S E C T I O N VIII

SUMMARIES, COMMENTS AND CONCLUSIONS

INTRODUCTION

This last Section of the Proceedings corresponds also to the last Session of the Symposium, which was chaired by Harlan Smith of the University of Texas who provided also the concluding remarks for the entire meeting. Let us begin with a brief summary of what has been achieved up to now and where we are heading in the next 10-20 years.

In Section I we discussed that the search for extraterrestrial life is about 25 years old. Actually our Symposium and the publication of its Proceedings coincided with two important anniversaries, the 25 years since the publication of the pioneering paper in Nature by Cocconi and Morrison in 1959, with an arousing call to action ("The probability of success is difficult to estimate; but if we never search the chance of success if zero"), and the 25th anniversary of the first radio search by Frank Drake in 1960. We celebrated the first anniversary during our Symposium in Boston, when we presented Dr. Morrison with a special commemorative plaque, while the second was celebrated in May 1985 with a special Symposium at the National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia, where the first search was conducted.

After a difficult beginning, this new field gained finally national and international recognition and our IAU Commission 51 - Search for Extraterrestrial Life was born at the 1982 IAU General Assembly. In less than two years our membership soared to over 250 members and we had our first IAU Symposium, which was attended by about 150 participants from 18 different countries from all around the world. It received very favorable publicity in many well respected media, including a whole page article by Walter Sullivan in the New York Times, and in general was recognized as a most successful scientific meeting. It was also an opportunity to build strong links with other international organizations, such as the IAF/IAA, ISSOL, COSPAR and the IUBS, and to strengthen the collaboration among scientists of different fields in this distinctly interdisciplinary field. This Volume of the Proceedings, with nearly 600 pages and about 70 contributions by scientists of many nations and many disciplines, is probably the best proof of the progress that has been achieved in the first 25 years of this new field, i.e., in the Search for Extraterrestrial Life and Extraterrestrial Intelligence, which is rapidly becoming known with the simpler term "Bioastronomy".

The search for planets around other stars received a big boost from the IRAS observations which revealed the presence of dust clouds or discs around about 20% of the younger stars observed. The development

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of speckle interferometric techniques have also made it possible to observe such discs with optical telescopes from the ground, while several groups are now working to develop instruments for the indirect detection of planets from the effects (position changes or doppler shifts) they produce on the central star. The Allegheny Observatory group is getting ready to undertake a comprehensive search for large planets around the 100-200 nearest stars, while there is guarded optimism about the contributions the Space Telescope might be able to make in this area. We will know relatively soon since the ST is expected to go into orbit in 1986. The general feeling is that through a combination of techniques we will know much more in 10-15 years about the abundance of planetary systems, of which at this moment we know very little from experimental data.

The abundance of complex organic matter in the Universe is a very important issue because it is generally believed to be the precursor of life when found in the appropriate environment, i.e., most likely in the presence of liquid water. Studies both inside our Solar System and in the interstellar space indicate that Nature favors the formation of complex organic compounds from simple gas molecules such as methane, ammonia, water vapor, etc,. which are quite abundant since the Universe is made of about 74% Hydrogen, 24% Helium, and 2% of all the other 90 chemical elements, of which Oxygen, Carbon and Nitrogen are the three most common. Besides reproducing these chemical processes in laboratory simulations, as was first done by Stanley Miller in 1953, we have also found complex organic compounds, including a variety of aminoacids and all five of the nitrogen bases of the nucleic acids DNA and RNA, in carbonaceous meteorites. They also seem to be present in the tholins, i.e., in the tiny solid particles of the murky atmosphere of Titan, and certainly in the many carbonaceous asteroids from which the above mentioned meteorites come. We have already detected reasonably complex organic compounds in the interstellar space, including alcohol and long chains of carbon atoms, but there is also good evidence from laboratory simulations that the icy cover of simple organic compounds that forms around the tiny interstellar grains, evolves slowly to highly complex organic compounds through the effects of interstellar ultraviolet radiation. All in all it appears that the path of chemical evolution leading to prebiotic compounds of importance to life is quite common throughout the Galaxy.

If planets with water would also turn out to be relatively common in the Galaxy, then life must have originated in many places in the Galaxy and would probably have been doing so far 5-10 billion years. The rate of biological evolution on a planet like the Earth is still a process not well understood. In part it seems to require lots of time, because before complex life may blossom the primitive life must convert the reducing early atmosphere of a planet into one with free oxygen, though even about this we are not totally sure. It appears also that the rate of the biological evolution depends on random and accidental factors which introduce changes that stimulate the evolution. Even the diurnal change and the seasons, which we take for granted, depend on the spinning and orbital parameters of each planet. Other changes with longer periods, such as the ice ages, continental drift, and even

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occasional disasters such as impacts of comets and asteroids might play an important role in the evolution of life. These catastrophic impacts might actually be blessings in disguise because they produce mass extinctions which open niches for the appearance of many new species. Life seems to start very early in the history of a planet with liquid water like the Earth, but we still do not know how long does it take the process of biological evolution to produce an advanced civilization. We also do not know if planets are able to retain liquid water over such long periods. We hope that interdisciplinary meetings such as ours will stimulate further work in this very important area, because a combination of these two factors, biological and planetary evolution, could make a critical difference in the number of advanced civilizations we might expect to find in the Galaxy.

Tremendous progress has been made in the radio searches for signals from other advanced civilizations in the Galaxy. Starting with the pioneering Project Ozma of Frank Drake in 1960, we can now list nearly 50 search projects, in which we have logged nearly 120,000 observing hours, and have involved observatories in seven different countries (USA, USSR, Australia, Canada, France, Germany, Holland), with Japan getting ready to join the group. We also have now two SETI dedicated facilities, the radio observatory of the Ohio State University near Columbus, Ohio, where the Ohio SETI Program of John Krauss and Robert Dixon has been in operation since 1973, and the Oak Ridge Observatory of Harvard-Smithsonian near Boston, Massachusetts, where Project Sentinel of Paul Horowitz has been in operation since 1983. NASA has now taken the leadership in SETI work and is preparing a comprehensive search program over a wide frequency range in the 1-10 GHz region. It will consist of a targeted, high sensitivity search which will focus on approximately 1,000 targets, most of them Sun-like stars up to a distance of about 82 light years, and an all-sky survey which at a lower sensitivity will scan the entire sky. It is expected that the NASA SETI Program will go into full operation around 1990 and its first full search will be completed by the end of this century.

The new search programs require much more sophisticated equipment, which is now being developed. Paul Horowitz is now completing a new 8.4 million spectrum analyzer that will replace his two 65,000 channel spectrum analyzer now in operation. This major improvement will free his search from the current stringent requirements of extraterrestrial involvement in correcting their signals for all the doppler effects between their star and ours. NASA has commissioned Stanford University to build an 8.25 million spectrum analyzer that will have a much larger spectral coverage (about 8 MHz vs 0.42 MHz of the one being built by P. Horowitz) and will become the cornerstone of the NASA SETI Program. It will consist of 112 units, each with about 74,000 channels, the first one of which began field testing in the spring of 1985. A lot of work goes on also at NASA-Ames and at JPL for the development of new antenna feeds capable of handling wide frequency ranges, and in the building of signal recognition algorithms that will be able to extract a meaningful, narrowband, but weak signal, with or without doppler drift, from the ever present noise. There are also several other projects in progress aiming to implement some very imaginative ideas. One such example is

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the use of computers to search for narrowband signals over a wide frequency range without the use of multichannel spectrum analyzers, that is now being developed by Sullivan and Knowles to search for radio leakages from any of the nearby stars. Another is Project Serendip of Werthimer and Boywer who are building some systems that will be able to search for radio signals in a piggyback mode, i.e., by processing for SETI all signals that a radiotelescope is acquiring for other projects.

It is also interesting that after almost a decade of heated debates on the concept of galactic colonization, where opinions ranged from the impossible to the inevitable, and on the apparent lack of any scientifically established evidence for extraterrestrial visits to Earth (often referred to as the Fermi Paradox or the Great Silence), we are finally beginning to reconcile our differences by recognizing that none of us can be too doctrinairial about a concept of which all know so little. We have also come to realize that debates will not solve this problem, and that the experimental approach is the only way to obtain meaningful answers. Still our lengthy debates had a usefulness in that they made us see the whole problem in a broader perspective, and we are now all uniting behind an experimental search program, which will have the NASA Program and a few others as its main body, but which will also be flexible enough to allow for the experimental testing of several other theoretical possibilities.

All in all it is fair to say that the search for extraterrestrial life and intelligence has finally come of age. It now has the endorsement of several major international organizations, such as the IAU, IAF/IAA, COSPAR and ISSOL, and the support of the majority of the scientific community. There are sessions on this subject in several national and international scientific meetings every year, and a good interdisciplinary collaboration in this new field is beginning to take hold. I believe that in the next 10 to 20 years we will witness substantial progress in our efforts to try to answer the old and intriguing question on the prevalence of life in the Universe.

The first three papers of this Section are summaries by G. Gatewood, W. Irvine and J. Billingham of the first three Sessions of the Symposium, i.e., of Sections II (Planets), III (Organic Matter), and IV (Biological Evolution) of this Volume. Sections V (Recent Observations) and VI (Technogical Developments) contain extensive review papers by Jill Tarter in V and by Bernard Oliver in VI, and therefore no summaries were repeated here. The next three papers of this Section are invited general comments by G. Marx, J. Ball, and M. Papagiannis, that pertain mostly to Section VII (The Fermi Paradox). This last Section closes with a general review of the entire Symposium and concluding remarks by Harlan Smith, who was also the Chairman of this last Session of the Symposium.

In the first paper George D. Gatewood of the University of Pittsburgh summarizes the Session on the search for planets around other stars. He notes that the clouds of dust and debris that IRAS found around 20% of the younger stars could be cosmic planetary nurseries, but could also be cosmic planetary miscarriages where planets did not manage to form. An interesting question he points out is whether planets are formed before or after the formation of the star. In the first case we would expect to find gas giant planets like Jupiter also close to the star, while in the second only at large distances. Astrometric techniques from the ground can detect only Jupiter-like planets in nearby stars, while astrometric technique from space, beyond the disturbing effects of the Earth's atmosphere, will be able to detect even small, Earth-like planets. Gatewood says that such a space astrometric telescope is now under active consideration by NASA. In the long run our goal is to collect statistics on the distribution of planets by mass and by distance from their central star. Also how these statistics vary with the mass and spinning rate of the central star.He concludes by saying that in his opinion Earth-like planets will always be a more attractive place to live than space colonies.

William M. Irvine of the University of Massachusetts at Amherst, gives a comprehensive summary on the presence of organic matter in the Universe. He notes the discoveries of complex organic compounds in carbonaceous meteorites, the exciting new results obtained from the Saturnian satellite Titan, and the radioastronomical observations of interstellar molecules. He points out the very non-equilibrium nature of interstellar chemistry, which is manifested by the considerable abundance of radicals, such as OH, and of energetically unfavorable isomers in interstellar space, both of which would have not survived in the atmosphere of the Earth with its high collision frequency and higher temperature. He praises the work of Davies, Delluva and Koch included in this Volume, who disproved with experimental data the evidence used by Hoyle and Wickramasinghe to support their idea that interstellar grains are actually "freeze-dried bacteria". He also says that we owe it to science and to the public to analyze rigorously even far-fetched hypothesies such as this, and either support them or reject them rather than simply ignore them, as we frequently seem to do.

John Billingham of the NASA-Ames Research Center summarizes the Session on the universal aspects of biological evolution. He praises the work of Leslie Orgel and says that the greatest mystery still is how did the exponential growth of self-replicating systems start on a newly formed planet. He also notes that an important question is whether life always takes about 4 billion years to reach high complexity. He says the appearance of free oxygen was related not only to the photosynthetic activity of microorganisms but also to continental stabilization which slowed down the production of reducing gases through tectonic recycling. On other planets this process could have taken considerably longer or shorter. If evolution on Earth were to start all over again, he says, the results would undoubtedly be very different, but there might still be some similarities in function, as it has happened on Earth when independent evolutionary paths tend to converge (e.g., mammalian wolfes and the marsupial wolves of Australia). This phenomenon is known as Evolutionary Convergence, and at the Symposium was discussed by Stephen Jay Gould of Harvard University. In the extraterrestrial realm there probably is a huge diversity of biologies, but there might also be some measure of convergence among them and between them and us.

George Marx of Eotvos University, Budapest, Hungary raises several important questions for which we do not yet have satisfactory answers. He stars with Drake's equation and points out the long period (more than

3 billion years) that elapsed from the emergence of life on Earth to the emergence of high intelligence. Also to the fact that in spite of the very delicate balance between a run-away glaciation and a run-away greenhouse effect, the Earth managed to maintain a steady temperature for billions of years. How unusual is this? He also wonders if we would ever succeed to communicate with other cosmic civilizations whether they will be biological beings or machines. He recounts a discussion on this subject that occurred in 1971 at the Byurakan conference. Minsky was favoring machines and said that "The price to be paid for sex is death", but Morrison noted "I see no difference in communications with smart people or with smart machines." George Marx closes his paper by extending "an extraterrestrially cordial welcome" to all of us to the next IAU Symposium of Commission 51, which has been scheduled to take place in Hungary in the summer of 1987.

John A. Ball of the Harvard-Smithsonian Center for Astrophysics notes that the two Nobel prizes awarded for discoveries in radio astrophysics (pulsars by Hewish, and the 3 degree background radiation by Penzias and Wilson) were both totally accidental, as was also the beginning of X-ray astronomy. He too therefore advocates strongly a more flexible search strategy that "maximizes the opportunities for accidental discoveries". He then discusses interstellar travel and forsees the following sequence of events: Detection of planets around other stars, fly-by probes to these stars, a probe orbiter, a probe lander, and then possibly landings of self-replicating probes. He notes that by the time we will be able to explore or colonize planets around nearby stars, we may not want to or need to. He also recalls the old adage that the farther you go, the longer you should plan to stay to make the trip worthwhile, and therefore he says if we were to plan to go really far to other stars, we better also plan to colonize. He concludes by saying "Limitations imposed on us by fundamental physics are important, but limitations imposed on us by federal budgets or human lifetimes are irrelevant".

Michael D. Papagiannis of Boston University and President of IAU Commission 51, starts by reviewing briefly the tremendous progress that has been made in the last 25 years in the search for extraterrestrial life and the recognition that this new field has achieved in the recent years. He then looks into future advances (discoveries of planets around other stars, the NASA SETI Program, etc) that are anticipated in the next 10-20 years, and concludes with a discussion of the technologies that might become available in the 21st century. He notes that our searches have always reflected the existing technology, and therefore in the next century with the possibility of large space observatories in space and/or on the Moon, it is very likely that we will be able to build a Large Infra-Red Array (LIRA) to obtain detailed statistics on planetary systems around other stars and even to identify among them Earth-like planets with liquid water. He says also that if in the meanwhile we have not discovered any extraterrestrial civilizations with our radio searches, we might begin to search from our space observatories for infrared laser signals using a far more advanced version of a multichannel spectrum analyzer to search wide ranges in the infrared for for coherent laser signals. He concludes by observing how close we might be to the victory line, and what a great loss would be if after a long and tortuous marathon of four billion years, life on Earth were to self-destruct just a cosmic second before reaching eternal fulfillment.

Harlan J. Smith of the University of Texas and Director of the McDonald Observatory, closed this final Session of the Symposium, and closes this last Section of the Proceedings with his Concluding Remarks. He parallels with good humor our search for extraterrestrial intelligence with a blind man in a dark room looking for a black cat that might not even be there. He admits, however, that we are not totally blind and that the room is not totally dark. As far as the cat is concerned, he discusses some of the controversial issues that have been the subjects of long debates, including the possibility that the civilization might have chosen to remain silent (the cats in the room are not meowing), which could also justify the term "black cats" in the same sense as in "black holes", i.e., not allowing any radiation to emerge that would reveal their presence. Also the possibility that the cats might have chosen not proliferate to fill the whole room to the point that some of them would be crawling by our feet. He too marvels of how did the Earth manage to walk the tightrope between deep freeze and greenhouse boiling, and wonders if sporadic mass extinctions are indeed helpful to the evolution of life on a planet. Also what might the optimum frequency of these events be to achieve the fastest rate of evolution. He says that it is vital for SETI to proceed with its observations to find out if there are any audible meows. Radio and X-ray astronomy are classic examples where before the observations most knowledgable people felt that there was nothing to be found. He concludes by advocating that besides listening for meows, we also ought to search for cosmic "kitty-litters", such as waste infrared radiation from extraterrestrial settlements, and for cosmic "claw-marks", such as skid tracks of decelerating interstellar vehicles. He closed his talk and closes also his paper by thanking Mike Papagiannis and his staff "for organizing such a fine Symposium, a real cat's meow of a meeting".

At the end of the meeting Robert Dixon, the Director of the Ohio SETI Program which is the oldest and longest active SETI program in the world, thanked also Michael D. Papagiannis on behalf of all the participants and presented him with the Flag of Earth, a beautiful flag designed by James Cadle of St. Joseph Illinois, that shows a blue Earth together with a segment of a yellow Sun and a small white Moon against the black background of space. This flag flies on a pole at the radio observatory of the Ohio State University to signify that SETI is a project of all the people of the Earth, and I also keep it in a prominent place in my office with fond memories of a fine meeting.

THE EDITOR