmy layer of strato-cirrus clouds through which the sun shone brightly.

Victor Hess had been busy from before lift off with his apparatus consisting of three ionization chambers and associated equipment. Each chamber was made of an air-tight, thick-walled metal cylinder the size of a two liter can with a small glass window for observing the electroscope leaves with the aid of a microscope. Hess took readings on all three instruments in rotation as the cold thin air of the high altitudes penetrated his clothing. He carefully recorded these values along with the barometric pressure readings, which indicated the altitude, as called out by Ernst Wolf.

On chamber number 2, which was rather typical of the three instruments, the ionization at the ground was about 12 units. At an altitude of 1000 meters it dropped to 10 but at 2000 meters the reading was up again to 12. At 3500 meters the ionization level had climbed to 15 and most startingly at 5000 meters it rose to 27 units or more than twice its value at the ground!

The descent was gradual, taking another two hours. On the way down Victor Hess continued to take readings which confirmed the ones he obtained on the ascent. At fifteen minutes past noon Captain Hoffory brought the *Böhmen* down in a pasture near a small village about 50 kilometers east of Berlin. They had been aloft six hours, traveled 200 kilometers and reached a maximum altitude of 5350 meters.

"Rays of very great penetrating power are entering our atmosphere from above."

Courtesy ALPHONZ WEBER, FORDHAM UNIVERSITY

Victor Hess surrounded by Austrian peasants after landing from one of his ascensions a few weeks before his record breaking ascent in the Böhmen.

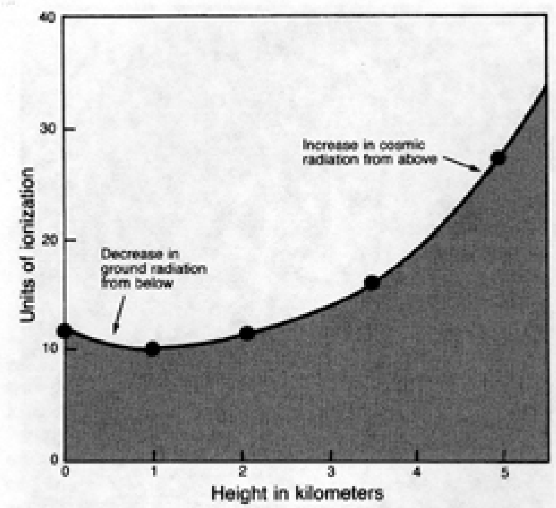
Victor Hess had been so preoccupied with his instruments and recording of the data that the full import of his results did not strike home until after the flight when he had the time to analyze the data carefully. But then there was no doubt. The increase with altitude demonstrated that it must be caused from above. The atmosphere was like an absorbing blanket. The higher one rose through it the stronger the radiation from above became. In his report published later that year in the *Physikalisches Zeitschrift* he stated,

"The results of the observations indicate that rays of very great penetrating power are entering our atmosphere from above."

During the next two years confirmation of Hess' results came from further balloon flights by Werner Kohlhörster which culminated in an ascension to 9300 meters from Bitterfield, near Leipsig, Germany on June 28, 1914. Rising above the height Hess had reached, Kohlhörster found that the ionization continued to increase at an increasing rate. But not every one was convinced by Hess' and Kohlörster's observations and a violent controversy ensued in scientific circles which raged for a dozen years.

On the same day as Kohlhörster's 9300 meter flight Archduke Francis Ferdinand, heir to the throne of Austria-Hungary, was assassinated and soon armies were on the march as Europe exploded and plunged into World War I. Strange radiations penetrating the earth's atmosphere from above now seemed of little consequence and further balloon measurements would have to wait.

Eventually Hess' results gained acceptance and the radiations he had discovered coming from beyond the earth were named *cosmic rays*. Perhaps, it was thought, they might be electromagnetic waves like x-rays, only of a more penetrating kind. Subsequently, however, they were shown to be material particles and not waves: protons (hydrogen atom nuclei) and nuclei of heavier atoms to at least uranium, often with enormous energy and penetrating power, which bombard the earth relentlessly. In 1936, Victor Hess received the Nobel prize for his discovery of cosmic rays.



Readings on ionization chamber Victor Hess carried aloft in the Böhmen. Above four kilometers the ionization rose rapidly indicating "that rays of very great penetrating power are entering our atmosphere from above". These cosmic rays contain the only modern samples of matter from outside our solar system which can be investigated directly.

The origin of cosmic rays is uncertain but it is presumed that many are generated during violent events, such as stellar explosions within our galaxy. It is entirely possible that a proton striking the earth today was shot out from the Crab nebula, the exploded star of 1054 A.D. In its long journey from the nebula, it has traveled at nearly the speed of light for thousands of years. Magnetic fields encountered along its way have deviated its path from a straight line, like cross-winds buffet a ship off course, so its direction on reaching the earth is not that of the Crab nebula. But this tiny particle is a messenger from a distant part of our galaxy with perhaps a fascinating tale to tell if it could.

Note: The term *radioactivity* came into use long before the word "radio" was coined. Radioactivity implies that a substance such as radium emits or radiates particles or very short electromagnetic waves called gamma rays. It does not mean that the substance emits radio waves which are very long wavelength electromagnetic waves. However, the similarity of the words leaves them open to confusion.

"Strategies for the Search for Life in the Universe"
A Joint Session of the International Astronomical Union

By: Michael D. Papagiannis

[Article in magazine started on page 24]

It was a happy moment, when on the morning of August 15, 1979, I stepped to the podium to welcome on behalf of the International Organizing Committee all the participants to our joint session. The large auditorium was full, creating a gratifying feeling after nearly two years of letter writing, telephone calls and telegrams to places all around the world. In my brief welcoming address, I said,

Michael Papagiannis (center) welcoming IAU members to the Montreal Joint Session on SETI. Philip Morrison (left) and Iosef Shklovsky (right) wave to the audience.

> "It is an important new step and a unique opportunity to hold a meeting on Life in the Universe during the General Assembly of the IAU when many of the best scientists in this field from around the world are gathered under the same roof. Our subject is a sensitive one that can easily lead to misunderstandings. It is our responsibility, therefore, to provide sensible leadership and to show that we can proceed in a scientific manner, without exaggerations and without premature headlines, toward the solution of this fundamental problem."

The **International Astronomical Union** (IAU) is an organization of the world's astronomers representing nearly fifty countries. The Unions purpose is to facilitate the exchange of scientific information and to foster international cooperation in astronomical activities. The Union is organized into about 50 commissions, each concerned with a specific area of astronomy. Every three years the Union holds a *General Assembly* at which all members and commissions may participate. The August 1979 meeting of the IAU in Montreal, Canada, was the Seventeenth General Assembly.

A special feature of the *General Assembly* was the one-day Joint Session of three of the IAU's Commissions (No. 16, *Physics of Planets*, No. 40. *Radio Astronomy* and No. 44. *Space Astronomy*) on Strategies for the Search for Life in the Universe" , as reported here by Michael D. Papagiannis, Chairman of the committee which organized the session. Professor Papagiannis is Chairman of the Astronomy Department of Boston University. Other members of the organizing committee were Frank Drake, Tobias Owen and Ben Zuckerman of the U.S.A., Nikolai Kardashev. Iosef Shklovsky and Vasevolod Triotsky of the U.S.S.R., J. C. Ribes of France. Sir Bernard Lovell and Martin Rees of the United Kingdom, George Marx of Hungary and Jun Jugaku of Japan.

Several of the members of the International Organizing Committee as well as several of the Section Chairman, namely Drake, Kardashev, Troitsky, Rees, Morrison, Oliver and von Hoemer, are also members of the Editorial Board of **COSMIC SEARCH**.

—Eds.

The topic of the first morning section was: **Alternative Views on the Value of N**, i.e., on the number of technologically advanced civilizations currently present in our galaxy. Iosef Shklovsky of the Academy of Sciences, Moscow, and Philip Morrison of M.I.T. were the Co-Chairmen of this section. Michael Hart, of Trinity University, who was the first speaker, supported the view that N is very small based on the lack of any evidence for extraterrestrial presence on earth. It is inconceivable, he said, that every one of millions of galactic civilizations has forbidden for billions of years interstellar travelling and this order has been obeyed without any exception by their trillions of inhabitants. Hence, he concluded, their absence from the earth is convincing evidence that they do not exist.

Thomas Kuiper of the Jet Propulsion Laboratory suggested that N is probably very large, because life seems to be able to operate an inverse 2nd law of thermodynamics, i.e., to use available energy to locally reduce entropy and thus progressively build organisms and societies of high complexity and sophistication. Frank Drake of Cornell University defended the view that N is neither very small nor very large based on the analysis that interstellar travelling would be prohibitively expensive. Using figures of energy consumption per head, he finds that the cost needed to send a few thousand people to another star in search of a better life would be equal to the cost needed to provide a high quality life for all the people on earth. Hence, he concluded, interstellar colonization would not be an appealing proposition to any civilization. It was pointed out by other participants, however, that man undertakes tasks not only for practical purposes, but, as in the case of climbing Mt. Everest or landing on the moon, for curiosity, glory, etc. Also that interstellar migration will never be used to offset the population problem of a planet, since it can involve only a minute fraction of its population, but rather to satisfy the spirit of seeking new worlds. Finally, the energy problem might not seem as severe after a few centuries in the light of future technological advances.

I supported the thesis that N is either very small or very large and that intermediate values are quite unlikely. I pointed out that life from the simplest to the most advanced forms has a natural tendency to expand like a gas to fill all available spaces. The slow biological evolution, which moved life from the waters to land and from land to air, has now been replaced by the explosive progress of technology which has allowed man to conquer the waters, the air and recently the outer space, the largest space of them all. Interstellar travelling and galactic colonization are not only technologically possible but also inevitable given this basic trait of life. It was generally agreed that the complete colonization of our galaxy can be achieved in about 10 million years, which is a very short interval when compared to the 10 billion, or so, year age of our galaxy. Hence, I concluded, either the colonization of our galaxy has already taken place and therefore every star must have been colonized, or it has not yet happened because nobody started it and therefore we must be one of the few if not the only technological civilization in our galaxy.

I also noted that in all probability colonizing civilizations could not come to live on planets, because they would be accustomed to living in space colonies, after their centuries-long interstellar journeys, and because it is highly unlikely that the conditions prevailing on any given planet would fit exactly their biological needs. They would continue, therefore, to live in their comfortable space colonies and their colonization of a solar system would amount to building more space colonies using the raw materials obtained from asteroids and small moons with low gravity. Consequently, their absence from the earth is not a proof of their absence from the solar system which we must search carefully and in particular the asteroid belt before we can conclude that the colonization of the galaxy has not yet taken place.

In addition to the above speakers Vasevolod Troitsky of the Radiophysical Scientific Research Institute of Gorky, U.S.S.R., presented an interesting paper dealing with the technological requirements of a radio antenna that could broadcast a beamed signal to a distance of 10,000 light years. He finds that these requirements are formidable, if not prohibitive. At the end of this section, Philip Morrison gave an articulate summary of the different views on the value of N and the directions we ought to proceed in the future in view of the alternatives discussed. These directions, he said, ought to include both the continuation of radio searches, as well as the further exploration of our solar system.

The topic for the second morning section was: **Strategies for SETI Through Radio Waves**. The Co-Chairmen were Bernard Oliver of the Hewlett-Packard Co. and Jun Jugaku of the Tokyo Astronomical Observatory. Oliver opened this section with a brief summary of the advantages of radio communications and the rapid progress that is being made in electronic support equipment, especially in the construction of multichannel analyzers. Analyzers with one million channels are within the capabilities of current technology, he said. Ben Zuckerman of the University of Maryland gave an extensive review of the six radio searches that have been performed up to now in the United States and Canada. The first one, Project OZMA by Frank Drake in 1960, looked only at 2 stars (Epsilon Eridani and Tau Ceti), while OZMA II by Palmer and Zuckerman looked at nearly 600 stars collecting data points 10 million times faster. Troitsky gave a similar, but less detailed summary of the several searches that have been going on in the Soviet Union and finally Samuel Gulkis of the Jet Propulsion Laboratory discussed different alternate possibilities, both small and large, for the future.

The topic of the first afternoon section was: **The Search for Early Forms of Life Both in Our Own Solar System and in Others**. The Co-Chairmen were Jesse Greenstein of the California Institute of Technology and Nikolai Kardashev of the Academy of Sciences, U.S.S.R. Gerald Soffen, the Director of Life Sciences of NASA, gave an exciting overview of the search for life in our solar system. He discussed the Viking mission to Mars and he noted that finding another independent origin of life would be of immense importance in our efforts to understand the mystery of life. He also pointed out that this is a multi-discipline task where experts from many different fields, including astronomers, geologists, biologists, chemists, physicists, etc. must work together. Tobias Owen of Stony Brook discussed how we hope some day to use spectroscopic observations, in particular those revealing the presence of water and oxygen, to search for life in other solar systems. Searching for life based on carbon, water and oxygen is not a projection of our chauvinistic bias because carbon, nitrogen and oxygen are the three most common heavy elements accounting for nearly 3/4 of all the heavy element atoms in the Cosmos. Carbon is unique for its ability to make complicated chemical compounds, while water is a superb solvent and medium for chemical reactions. In addition it can dissolve large quantities of carbon dioxide and can co-exist nicely with oxygen, which ammonia cannot.

Searching for signs of life in other solar systems, however, is still a task for the future because we have not yet been able to detect any planets even in the nearest stars. The problem is that the faint planets are so close to the extremely bright stars that it is like trying to see a firefly sitting at the edge of a powerful searchlight. Great progress, however, is being made in this area, and many new techniques were discussed by experts in the field. George Gatewood of Allegheny Observatory described the astronometric methods and said that the recent replacement of the photographic processes by photoelectric techniques has led to a dramatic improvement in the sensitivity of astrometric methods which are looking for minute changes (one to one-tenth milliarcseconds) in the position of a star produced by the rotation around it of one or more planets.

Douglas Currie of the University of Maryland described the interferometric methods where efforts are being made to develop a two aperture set-up, like a radio interferometer. Single aperture techniques, using speckle interferometry, have already made it possible to measure the diameters of some large red giant stars. Ian McLean, of the laboratory of Krzysztof Serkowski at the University of Arizona, described the progress being made in developing the sensitive spectroscopic techniques needed to measure the orbital velocity (10-20 m/sec) of a star about the common center of mass of the star and a large planet orbiting around it. William Baum of Lowell Observatory described the advantages the space telescope will have in this area since it will be able to detect objects as faint as 28th magnitude by avoiding the airglow and the smearing of a star's image by atmospheric seeing. It seems that the combination of the space telescope and the new photoelectric astrometric technique might be able to provide some impressive results in the next 5 to 10 years. Finally, David Black of NASA-Ames Research Center gave an excellent summary of the advantages and disadvantages of the different presently available methods for the detection of planets and their prospects for the future. He also discussed some direct methods that are currently being proposed, including occulting disks, apodized images and the infrared space interferometer proposed by Ronald Bracewell of Stanford University which might hold a great promise for the future.

The topic of the last section was: **The Different Manifestations of Advanced Cosmic Civilizations**. The Co-Chairmen were Sebastian von Hoerner of the National Radio Astronomy Observatory and Martin Rees of Cambridge University, England. Woodruff Sullivan of the University of Washington discussed the possibility of eavesdropping on other neighboring civilizations by considering what they could have learned by doing the same to the earth. Since strong narrow-band signals, such as the carrier frequencies of TV stations, come from discrete locations on the earth, it is possible from the Doppler effects to determine the rotation of the earth and its orbital period around the sun. From the mass of the sun, which one could figure out from its luminosity, one could then determine the distance of the earth from the sun and hence also its average temperature. Von Hoerner summarized different astroengineering projects that advanced civilizations might undertake, including the building of "Dyson spheres." Philip Morrison noted that it is uneconomical and therefore unrealistic to expect these civilizations to surround their stars completely with opaque spheres in order to absorb all of the star's radiation. It is more reasonable to expect them to deploy space colonies and solar energy satellites that would cover up to about 10 percent of the area around the star, so that such stars would appear to have a normal spectrum with an abnormally intensified infrared component. I proposed to name these "modified Dyson spheres" or better "Dyson-Morrison spheres".

Sebastian von Hoerner discussed also the possibilities for interstellar travelling. He noted that theoretical computations such as those performed by Freeman Dyson of Princeton University in project Orion, or by the group headed by Anthony Martin and Alan Bond of the British Interplanetary Society in *Project Daedalus*, have shown that it is possible to propel a spaceship over interstellar distances even with present day technology. These projects require the continuous explosion of nuclear bombs a certain distance behind the spaceship which provide the thrust needed to accelerate the spaceship to velocities in the range of one-hundredth to one-tenth of the speed of light. Von Hoerner noted that the undertaking of such a project today would wipe out completely all the nuclear stockpiles on earth. This remark brought glitters to the eyes of all the participants, because if sending a mission to another star would eliminate the threat of a nuclear holocaust on earth, what more could one ask for.

More than 300 astronomers attended the Joint Session and all four sections were followed by lively discussions. The next day the Executive Committee of the IAU had scheduled an Open Evening Session in which we were asked to summarize the discussions and the conclusions of our Joint Session for the general membership of the IAU. The large participation of the previous day necessitated the moving of the Open Evening Session to the main auditorium of the University of Montreal. Leo Goldberg, President of the IAU from 1973 to 1976, was the Chairman of this Evening Session and presented Frank Drake of Cornell University and myself. Drake reviewed the two morning sections and I reviewed the two afternoon sections. The attendance was probably the largest of all the meetings of the General Assembly, having many people standing in an auditorium with a seating capacity in excess of 1000 people. All in all it was an exciting meeting that brought together many distinguished workers in this field from around the world. It focused strongly on the controversy of the colonization of the galaxy and on the progress being made in the search for planets in other stars. The possibility of galactic colonization seems to call for a careful search inside our own solar system and for the parallel study with radio antennas of all nearby stars. These tasks, as well as the search for planets, can be comfortably woven into the current goals of space exploration and astronomical research for the 1980s. Thus, it seems that the proper strategy at this time is to amalgamate our Search for Life in the Universe into our normal scientific research and space exploration, keeping always a keen eye and an attentive ear for opportunities that might advance the cause for this exciting quest.

ABCs of Space

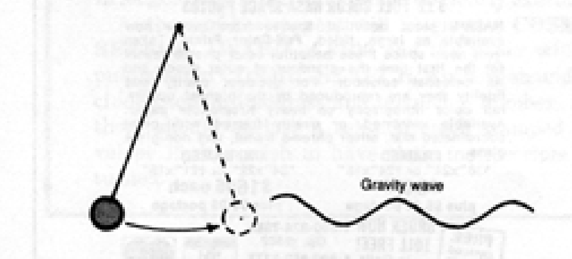
By: John Kraus

[Article in magazine started on page 28]

A. Gravity Waves. A Revolutionary New Way to Communicate with the Stars?

Light, x-rays and radio waves are all basically similar except for differences in wavelength. X-rays are short, radio waves long and light waves intermediate. They all travel through empty space at the velocity of light (300,000 kilometers per second).

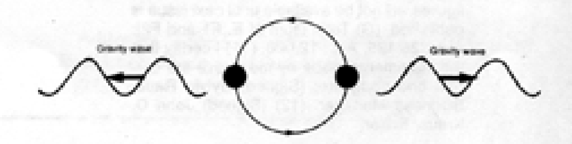
Are gravity waves similar? It is believed that gravity waves travel at the speed of light but there the similarity ends. Light, radio waves and x-rays involve propagation through space of electric and magnetic effects, so they are all classed as *electromagnetic waves*. Gravity waves, on the other hand, are gravitational and involve fluctuations in *gravitational forces*.



Golf ball pendulum produces gravity waves.

Any object, be it a golf ball or the earth, produces a gravitational attraction which is proportional to its mass, the larger the mass the larger the attraction. If a golf ball is suspended on a string and swings back and forth toward you and away, like a pendulum, it produces gravity waves in the sense that when it swings closer to you its gravitational effect is greater than when it swings farther away. Thus, its oscillation results in a variation of the gravitational attraction which fluctuates in a wave-like manner. For the golf ball, however, the strength of the wave is exceedingly small.

The motion of any object produces gravity waves so whenever you move you produce gravity waves; you are a gravity wave transmitter, albeit a very weak one.


"Two stars revolving around each other, like swinging partners in a square dance, can send out gravity waves of substantial power."

To generate gravity waves of significant strength more massive objects are needed. Thus, for example, two stars, each as massive as our sun, revolving around each other like swinging partners in a square dance, will send out gravity waves of substantial power.* (*The revolving stars constitute a gravitational *quadrupole*. By contrast, electromagnetic waves can radiate from electric charges oscillating along a straight wire constituting an electric *dipole*. Gravitational radiation, that is, gravity waves at a large distance from their origin and completely detached from it, cannot be of the dipole type but can be of the quadrupole type.) Likewise, a star with nuclear fuel depleted, which collapses on itself into a pulsar or black hole, will radiate a strong pulse of gravity waves. Although gravity waves are theoretically possible and searches for them have been in progress for some years, none have as yet been detected for sure.

Assuming that as techniques are improved, gravity waves will be detected and, further, that it may be possible to generate sufficiently strong gravity waves under intelligent control to send messages via these waves, could gravity waves become a revolutionary new method for interstellar communication? This intriguing possibility is the subject of an article being prepared for **COSMIC SEARCH** by Professor David Douglass of the University of Rochester, who has been operating gravity wave detectors for a number of years and is developing new, more sensitive types.

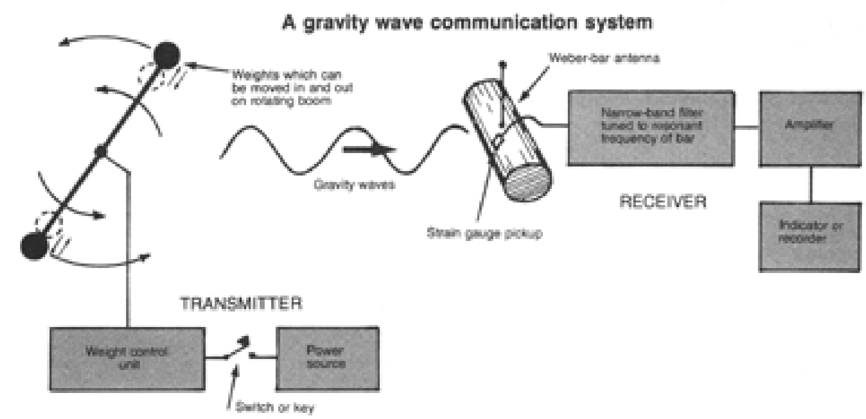
A purpose of this ABCs item on gravity waves is to provide a bit of background in anticipation of Douglass' article.

In an article by Jay Pasachoff and Marc Kutner on "Neutrinos for Interstellar Communication" in the Summer 1979 issue of **COSMIC SEARCH**, a possible neutrino transmitter and receiver, or communication system, was described on page 6 which might lead to a practical system of the future. Let's look ahead at what might be involved in a system for sending messages with gravity waves, remembering that with gravity waves we are even further from a practical system than we are for neutrinos.

[Caption for Photo to the Left.] **Joseph Weber adjusting sensors on his big cylindrical aluminum bar often called a "Weber-bar antenna". The bar is suspended from its mid-point and during observations is enclosed in a sound-proof, shock-proof chamber from which the air is pumped out.**

For a receiver we might use a device similar to the basic one developed by Professor Joseph Weber, pioneer gravity-wave scientist, of the University of Maryland, consisting of a large aluminum bar suspended at its mid-point and isolated from atmospheric and vibrational effects by enclosing it in a cushioned, evacuated tank. A passing gravitational wave tends to make the bar vibrate as though tapped by a small hammer. The vibration of the bar generates electrical signals in sensors attached to the bar and these signals are then amplified and recorded.

For a transmitter suppose we place a large mass or weight at each end of a long boom which rotates rapidly in a big evacuated tank so that the masses revolve like two riders at opposite sides of a merry-go-round. This arrangement is really a greatly scaled down version of the double star system we talked about earlier.



Arrangement which could be used for gravity wave communication if sensitivity could be increased sufficiently. Rotating boom idles with weights out. With weights pulled in, the boom speeds up sending out gravity waves at frequency to which massive aluminum bar antenna is tuned.

If the gravity wave bar-detector or receiver is tuned to a frequency of 1000 cycles per second and the gravity waves sent out by the transmitter are at a considerably lower frequency, there will be little or no signal received. However, if the two weights are moved inward along the boom, their rotation rate will increase, in the same way a pirouetting ice skater speeds up when arms are drawn inward. If the rate now corresponds to a 1000 cycle per second gravity wave, the detector could receive a signal. Thus, by moving the weights in and out, making them spin around faster or slower, we would have a crude frequency shift transmitter for sending code signals. The device for moving the weights in or out could be controlled by a switch or key as in a radio code transmitter.

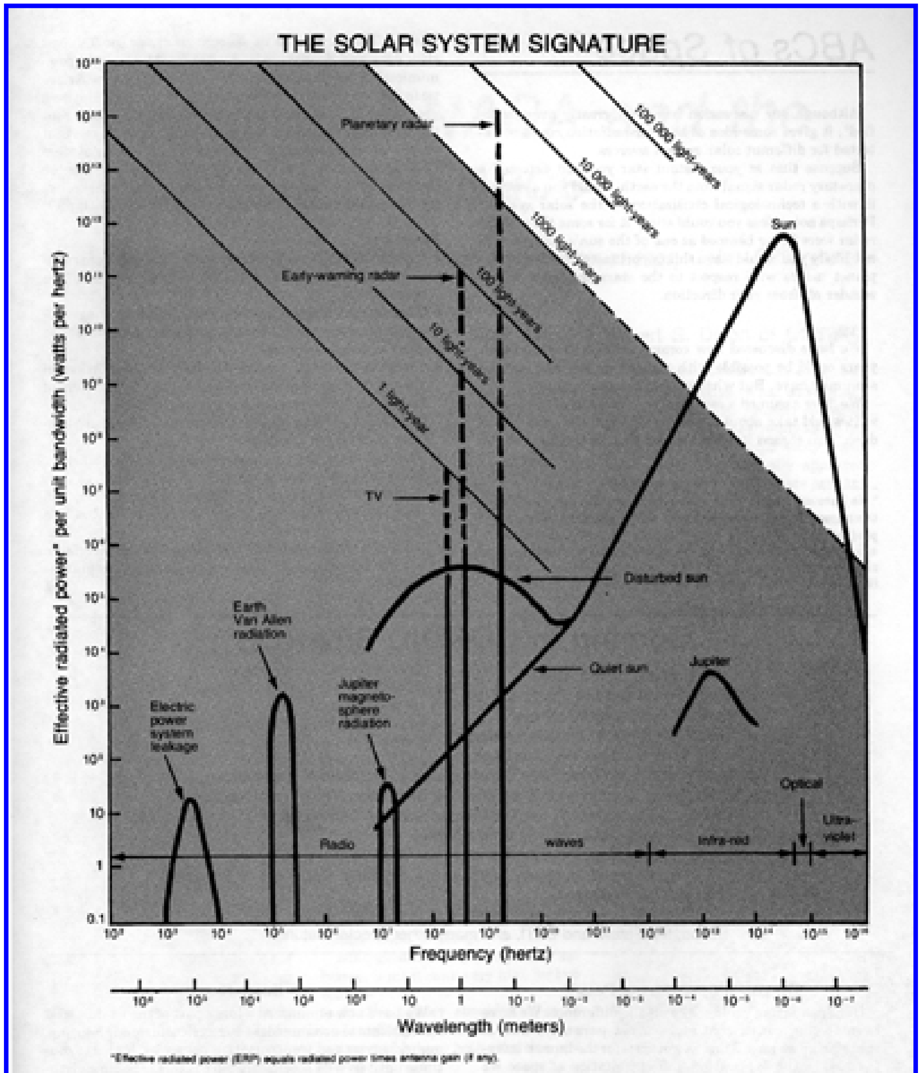
Although the message sending rate would necessarily need to be very slow and although the gravity waves might be much too weak to be practical, (like 30 or more orders of magnitude too weak) the arrangement illustrates the basic elements required for a gravity wave communication system.

Summary

- Gravity waves are believed to travel at the speed of light.
- In principle, gravity waves could be used for communication purposes.
- A gravity wave communication system is, at present, further from practical realization than, for example, a neutrino communication system.

B. The Solar System Signature. How Our Solar System Would Appear to an Observer at a Distant Star

Although the sun is the largest object and the principal source of radiation from the solar system, two of the planets, Jupiter and the earth, also contribute. While the sun is strongest at optical wavelengths, Jupiter and the earth are radio emitters.



A distant observer 1000 light-years from the solar system could detect one of the earth's planetary radars and also the sun. At 100 light-years the observer might also just marginally detect one of the earth's early-warning radars and at 1 light-year do the same for the carrier of a TV station but would not be aware of any sound or picture. (See text for assumptions involved).

For an overall view of the radiation from the solar system as it might appear from a distant star, let us make a graph of the power radiated (per unit bandwidth) versus the frequency as done in the accompanying **Solar System Signature** or spectrum.

At the lower left of the "signature" is a small peak at a few kilohertz (10^3 to 10^4 hertz) due to leakage from the earth's open wire electric power distribution lines. Higher harmonics of the 60 hertz currents penetrate the earth's ionosphere and in the magnetosphere or Van Allen region are amplified as much as 1000-fold by wave-particle interactions.* (*C. G. Park and R. A. Helliwell, *Science*, May 19, 1978.)

A larger peak at 200 kilohertz (1500 meters wavelength) is from radio waves generated by fast particles in the Van Allen belts. The power level fluctuates, being associated at times with auroral (northern or southern) light activity. The total power from this radiation source sometimes amounts to a billion watts. The peak would be higher if it weren't for the fact that the radiation is spread out over a relatively wide bandwidth of a couple hundred kilohertz. The ionosphere between the Van Allen belts and the earth acts like a metallic shield and prevents this strong radiation from pentrating down to the earth. If it were not for this shielding this Van Allen noise would severly jam the European broadcasts in the long wave radio band.

Still higher in frequency, around 20 megahertz (15 meters wavelength), Jupiter makes itself heard due to radiation from fast particles in its magnetosphere. The radiation appears to be initiated or controlled in some way by Jupiter's small inner moon Io. The total power of this radiation at its maximum is perhaps a billion watts, the same as the earth's Van Allen radiation, but the power per unit bandwidth (chart vertical scale) is less because the bandwidth is greater.

At about this frequency the radio emission from the sun becomes significant even during the relatively quiet periods between sunspot maxima which occur every 11 years. During a spot maximum the radiation may be a thousand times greater and much in excess of the Jupiter radiation, and even enough to mask TV signals from the earth as discussed in the next paragraph.

Next on the "signature" are three tall spikes near 200 megahertz (1.5 meters wavelength), 400 megahertz (75 centimeters wavelength) and 2 gigahertz (15 centimeters wavelength) due to man-made signals from television, military early-warning radar and planetary radar stations. The bandwidths are narrow so the power per unit bandwidth is large. All of these stations use antennas which increase the effective power in certain directions. The solid part of each spike shows the power level if the power is radiated uniformly in all directions while the dashed extension indicates the increase in effective power due to the antenna.

The television station spike is *not* due to the modulation which produces the picture but to the very narrow bandwidth carrier (less than 1 hertz bandwidth) which is the backbone of the signal. Sullivan, Brown and Wetherill† († *Science*, Jan. 27, 1978.) have pointed out that although an Arecibo system might detect a television carrier at a distance of a light-year or so, "ten thousand times more sensitivity would be required to obtain program material."

The most intense signals from the earth are from planetary radar stations which bounce radio waves off the moon, Venus and Mars. Such stations are located at Arecibo in Puerto Rico, Jodrell Bank in England, Goldstone in California and elsewhere. These radar stations may transmit with very narrow bandwidth. Since much of the effective power results from the large antenna used (dashed part of the spike), this means that the direction in which a strong signal is transmitted is very limited in angular extent, as in a very narrow searchlight beam, so even though the signal is strong the chances of it being picked up by an observer at another star is very small.

The world's AM broadcasting stations, including the most powerful ones of several million watts in Saudi Arabia, are confined in coverage to the earth by the ionosphere, and while the FM stations' frequencies are high enough to penetrate the ionosphere, they are not powerful enough to be contenders.

As we go to still higher frequencies on the "signature" the radio, infra-red, optical and ultra-violet radiation from the sun becomes dominant.

Now suppose you live on a planet revolving around a star 1000 light-years from our sun. At this distance the solar system out to the orbit of the planet Pluto subtends an angle like that of a penny seen from a distance of 10 miles so when you point your radio telescope at the sun you also have the planets in the beam and observe the whole solar system as single entity. Suppose your radio telescope has 100 times the sensitivity of Arecibo (such as a large orbiting telescope now under consideration) and also you have a sizable optical telescope (the sun would be too faint to be seen by unaided eye at 1000 light-years).

Referring to the "signature" you could detect everything projecting above the line marked 1000 light-years or the sun and a planetary radar. Things below (shaded) would be too weak or, as communication engineers would say, "buried in the noise". If you were at 10,000 light-years only the sun could be detected (above line marked 10,000 light-years). On the other hand, at 100 light-years an early warning radar station could just be detected but even at the relatively close-up distance of one light-year a TV station would not yet be detectable, and the Van Allen, Jupiter and earth power line radiation would also be too weak.

Although our discussion has been greatly oversimplified* (*We have assumed that the receiver bandwidth matches that of the transmitter or source and that the bandwidth-time-constant product of the receiver is unity. Other factors affecting the results are sky background temperature, wavelength and signal-to-noise ratio (assumed equal to 10). With somewhat different assumptions, ranges could easily change by a factor of 10 or more.), it gives some idea of how far radiation could be detected for different solar system sources.

Suppose that at your distant star you had detected a planetary radar signal from the earth, would you associate it with a technological civilization in the solar system? Perhaps not unless you could study it for some time. If the radar were being beamed at one of the sun's planets, it is not likely you would have this opportunity because as the planet moves with respect to the stars the beam would wander off from your direction.

We have discussed how communication at 1000 light-years could be possible with technology we now have or soon may have. But what kind of communication?

We have assumed a receiver time constant of 10 seconds so it would take about a minute for a dot and longer for a dash. This means it could take an hour or so to just to say "Hello". There could be no speech, no music, no TV, just slow dots and dashes—a rudimentary Morse code communication like Marconi's first three dots across the Atlantic in 1903. *And* there would also be a 1000 year delay so a good question would be whether the civilization which sent the signals still existed. The signals could only tell you that there *was* a technological civilization in the solar system 1000 years before. Could the signals, you might ask, be artifacts of a vanished society—electromagnetic relics from antiquity rushing through space at the speed of light?

Summary:

- The sun dominates the solar system signature from radio wavelengths through infra-red, optical and into the ultra-violet.
- The natural radio emissions from Jupiter's magnetosphere and the earth's Van Allen regions are part of the solar system signature.
- Protracted extremely narrow-bandwidth observations of the sun from another star might result in the discovery of terrestrial radar transmissions but these might not be recognized as being produced by a technological civilization, at least not initially.
- The chances of the very narrow beam from a planetary radar being detected at random are very small.
- Radiation from the earth's electric power distribution lines penetrates the ionosphere and is radiated but it is not as strong as other sources.
- Although the carrier of a TV station might be detectable at light-year distances, the recognition of any program is unlikely.

SETI Meetings

By: Editors

[Article in magazine found on page 33]

The great interest in SETI is evidenced by the many meetings and conferences held on this subject. In this and future issues of **COSMIC SEARCH** we will report on all of the conferences of which we are aware and, whenever possible, to list the titles of papers given and the authors presenting them.

1. National Aeronautics and Space Administration (NASA) Ames Research Center Conference on "Life in the Universe" at Moffett Field, California, June 19 and 20, 1979. Some attendees called this meeting the largest and most wide-ranging SETI conference ever held. Highlights of this conference are given by Robert S. Dixon in this issue's **SEnTInel**. Watch **COSMIC SEARCH** for announcement of publication of complete proceedings expected to be available later this year.

2. Congress of the International Astronautical Federation (IAF) at Munich, Germany, September 16-22, 1979. 8th Annual International Review Meeting on Communication with Extraterrestrial Intelligence, sponsored by the International Academy of Astronautics. Rudolph Pesek and Jill Tarter were Co-Chairmen. There were two sessions with a total of 8 papers. Jill Tarter of NASA-Ames, the Co-Chairman, will be reporting on this meeting in the next issue of **COSMIC SEARCH**.

3. International Astronomical Union (IAU) Joint Session on "Strategies for the Search for Life in the Universe" at Montreal, Canada, August 15, 1979. An account of this historic meeting is presented elsewhere in this issue of **COSMIC SEARCH** by Michael D. Papagiannis, Chairman of the Organizing Committee for the session.

4. Conference on "Where Are They? A Symposium on the Implications of Our Failure to Observe Extraterrestrials" at College Park, Maryland, on November 2 and 3, 1979. Michael H. Hart, Trinity University, Ben Zuckerman, University of Maryland, and Michael D. Papagiannis, Boston University, were the organizers. The meeting is divided into four sessions as follows:

Session I: Overview

Michael H. Hart, "Introduction: Where Is Everybody?"
Benjamin Zuckerman, "The Search for Radio Signals from Extraterrestrial Civilizations"
Robert Sheaffer, "Shortcomings in the Hypothesis that the Earth Is Being Visited by Extraterrestrials"

Sebastian von Hoerner, "The Unlikelihood, If *N* is Large, That *No* Race Will Explore and Colonize"
Ronald Bracewell, "Preemption of the Galaxy by the First Advanced Civilization"

Session II: Feasibility of Interstellar Travel and Colonization

Freeman Dyson, "Spaceships and Propulsion Techniques"
Cliff E. Singer, "O'Neill Colonies in Space"
Robert Ettinger, "Possible Techniques for Freezing Space Voyagers"
James Oberg, "Planetary Engineering"
Eric C. Jones, "An Estimate of the Time Needed to Colonize the Galaxy"

Session III: Biological Considerations

Cyril Ponnamperuma, "Pre-biotic Chemical Evolution"
Hubert Yockey, "A Calculation, Using Information Theory, of the Probability of Spontaneous Biogenesis"
P. Edward Argyle, "Chance and Origin of Life"
Gerald Feinberg and Robert Shapiro, "Possible Forms of Life in Environments Very Different from the Earth"
Gerrit L. Verschuur, "Cosmic Hazards to Planetary Life"

Session IV: Possible Sites for Extraterrestrial Life

Michael Papagiannis, "Colonies in the Asteroid Belt, and a Missing Term in the Drake-Sagan Equation"
Virginia Trimble, "The Age of the Galactic Disk"
Shiv S. Kumar, "The Relative Frequency of Single and Multiple Stars"
Pat Harrington, "The Frequency of Planetary Systems in Our Galaxy"
Michael H. Hart, "Atmospheric Evolution, and an Analysis of the Drake-Sagan Formula"

Virginia Trimble will be reporting on this meeting in the next issue of **COSMIC SEARCH**.

5. Parliamentary Assembly of the Council of Europe Conference on "Life in the Universe" at Paris, France, November 19-21, 1979. The conference session Chairmen are Frank Drake and Nikolai Kardashev. Nine speakers are scheduled to discuss the evolution of intelligence and the search for extraterrestrial intelligence. The session is organized by the Research Group on Cosmic Chemistry, Chemical Evolution and Exobiology in collaboration with UNESCO, the European Space Agency and the Centre National d'Etudes Spatiales. The Organizing Chairman is Dr. Yves Coeckelenbergh, Secretary of the Joint Committee for Scientific Cooperation of the Council of Europe, F-67006, Strasbourg, CEDEX, France. Jill Tarter will be reporting on this meeting in the next issue of **COSMIC SEARCH**.

6. Congress of the International Astronautical Federation (IAF) at Tokyo, Japan, September 21-28, 1980. 9th Annual International Review Meeting on Communication with Extraterrestrial Intelligence sponsored by the International Academy of Astronautics. The Organizing Committee for this meeting consists of Rudolph Pesek, Czechoslovakia; Jill Tarter, U.S.A., V. V. Gogosov, U.S.S.R.; George Marx, Hungary; and M. Subotowich, Poland.

In Review:

By: John Kraus

"ENTERPRISE"

by Jerry Grey,
Wm. Morrow and Co.,
New York, 1979

[Article in magazine found on page 34]

"Enterprise" is a book about the future — a breathtaking, exhilarating, refreshing picture of what mankind might accomplish if given half a chance.

Myopic opponents of the space program come in for sharp criticism. Space development is not simply a generator of spin-offs that give housewives a better frying pan or swimmers a pen that writes under water. Space development can lead to a whole new economy and opportunities for *all* mankind.

Grey notes that in 1829, Martin Van Buren, Governor of New York and later President of the United States, said,

"Railroad carriages are pulled at the enormous speed of fifteen miles per hour by 'engines' which roar and snort their way through the countryside, setting fire to the crops, scaring the livestock and frightening women and children. The Almighty certainly never intended that people should travel at such breakneck speed."

Further, Grey quotes the famous American astronomer, William Pickering, who first predicted the existence of the planet Pluto, as saying in 1910,

"The popular mind often pictures gigantic flying machines speeding across the Atlantic carrying innumerable passengers in a way analogous to our modern steamships. It seems safe to say that such ideas are wholly visionary."

Zeroing in on the present, Grey quotes Senator William Proxmire of Wisconsin as stating (in October 1977),

"As chairman of the Senate subcommittee responsible for NASA appropriations, I say not a penny for this nutty fantasy (the colonization of space)."

That ideas of space development, continues Grey, "do indeed instill a 'future shock' reaction, not only in Senator Proxmire, but in many others as well, is perhaps a result of our modern heritage of science *fiction*", but certainly *not* a result of *rational* analysis.

Grey calls attention to the perceptive analysis of Robert Frosch, NASA Administrator, who said in 1977,

"There is no sense in trying to look at future situations involving technology in terms of the current system, because *technological change does not simply modulate the system; it changes it into a new system*. (Italics mine.)

"Certainly there was no market waiting for the automobile. If we used current assessment techniques, we would have concluded" that the automobile would be a silly investment. We would have been appalled at the amount of capital required (500 billion dollars) to build the road network, the gasoline station network and the whole system. Clearly anybody would have simply said that the country could not produce the capital to do it. Of course, *that* country ran on horses and could not have produced such capital. "The country that produced the capital for the automobile was also *the product of the automobile. The system that produced the capital was a different system.* (Italics mine). This is exactly the modeling problem that most economists not only have not coped with, but they have not even discovered it to be a problem!"

As background, Jerry Grey spins a fascinating tale about the dreams, the planning, the battles and the personalities involved in the development and construction of the Space Shuttle, christened "Enterprise" at the insistence of hundreds of thousands of Star Trek fans. The shuttle is the brain-child of Dr. George Mueller, NASA Associate Administrator for Manned Space Flight during the Apollo Moon missions and before that professor of electrical engineering at the Ohio State University.

The idea behind the shuttle is to greatly reduce the cost of space development by means of a reusable space ship. An automobile would not be a very economical means of transportation if you had to discard it after each trip.

Grey gives the reader a clear, penetrating insight into the technical problems and the intricate political wheeling and dealing involved in this mind-boggling project. It is a great tribute to the U.S. technological development and production capability that such a new, difficult and revolutionary concept could be translated into an actual space craft so quickly and economically.

From the shuttle story Grey takes off into the future like a rocket discussing the great potentials and possibilities of space. He says,

"There exists today a small band of dedicated scientists whose faith in their quest has withstood ridicule, budgetary starvation and decades barren of promising results or even vague indications of potential success. Their grail is the elusive concept of probability; their altar is the inconceivable enormity of the cosmos. They seek to detect intelligent life elsewhere in the universe."

And he concludes,

"This search just *might turn out to be the most important single action ever taken by mankind*." (Italics mine.)

"Enterprise" is a book that makes you tingle with excitement. It's about grand visions of the future and the fact that "the enterprise of space is the future of the human race, and *that future* is in the process of becoming the present — *right now*."

Everyone should read "Enterprise"!

John Kraus

Towards a Cosmic Language

By: Hans Freudenthal

[Article in magazine started on page 35]

I have chosen the problem of designing a language for communication with rational beings who do not know any of the languages of our planet and to whom we cannot show things. We shall assume that they are akin to humanity in their mental facilities and development, though of course not necessarily with respect to their physical form.


Freudenthal

This problem was the subject of an amusingly written but serious article published in 1896 by the brilliant mathematician and anthropologist Francis Galton. Today the technological possibilities for cosmic communication are much more favorable than in Galton's time. We now have electromagnetic waves on which we can send radio-signals into space. I do not know what distance they can cover at the time being. I am not an expert in communication engineering, and I am happy to leave such questions to more competent people. Nor can I say whether there are in fact rational beings somewhere in the universe who can receive and interpret our signals (though on this point my ignorance is not greater than anyone else's). However, I find it hard to believe that our earth is the only spot in the universe inhabited by rational beings, though I would be quick to admit that even if there are many mansions such as ours in our Father's house, our next neighbor could dwell thousands, even millions of light-years from here.

And then it might well be that this idea of a cosmic language is a belated inspiration. Perhaps news from remote worlds is incessantly crossing the universe on ether-waves, and the only thing we are expected to do is to listen. Perhaps they are travelling on wavelengths that cannot penetrate the curtain of our atmosphere, and in that case we will have to listen from an outpost in space, from an artificial satellite, and to build a station there so that we can listen to the network of cosmic communication. But these are fantasies for the physicist and the astronomer to toy with. Let us return to the proper subject of this article. I have made some effort to design a language for cosmic intercourse, which I call *Lincos* (an abbreviation of" Lingua Cosmica"). No doubt the reader will find I have achieved very little up to now. A volume of several hundred pages is necessary to expound a vocabulary of, say, two hundred words, excluding purely mathematical and logistic terms. And that is only the beginning. This vocabularly is tentative. It must be subjected to probing criticism, and analyzed for inconsistencies and needlessly clumsy constructions. Even aside from the technical difficulties we can hardly expect to be able to talk with other worlds in *Lincos* in the near future.

The sounds of Lincos are radio signals of different lengths and wavelengths. From these sounds words are built up. Only in a few cases have I prescribed how a word will be composed: for most of the words this is a rather unimportant question which may be left for future consideration. Instead of the *Lincos* words proper, which will consist of radio signals, I am using arbitrary code-words in my text. These code-words are written representations of the true *Lincos* words (as $ is for "dollar").

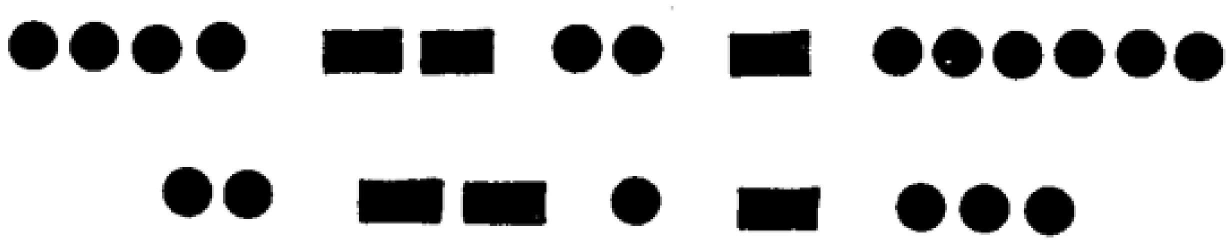
Out of these words sentences can be formed, which will be linked together in program texts. It is assumed that the listeners will recognize the stream of signals as a language and not as a celestial harmony. If they are at all like human beings, they will do with these messages the same thing we would do if we received them: they will try to decode them. They are not acquainted with the language, but in one respect their work will be easier than that of people who have to decipher a diplomatic or military code. Such codes are designed to resist all reasonable efforts at decoding and to be unreadable without the key, whereas in *Lincos* messages we shall do our best to make the text as clearly understandable as possible for the listener.

Designing a cosmic language has been made much easier by the work of the modern logisticians. The skeleton of the structure—the syntax—is ready. It is now the task of the workmen to pour the concrete and to lay the bricks—that is to say to create a vocabulary. In *Lincos* transmissions, pauses will be used as punctuation. The longer a pause the more emphatic it is as a punctuation mark. The listener will understand the principle without an explanation, if he understands anything at all. Pauses are self-explanatory.

First Words

But what shall we communicate? How can we start? With mathematics, of course. We cannot introduce things visually, hence our start cannot be concrete. And there is nothing as abstract as mathematics.

The first texts might be of this kind: four dots, a complex of signs we shall arbitrarily call POF, then two dots, another complex of signs we shall call RIK, then six dots. After this: 2 dots POF 1 dot RIK 3 dots.



The reader—and the receiver somewhere in the universe—are expected to understand that POF means "plus" and RIK means "equals". But that is a bit too hasty. The message could also be interpreted that POF means 'equals' and RIK means "subtracted from". Thus, 4 equals 2 subtracted from 6.

Obviously, then, this was a false start. Designing a language means crossing a field with a great many snares, and I am sure I have fallen in quite a few of them. Let us start more cautiously, with sentences that contain no more than one doubtful word, for example 4 dots RIK 4 dots,

and so on. With the meaning of RIK as 'equals' made clear, we can send sentences of the first type without danger. In the same way we can introduce words expressing the other fundamental operations of arithmetic, and terms denoting 'greater than' and 'less than'. We shall simply send numerical formulas in which these words appear. Excluding the infinite number of numerals 1, 2, 3 ... denoted by one, two, three, or more dots, we then have at our disposal a vocabulary of seven words. These are plus, minus, multiplied by, divided by, equals, less than, and greater than.

Dot-numerals are, of course, too clumsy in the long run. In due time we shall send a list telling the receiver how to transcribe numbers in a more compact way. We shall naturally not use decimal notation, but binary, for there is no reason to suppose that rational beings of other worlds all have ten fingers and ten toes. But for the convenience of the terrestrial reader I shall here stick to decimal notation.

The next step is to introduce variables. We shall send a sequence of equations like 3+7=7+3, 3+11=11+3, 3+1=1+3, 3+8=8+3, and finally 3+A=A+3, from which the listener must conclude that the unknown complex A must designate a variable. Gradually such formulas with "letters" will be made more and more complicated.

Then the first logical symbol can be introduced. We shall transmit pairs of algebraic formulas, each pair such that the second element always follows from the first, and between them a word that should be interpreted as 'implies'. From the context the receiver will be able to conclude that the word does have meaning. In the same way words meaning "and" and "or" can be introduced.

Zero, negative numbers, and fractions will then be established in contexts which recall those of secondary-school algebra. The next step is that of decimal (or rather binary) fractions. Common fractions are converted into the binary system. And with the introduction of repeating fractions it will be possible to familiarize the listener with the one term that is the key to all mathematics: the term "and so on", which will become one of the most frequent *Lincos* terms. Then words are introduced meaning "integer" and 'fraction', and a word meaning "is" as used in the statement "3 is an integer".

Time Concepts

The second chapter of *Lincos* bears the heading "time". A message is sent consisting of an as-yet-unknown word, say DUR, a rather long dash, the word meaning "equals", another unknown word, say SEC, and finally a numeral equalling the actual duration of the dash measured in seconds.

The message, then, would mean that the duration of the dash equals so and so many seconds. This message will then be repeated with another length of dash (and consequently with another numeral following it).

If this is done a number of times the listener will notice that the number in the message is always proportional to the length of the dash, and he will conclude that the unknown word DUR means duration and that SEC designates our conventional time unit.

"It is easier to forget something you don't want to forget than to forget something you do want to forget."

In the same way we can also introduce "wave length" and "frequency". Similarly the ideas "before" and "after" can be demonstrated by means of a pair of dashes on different wave lengths and a text that states: dash on wave length x before (or after) dash on wave length y. Then a clock can be installed on a fixed wave length, ticking in the background through the whole program, with directions added how to "read" the clock. From then on if we wish to mention a past or future event, we shall be able to quote it by its date. Mentioning events will be illustrated by many examples: a certain event is produced (for instance a complicated sequence of signals), and afterwards it is stated that "between moment 1 and 2 such and such happened", with "such and such" replaced by a replica of the event that had happened. In this way the receiver will learn that the *Lincos* word used means "happen".

More Advanced Concepts

The third chapter of *Lincos* deals with human behavior, the most substantial and the most difficult chapter up to now. Of course, we cannot tell the receiver anything about humans in abstract terms. In the same way we demonstrated numerals by sequences of dots and durations by dashes, we will now stage human behaviour in a sort of radio-play. The actors will have arbitrary names, say Ha, Hi, Ho and so on. Of course these actors must display some sort of activity, and as no words are available to indicate space or movement, the only activity we can have them perform is that of speaking. Speaking, that is to say communicating; it does not matter for the moment what physical methods of communicating are used on earth. But besides actors and an activity we need a third feature, some means to distinguish between good and bad actions, for it is impossible to stage good actions only. So we shall put two words, "right" and "wrong", in the actors' mouths as signs of approval or disapproval.

Finally, we must decide what subject we want the actors to talk about. Of course, it will be mathematics, for mathematics has been previously outlined in detail, and there is no other subject available. The conversation will consist of questions and answers in classroom style.

The first conversation might run like this:

> Ha says to Hi: "?X (X=2+2)"
> Hi says to Ha: "4"
> Ha says to Hi: "Right"

A good many similar conversations will be transmitted. The sequences of alternating questions and answers will evoke an impression of conversations, and the listener will guess what "says to" means and that Ha, Hi, Ho ... are names of beings who can converse. Since correct answers are followed by "right" and poor answers by "wrong", the receiver will guess what these words mean.

For our conversations we can dispense with a vocabulary of interrogatives, since each question can be formulated as a problem of finding an unknown. Thus, "who said to Ha:

> 2+2=4?" can be verbalized:
> "?X (X said to Ha 2+2=4)"

Or "what did Ha say to Hi?" would run:

> "?X (Ha said to Hi X)"

And finally "Did Ha say to Hi: 2+2=4?" can be expressed:

> "?X [X=truth value (Ha said to Hi 2+2=4)]"

Now we can proceed to stage a few other actions which are actually elaborations of the act of speaking, most of them speaking with oneself. A series of dots is broadcast, and at the same time Ha counting them, that is to say pronouncing numerals. Afterwards Hi states, "Ha has counted". Or we hear Ha making a calculation, and then Hi says, "Ha has computed". He tries to find something (say the first prime number beyond a certain bound, by calculating, or a person who said something, by repeating the question "did you say that"), and afterwards Hi states that "Ha has searched for (and found)". "Proving", "describing", "modifying", "adding", "dropping" can be demonstrated by the same method.

"Knowing" is a much more difficult term. Conversations are started in which Ha asks Hi how much 2+2 is; Hi answers "4", and subsequently Ha states that Hi "knows". This, however, is not sufficient. Less direct methods can better demonstrate what "knowing" means. For instance, Ha asks Hi how much 2+2 is, and Hi answers "4". Ha then says, "Hi knows what I have asked".

The next word is "perceiving". It appears that Hi has knowledge of a certain event although nobody has told him about it; Hi knew it as soon as it happened. Hence Ha states, "Hi perceived it". This word requires a broad context. The words understanding" and "slip of the tongue" are easier. They can be illustrated by simple examples.

A very important and rather easy word is "nearly". Approximate solutions of algebraic equations, approximate imitations of noises, and so on may serve to put this word into a context.

A rather simple word is "age" (of a person). Ha states that Hi was not able to perceive a certain event, because it happened too long ago, and from this Ho concludes that Hi's age is less than a certain number of seconds. The beginning and the end of a human "existence" are defined as the limits within which that individual can have observed something—a provisional definition that is sufficient for the moment. A chart of individual development can be added: at what age a human can speak, count, calculate, solve quadratic equations, and so on.

Then a new actor Ba enters. Ba can observe events and produce unintelligible sounds, but cannot speak, count, calculate, and the like. It will then be stated that Ha, Hi, and Ho belong to the class "human", whereas Ba is a member of the class "animal"—a class which will not be subdivided for the time being. A short statistical survey of living mankind according to age classes can be added at this point.

Now we can turn to a category of words like "wishing", "permitting", "being obliged", "being allowed", "forbidding", "it is decent", "it is polite". A person who is addressed refuses to answer: "I don't want to... " Persons announce that they, or other persons, will do something, with the formula "I want to ... " Two persons "promise" to each other that they will do something, and a third person states that consequently they are "obliged" to do it. A liar is "called upon" to speak the truth. One is "allowed" to say "I want you to do this", but it is more "polite" to say, "May I ask you to do this?"

This conflict between necessity, duty, will, power and possibility reaches its climax at the end of this chapter on human behaviour, when games are organized among the actors. Such games will end with the "victory" of one of the partners and the "payment" of a forfeit by the other. Ha and Hi play a very simple arithmetical game: by turns they choose a number between one and ten. All the numbers are added together. The person who passes the hundred mark wins the game. Or Ha and Hi gamble, playing something like "matching pennies": simultaneously and independently of one another they say either "one" or "two". If they have chosen the same number, Ha wins, if the numbers are different, Hi wins. And finally there are games for three persons: two of them can combine against the third, who will try to break the alliance by offering advantages to one of the allies.

Although the subject matter of the conversations is still dominated by mathematics, and behavior is primarily rational, we can already account for the emotional background ofthat behavior. The rather sophisticated character of the talks now possible might be illustrated by an example that in common language would run as follows. Ha makes a statement to Hi. Then he perceives that Ho might have heard what has been said. Ha asks Ho whether he has heard, and Ho confirms that he has. Ha asks Ho if he will be so good as not to remember it. Ho answers: "I will try to forget, but I don't know whether I can, for there are many things which are immediately forgotten, but there are also things which are remembered all one's life. It is easier to forget something you don't want to forget than to forget something you do want to forget."

Concepts of Space, Distance, and Motion

The fourth chapter of *Lincos* deals with mechanics, but human behavior still plays a part in it, though on another level. Human beings, as introduced in the third chapter, had one dimension only: time. There was no space in which they could move; no mention was made of their bodies. The actors who spoke, who expressed and imposed their wills, and played and fought together, were nothing but vague shadows.

The first new concept in this chapter is that of "difference in location". Ha and Hi perceive the same event at different times, hence are in different places. Distance is defined: the distance between Ha and Hi is proportional to the delay a message from Ha to Hi undergoes. Space is then defined as that which embraces all places and within which distances are given. After this experimental introduction space and distance can be defined in a strictly mathematical sense, with the aid of analytic geometry. By means of it spatial figures can be described in formulas. Of course the receiver does not yet know our unit of length. The only absolute measures we can indicate at this point are the average length and volume of adult people, and no more than rough estimations of our unit of length can be derived from such data.

"Motion" is introduced by telling about humans and animals who change place, then soon afterward redefined with mathematical precision. Humans and animals can move by their own will, things cannot. Humans and animals can move things with them and away from them; they can carry and throw things. As an amusing interlude three persons play ball.

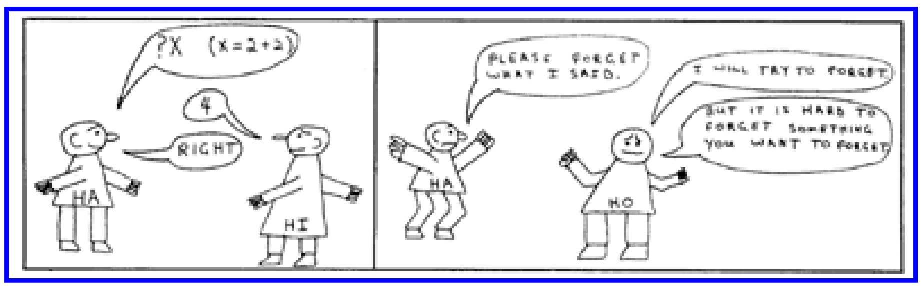
A special kind of motion is that of waves and oscillations. There are oscillations which propagate with a huge velocity, called light (or radio). The speed of light can now be indicated, and the receiver who more or less knows our time-unit can now translate our unit of length into his by comparing our data on light with those of his own experience. After this we can communicate a formula comprising the wave lengths emitted by the hydrogen atom. This formula contains the so-called Rydberg constant, from which our unit of length can be derived with much greater precision.

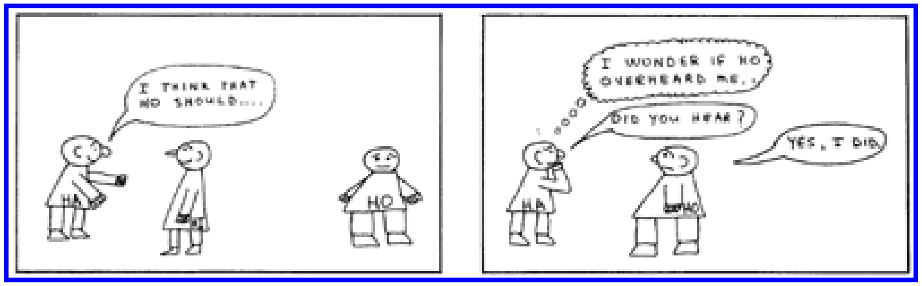
The next notion is that of "mass". An actor states that of two things one is more difficult to carry than the other. They have the same volume, so the difference is due to another factor, mass. Then a collision is reported and explained by the classical laws of elastic collision. From this the receiver can conclude what we mean by mass, though our unit of mass is still unknown. We can then describe phenomena of "gravitation" and state Newton's law. By comparing it with the law of his own Newton, he will be able to calculate our unit of mass. These are fundamental notions of mechanics.

We have also reported that humans, animals, and things have a characteristic that may be called a body, which can change in the course of time. The average mass of human bodies can be indicated. Then we can describe where and how human bodies come into existence.

Afterwards reference can be made to bodies with masses so large that they must be celestial bodies: the sun, the planets, and the nearest fixed stars. The masses, orbits, velocities, and so forth of the planets in our solar system will be quoted, and then one of those bodies can be specified as the residence of mankind. If we then proceed to draw a map of our part of the universe, the receiver beyond our solar system will be able to seek out the spot where mankind dwells.

This fourth chapter is concluded with an exposition of relatively — an indispensable theme, for without it there would be serious inconsistencies in our broadcasts. The subsequent chapters are planned to deal with matter, geography, anatomy and physiology, and, for a second time, human behaviour. These chapters still have to be worked out. Meanwhile the four themes sketched here are described in detail in the first *Lincos* volume.





This article is adapted from an article of the same name published in the summer 1958 issue of "Delta — A Review of Arts, Life and Thought in the Netherlands." It describes and introduces Prof. Freudenthal's famous book" *Lincos* — Design of a Language for Cosmic Intercourse" (North-Holland Publishing Co., Amsterdam, 1960).

It should be noted that the author's primary intention was not to develop a language, but to give an example of how the science of logistics can be applied to solve interesting and significant problems. Nevertheless the language has become widely known as an "existence proof" that ways could be found to converse with other civilizations. Further details of the logistics background of *Lingua Cosmica* may be found in the book or the original "Delta" paper.


Freudenthal

Hans Freudenthal was born in Luckenwalde Germany in 1905. He studied mathematics at Berlin and Paris Universities, and was on the faculty of Amsterdam University from 1930 to 1946. He served as professor of mathematics at Utrecht University, Netherlands from 1946 to 1976, with visiting professorships at the University of California in Berkeley, Yale University, and Pennsylvania State University. From 1964 to 1965 he was Rector of Utrecht University. He has received honorary doctorates from Humboldt, Erlangen, Brussels, York and Amsterdam Universities.

His research has been in the fields of topology, linear analysis, probability, geometry, Lie groups, logic, the history and philosophy of mathematics and mathematical education. He has written several hundred papers and several books in the field of mathematics. He is still associated with Utrecht University and since 1970 his primary work has been the development of mathematical education programs.

The SEnTInel

By: Robert S. Dixon

Highlights of the Conference on Life in the Universe

[Article in magazine started on page 40]

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

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	⅕ 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

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

SETI Popular in Colleges

By: Editors

[Article in magazine started on page 46]

SETI SYLLABUS

The topics covered in the SETI course "Life in the Universe" (Astronomy 305) at Bowling Green State University given by Professor Roger Ptak are listed below. Although many SETI courses follow a similar outline, the Bowling Green syllabus shows in a concise step-by-step fashion how an appreciation of SETI requires a background of knowledge about the universe.

Preface
Our star
Other suns
Starbirth
Regular stars
Dying stars
And then there was iron
The Galaxy
When did time begin?
Looking for other worlds
Planet formation
First midterm exam
"The Ladder of Creation"
The early earth
From algae to algorithms
Viking goes to Mars
"The Search for Life"
Life on Mars?
The outer planets
The zone of life

How many are out there?
Messages from space
Tuning in
Second midterm exam
Space at last!
The greening of space
"The Final Frontier"
Cities in space
Remaking the Universe
Final exam

Many colleges and universities are giving or planning to give courses about the Search for Extra-Terrestrial Intelligence (SETI). In previous issues we have listed courses at the following institutions:

Case Western Reserve University
Cleveland, Ohio

Consumes River College
Sacremento, California

John Carroll University
University Heights, Ohio

Leeward Community College
Kaneohe, Hawaii

Louisiana State University
Baton Rouge, Louisiana

Menlo College
Menlo Park, California

Ohio State University
Columbus, Ohio

Otterbein College

Westerville, Ohio

San Diego State University
San Diego, California

University of San Francisco
San Francisco, California

Stanford University
Stanford, California

Stockton State College
Pomona, New Jersey

Washington and Jefferson College
Washington, Pennsylvania

Wheaton College
Norton, Massachusetts

In this issue we list courses at seven more institutions as follows:

Institution: Appalachian State University, Boone, North Carolina, 28608
Instructor: Prof. Thomas L. Rokoske, Dept. of Physics
Title: Search for Extraterrestrial Intelligence (1 hour credit)
Content: Development of SETI. Probability of life in the galaxy. Radio telescopes. Space travel. Space colonization. Physical and biological characterization of extraterrestrial intelligence.
References: Marcia S. Smith, "Possibility of Intelligent Life in the Universe" (U.S. Government Printing Office); Ronald Bracewell, "The Galactic Club"; Philip Morrison, John Billingham and John Wolfe, "The Search for Extraterrestrial Intelligence" (NASA SP-419); and others.
Years given: 1978, 1979.
Enrollment: 100 (1979).

Institution: Bowling Green State University, Bowling Green, Ohio 43403

Instructor: Prof. Roger Ptak, Director of Astronomy
Title: Life in the Universe (Astronomy 305)
Content: Possibilities for life on other planets and other star systems, methods for communicating with other intelligent life, and the movement of human life into space. (See accompanying box for more details).
Reference: Shklovskii and Sagan, "Intelligent Life in the Universe".
Years given: Each year beginning with 1976.
Enrollment: 30 (1976), 55 (1977), 80 (1978), 135 (1979).

Institution: California State University, Fullerton, California 92634
Instructor: Robert H. Rubin, Dept. of Physics
Title: Extraterrestrial Intelligence (Physics 111, 3 units).
Content: Origin of the universe, origin of the elements, formation and evolution of stars, formation of planetary systems, habitable zones for planets, chemical evolution, origin of life and biological evolution, evolution of intelligence, the Drake equation, over-view of the universe, contact between extraterrestrial civilizations, space colonization.
Year given: 1979.

Institution: Kansas State University, Manhattan, Kansas 66506
Instructor: Prof. C. E. Hathaway, Head, Dept. of Physics
Title: Life in the Universe—Are We Alone?"
Format: The Department of Physics has for four years operated a telephone-based course for honors high school students throughout Kansas. The telenet system allows two-way conversation to take place between enrolled students and scientists who speak from their own laboratories or offices. A speaker this year is Professor Philip Morrison of M.I.T.
Enrollment: 40 to 100.

Institution: St. Olaf College, Northfield, Minnesota 55057
Instructor: Prof. Howard I. Thorsheim, Dept. of Psychology
Title: The Human Factor in Space Colonization and Long-Duration Spaceflight (Psychology la).
Format: Discussion of human factors on earth and in space environment, community and environmental psychology, time perception and value questions implicit or explicit in human-system interactions. Guest speakers, films (such as NASA's "Apollo-Soyuz"), taped interviews with Michael Collins, Gerard O'Neill, Isaac Asimov and others and field trips, as to Minneapolis-Honeywell, provide a stimulating perspective. Cultures beyond the earth are considered. Since many of the

students at St. Olaf College are of Scandinavian descent, the idea of space colonization has special relevance in comparison with an earlier period of "space" utilization, in which "space" was the Great Plains of the United States and the persons involved were the grandparents or great-grandparents of the students.
References: R. D. Johnson and C. Holbrow, Editors, "Space Settlements: A Design Study" (NASA, 1977); Gerard K. O'Neill, "The High Frontier"; Carl Sagan, "Cosmic Connection".
Years given: 1977, 1978, 1979, 1980 (January Interim Term).
Enrollment: Limited to 20.

Institution: Sheridan College, Sheridan, Wyoming 82801
Instructor: Dr. Kenneth R. Ohm, Professor of Astronomy.
Title: The Search for Extraterrestrial Intelligence (non-credit).
Content: History and recent developments in SETI. Exploration of the solar system (Pioneer, Viking, Voyager, etc.).
References: Carl Sagan, "Murmurs of Earth"; **COSMIC SEARCH**.
Year given: Fall 1979.
Enrollment: 150.

Institution: Western Michigan University, Kalamazoo, Michigan 49008
Instructor: Prof. Michael D. Swords, Natural Science.
Title: Aims and Achievements of Science.
Content: Cosmo-evolution (Big Bang to extraterrestrial intelligence); microcosmic frontiers (quarks to organisms).
Years given: 1975 to date.
Enrollment: Limited to 30.

Institution: Western Michigan University, Kalamazoo, Michigan 49008
Instructor: Prof. Michael D. Swords, Natural Science.
Title: Science and Parascience.
Content: Examination of various debatable hypotheses on the frontiers and ragged edges of established science. Includes cosmo-evolution and extraterrestrial intelligence as necessary foundation information for examining the UFO and ancient astronaut questions.
Years given: 1975 to date.

Enrollment: Limited to 25.

Off the Shelf

By: Mirjana Gearhart

[Article in magazine found on page 48]

Space, the Future, and the Search for Extraterrestrial Intelligence have always fascinated Man, as can be seen by the thousands upon thousands of books and articles written since the days of ancient Greece. In this, and future issues of COSMIC SEARCH, selected books and other publications are presented for interested readers. Space prevents inclusion of more than a few in each issue, but we believe that in these references, both old and new, you will find much that will add to your knowledge, understanding and enjoyment.

American Institute of Astronautics and Aeronautics (AIAA), SPACE: A RESOURCE FOR EARTH (AN AIAA REVIEW), 1977, AIAA, New York, N.Y. (177 pgs., hardbound). A glimpse into man's future as he learns to harness and utilize the space around him — terraforming, engineering, mining, etc.

Isaac Asimov, EXTRATERRESTRIAL CIVILIZATIONS, 1979, Crown Publishers, New York, N.Y. (158 pgs., hardbound). Popular science writer poses THE question on the minds of all SETI enthusiasts — "Are we alone?", and strives to show that extraterrestrials do exist and may, in fact, be out there waiting.

Arthur C. Clarke, THE PROMISE OF SPACE, 1968, Harper and Row, Publishers, New York, N.Y. (325 pgs., hardbound). The foremost science fiction writer and futurist of our times gazes into the future of man's romance with space and tells how man will come to use the space around the Earth.

I. F. Clarke, THE PATTERN OF EXPECTATION, 1644-2001, 1979, Basic Books, New York, N.Y. (344 pgs., hardbound). A futurist presents the essence of almost four hundred years of history to show that the future is not "accurately predictable on any scale or in any detail".

Dandrige Cole and D. W. Coxe, ISLANDS IN SPACE, 1964, Chilton Press, New York, N.Y. (147 pgs., hardbound). A pioneer book that first envisioned astroengineering and coined the popular phrase "space colonies".

Dose, Fox, Deborin, and Pavlovskaya, eds., THE ORIGINS OF LIFE AND EVOLUTIONARY BIOCHEMISTRY, 1974, Plenum Press, New York, N.Y. (200 pgs., hardbound). A technical treatise on the biochemical origins of life by four leaders in the field of biochemistry.

Freeman Dyson, DISTURBING THE UNIVERSE, 1979, Harper and Row, Publishers, New York, N.Y. (283 pgs., hardbound). A stimulating autobiography by one of the world's foremost thinkers on man's destiny in space.

Clair E. Folsome, THE ORIGIN OF LIFE: A WARM LITTLE POND, 1979, W. H. Freeman and Company, San Francisco, Ca. (168 pgs., hardbound). Arguing that important discoveries in biology, physics, chemistry and astronomy show that evolution on Earth was inevitable, Folsome extrapolates these arguments to show life on other planets is just as possible.

T. A. Heppenheimer, TOWARD DISTANT SUNS, 1979, Stackpole Books, Harrisburg, Pa. (244 pgs., hardbound). Communications platforms, the space shuttle, space colonies and life in space are some of the fascinating topics covered by this noted author. Foreword by Gerard K. O'Neill.

Carl Sagan, BROCA'S BRAIN REFLECTIONS ON THE ROMANCE OF SCIENCE, 1979, Random House, New York, N.Y. 327 pgs., hardbound). Astronomy and exobiology's popular spokesman writes another interesting and fascinating book — this one about the history of science and some of the obscure events that have led to our modern technology.

Frank Stilley, THE SEARCH — OUR QUEST FOR INTELLIGENT LIFE IN OUTER SPACE, 1978, G. P. Putnam's Sons, New York, N.Y. (182 pgs., hardbound). An up-to-date, easily understood book about searches for extraterrestrial life forms.

Walter Sullivan, BLACK HOLES, 1979, Anchor Press/ Doubleday, Garden City, N.Y. (269 pgs., hardbound). The popular N. Y. Times science writer presents this easy-to-comprehend and highly-readable book about the intrigue and mystery of black holes — from speculations about their existence in the early twentieth century to experiments designed to show their physical existence.

G. E. Tauber, MAN'S VIEW OF THE UNIVERSE, 1979, Crown Publishers, Inc., New York, N.Y. (352 pgs., hardbound). Starting with astronomy as perceived by early civilizations like the Chaldeans and Egyptians, and working his way to modern theories of cosmology, the author presents a thorough and well-illustrated story of man and his starry surroundings.

Miscellaneous Items

[Miscellaneous items found throughout the magazine]

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(Internal links to categories of items in this webpage)

Information About the Publication
(Editorial Board, Editors, Table of Contents)

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[This statement was found on page 27 of the magazine.]

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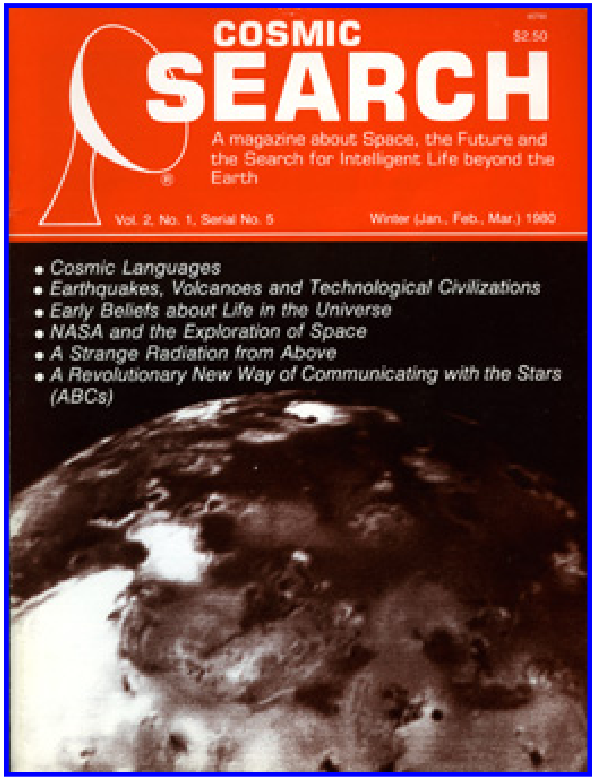
Front Cover



Jupiter's moon to as viewed from Voyager I during its close approach last spring. See article by Virginia Trimble. Photo courtesy NASA and Jet Propulsion Laboratory.

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THANK YOU!

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Coming in COSMIC SEARCH

- "Chief Entities" by **I. J. Good**
- "Space Travel and Life" by **E. J. Öpik**
- "Marconi" by **George H. Brown**
- "Not as We Know It" by **Isaac Asimov**
- "In the Time Machine" by **Don Lago**
- "Gravity Waves for Interstellar Communication" by **David H. Douglass**
- "Strategies of Searching for Extraterrestrial Civilizations" by **Nikolai Kardashev**
- **FORUM:** Discussion with **Patrick Palmer** and **Lee Rickart** on "SETI Perspectives"

- **ABCs of Space** will explain in simple terms:
  - Signals versus Noise. How to hear what you want amid a lot of noise.
  - The Electromagnetic Spectrum. Light, x-rays and radio waves are all the same except for wavelength.
- More **SEnTlnel** news reports, highlights of meetings, "Off the Shelf" books on Space, the Future and SETI, and many other special features.

Glossary

Anthropocentric:
: Man-centered.

Astronomical Unit:
: A unit of length equal to the distance of the earth from the sun, about 150 million kilometers.

Bandwidth:
: The wavelength or frequency range to which a receiver responds. Bandwidths can be described as narrow or wide, according to their range.

Big Bang:
: The beginning event in the Universe. The explosion of this primordial fireball some 15 billion years ago caused the initial outward expansion of gas and dust which formed the universe.

Black Hole:
: An end state of matter of a massive star. Once trapped within the gravitational field of a black hole, nothing can escape.

CETI:
: An acronym for Communication with Extra-Terrestrial Intelligence.

Continental drift:
: The geological theory that says continental land masses are moving slowly.

Cosmology:
: The study of the origin of the universe and how it has developed and what its future will be.

Electromagnetic radiation:

Energy which is propagated by changing magnetic and electric fields, and in a vacuum, moving at the speed of light. Electromagnetic radiation covers the entire spectrum from long-wavelength radio radiation to short-wave gamma radiation.

Galaxy:

A large system of stars. Our galaxy, the Milky Way, is a spiral galaxy containing some 100,000 million stars, 100,000 light years in diameter and 10,000 light years thick.

Gigahertz:

A unit of frequency equal to 1,000 million hertz.

Hertz:

A unit of frequency equal to one cycle per second.

Hydrogen:

The most abundant element in the universe. It radiates naturally at a wavelength of 21 centimeters.

Kelvin degrees:

Absolute temperature measured in the celsius scale. Ten degrees kelvin equals ten degrees celsius above absolute zero.

Light-Year:

The distance traveled by light in one year, about 10 trillion kilometers.

Light (speed of):

In empty space: 300,000 kilometers per second.

Macrocosm:

The entire universe

Malthusian:

Pertaining to political economist Thomas R. Malthus' (1766-1834) contention that population tends to outdistance its means of support. Eventually population will be held in check by disaster, unless otherwise constrained.

Megahertz:

A unit of frequency equal to one million hertz.

Microcosm:
The universe in miniature

Nanosecond:
One billionth of a second.

Plate tectonics:
In geology, relating to the structure of the earth's crust or plates.

Pulsar:
A relatively small, rapidly rotating radio source which is believed to have a neutron star at its center.

Radio Astronomy:
The science of making astronomical observations using instruments sensitive to radio wavelengths.

Redshift:
A shift toward the longer wavelengths of the optical spectrum due to recessional velocity (Doppler effect).

SETI:
An acronym for Search for Extra-Terrestrial Intelligence.

Universe:
The amalgam of Time, Space, Matter and Energy.

COSMIC SEARCH AWARDS

For best papers on SETI

Category 1. Undergraduate students
Category 2. Graduate students
Category 3. Anyone else under 30 years of age

Papers may be on any aspect of the Search for Extra-Terrestrial Intelligence (SETI). Papers must be double-spaced typewritten with one inch margins on 8 1/2 by 11 inch bond paper and less than 2000 words in length. Any illustrations must be clearly executed.

Authors of best papers will be given a **COSMIC SEARCH AWARD** of $100 and the paper will be published in **COSMIC SEARCH**. Authors should include their full address and telephone number. Authors should enclose a self-addressed stamped envelope if they wish to have their manuscripts returned.

Manuscripts may be submitted at any time. Their review is a continuous, on-going process. Each article received is reviewed by a special committee and if judged worthy, either in its original form or after revisions, will be given a **COSMIC SEARCH AWARD**. The opinion of the committee is final.

A contestant may submit and have under review only one manuscript at a time and be eligible for only one **COSMIC SEARCH AWARD** in one category. However, it is possible for one person to achieve **COSMIC SEARCH AWARDS** sequentially in each of the three categories.

Address **COSMIC SEARCH AWARD** Committee, Radio Observatory, P.O. Box 293, Delaware, Ohio 43015.

Cosmic Calendar

15 billion BC	Universe began (BIG BANG)
10 billion BC	Our galaxy formed
5 billion BC	Solar system (sun, earth and other planets) formed
2 million BC	Homo sapiens emerged
5000 BC	Writing invented
1888 AD	Hertz produced radio waves
1903 AD	Letter "S" sent by radio waves across Atlantic Ocean by Marconi
1959 AD	Cocconi and Morrison proposed SETI
1960 AD	First attempt to detect extraterrestrial civilizations by Drake
1979 AD	First issue of COSMIC SEARCH

Distance Table

Distances in light travel time (approx.)

Earth to moon	1 second
Earth to sun	500 seconds (8 min.)
Sun to Mars	12.5 minutes
Sun to Jupiter	40 minutes
Sun to Pluto	5.5 hours
Solar system diameter (at orbit of Pluto)	11 hours
Sun to nearest star	4 years
Sun to center of galaxy	30,000 years
Diameter of galaxy	100,000 years
Distance of Andromeda galaxy	2 million years
Distance to "edge" of universe	15 billion years

To convert light travel time to kilometers multiply travel time in seconds by velocity of light (300,000 kilometers per second).

Miscellaneous Quotes

The following quotes are not directly associated with any article. They are listed here in the order in which they appear in the magazine; page numbers are given. Uncredited quotes should be credited to the Editors of **COSMIC SEARCH** magazine.

Quote on page 10

Evolution
A billion years is a long time in evolution; one billion years ago, the highest form of life on the earth was a worm. The intelligent life in other, older solar systems must be as different from us as we are from creatures wriggling in the ooze.
— Robert Jastrow

Quote on page 16

Piano Tops
"I am enthusiastic over humanity's extraordinary and sometimes very timely ingenuities. If you are in a shipwreck and all the boats are gone, a piano top that comes along may make a fortuitous life preserver. But this is not to say that the best way to design a life preserver is in the form of a piano top. I think that we are clinging to a great many piano tops in

accepting yesterday's fortuitous contrivings as constituting the only means for solving a given problem."
— Buckminster Fuller in "Operating Manual for Spaceship Earth", E. P. Dutton, 1978.

Quotes on page 32

We Are a Spacefaring People

Our spacefaring could make all the difference. We have been feeling constricted and almost paranoid. But in spacefaring we have found new realms for the human imagination. In the exploration and exploitation of space we may be making the greatest discoveries of all — seeing where we are, appreciating our earthly frailties and finiteness for the first time, and sensing a future that may not be infinite but at least will never again be bound entirely to the cosmic frog pond of Earth. We are a spacefaring people. — John Noble Wilford

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Homo Sap

We have now eliminated a large part of the world's wild life habitats to accommodate our agriculture, our housing, our industries and transportation networks. Is this to continue until no wild species are left? Is this to become virtually a "one-crop" planet — the single crop being Homo Sapiens, exposed to all the epidemic threats that endanger one-crop regimes?
Walter Sullivan in "Continents in Motion"

Quote on page 34

Technology and Thought

So long as we can negotiate the triumph of technology successfully, we are unconcerned to ask what the presuppositions of the technical world are and how they bind us to its framework. Already these presuppositions are so much the invisible medium of our actual life that we have become unconscious of them. We may eventually become so enclosed in them that we cannot even imagine any other way of thought but technical thinking.
William Barrett in *The Illusion of Technique: A Search for Meaning in a Technological Civilization*

Quotes on page 45

The Nebular Hypothesis

The stars are as thick as flowers in the sky;
Tonight is a night for lovers to kiss;
But we are arguing, you and I,
On the nebular hypothesis.

Mary Burwell

The Best People

The fact that space exploration and space habitation may involve difficulties will constitute a particularly strong challenge to the best nations and the best people.

— Wernher von Braun

Our Technological Civilization

Never have so many people understood so little about so much.

James Burke in "Connections"

Humanism versus Materialism

The humanistic values stated at the founding of our society and the materialistic ones which have predominated throughout our history have often been in conflict. The outcome of the revolution will depend on how that conflict is resolved.

John D. Rockefeller, 3rd, in *The Second American Revolution*

Quote on page 47

Birds and Stars

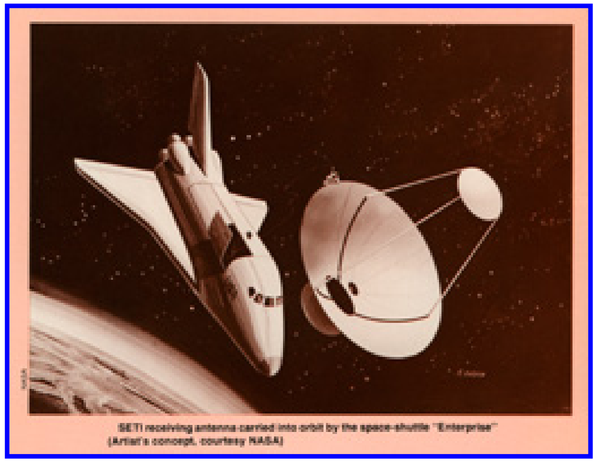
If birds among us on this planet
can use the stars to give
direction to their flight,
then maybe birds on planets
very far away use our raging sun
– but only as a tiny hint of light –
to guide their way to home in midst of night.

— Don Lago

Miscellaneous Photos

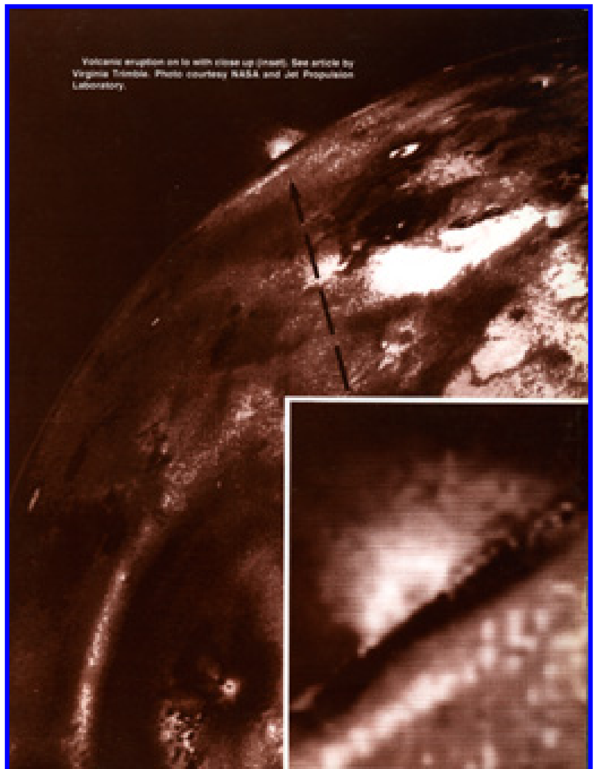
The following two photos are shown on this webpage at a relatively small size; click on each one to obtain a larger size version.

Photo on Inside Front Cover



SETI receiving antenna carried into orbit by the space-shuttle "Enterprise"
(Artist's concept, courtesy NASA)

Photo on Outside Back Cover



Volcanic eruption on Io with close up (inset). See article by Virginia Trimble. Photo courtesy NASA and Jet Propulsion Laboratory.

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