COMMISSION 51: SEARCH FOR EXTRATERRESTRIAL LIFE (RECHERCHE DE LA VIE DANS L'UNIVERS)

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I. INTRODUCTION

The possibility that life, primitive or advanced, might exist in other places of the Universe has occupied the minds of scientists and lay-people for thousands of years. It is only in the last 25 years, however, that we have finally begun to search for answers to this profound question using experimental techniques. The goal of Astronomy is to understand the origin and evolution of planets, stars, galaxies and of the Universe as a whole. The appearance of life is an integral part of this whole process and our picture of the Universe will never be complete until we will comprehend also the significance of life in the process of Cosmic Evolution.

The modern era in the search for extraterrestrial life, both primitive and advanced, originated in 1959. This was the year that the USSR launched the first Sputnik (October 4, 1959) that opened the new frontier of outer space, and was also the year Giuseppe Cocconi and Philip Morrison [1] published in NATURE their pioneering paper "Searching for Interstellar Communications" (September 19, 1959).

The advent of the space era made possible the exploration of our solar system where we have already searched for primitive life on the Moon (Apollo Missions in 1969) and on Mars (Viking Landers in 1975), and have also landed repeatedly on the infernal surface of Venus (Venera Missions). We have obtained excellent photographs and scientific data on planets and moons from Mercury to Saturn, with Uranus and the comet of Halley coming up soon. Though no signs of primitive life have been found as yet in our solar system, and the prospects for the future are not very encouraging, still these explorations have yielded valuable data on the formation of organic compounds of importance to life throughout our solar system, and have given us importnt insights on the origin and evolution of planets and moons. Parallel studies of interstellar molecules and interstellar grains are showing us that these organic compounds are quite common in the Universe, while the search for extrasolar planetary systems is now entering its critical stage. All this information will help us understand better the conditions that made it possible for life to originate on Earth and slowly, over billions of years, to evolve into an advanced technological civilization.

The search for extraterrestrial intelligence, SETI as it is commonly called, turned to other solar systems after the ideas of Percival Lowell (1855-1917) about Martian water-canals, etc, which had excited the imagination of many people during the first half of this century, were finally abandonned. In their 1954 paper to NATURE, Cocconi and Morrison suggested to search for radio signals from other stellar civilizations concentrating on the 21 cm line of atomic Hydrogen, which as they said "must be known to every observer in the Universe." The Hydrogen line was discovered by E.M. Purcell (Nobel Laureate for the discovery of NMR) and H.I. Ewen (his thesis student at Harvard) in 1951, and in 1959 was the only radio spectral line known. Today we know close to 100 radio lines but the Hydrogen line continues to dominate our searches, possibly because of inertia but also because Hydrogen is the first and most abundant chemical element in the Universe.

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The last sentence in the Cocconi and Morrison paper read: "The probability of success is difficult to estimate, but if we never search the chance of success is zero." This challenge was answered almost immediately by Frank Drake [2], the current Vice President of our Commission, who was then a young (29) radioastronomer with the U.S. National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia. In April 1960, in his celebrated Project Ozma, Frank Drake used the 85 ft radio telescope of NRAO to search for radio signals at the Hydrogen line from the two nearby Sun-like stars, Epsilon Eridani (10.7 l.y.) and Tau Ceti (11.9 l.y.).

Figure 1 is from our recent IAU Symposium which brought together several of the protagonists mentioned above. Shown together from the Symposium Banquet are from left to right: Edward M. Purcell, Philip Morrison, Carl Sagan, Michael D. Papagiannis and Frank Drake.

II. THE NEW IAU COMMISSION

The acceptance of the idea that the search for extraterrestrial life is an important scientific task, and the realization that, though this is an interdisciplinary subject, the main thrust in the actual searches must come from the astronomers, led finally to the establishment of IAU Commission 51 - Search for Extraterrestrial Life in the 1982 General Assembly at Patras, Greece. Michael D. Papagiannis of Boston University was elected the first President, and Nikolai S. Kardashev of the Institute for Space Research of the USSR Academy of Sciences and Frank D. Drake of Cornell University were elected Vice Presidents.

The first exposure of the IAU to this new subject was made at the 1979 General Assembly in Montreal when M.D. Papagiannis organized a one-day Session on "Strategies for the Search for Life in the Universe". This was a very successful meeting, and when in an open evening Session Drake and Papagiannis reported on this Session to the general membership of the IAU, the large Auditorium of the University of Montreal was packed to standing room only, with more than 1.000 astronomers present from all around the world. The Proceedings of this meeting were published by D. Reidel Publ. Co. (Papagiannis [3]). The success of this event, and the interest demonstrated by many IAU members, led to the establishment of IAU Commission 51 in 1982, which makes it the youngest of all IAU Commissions.

The new Commission grew rapidly and in only two years its membership reached 250, 210 of which are astronomers members of the IAU and about 40 are IAU Consultants, i.e., distinguished scientists from related fields with common interests with IAU Commission 51. We established also a Commission Newsletter called BIOASTRONOMY NEWS, and we set out to organize our first IAU Symposium, which was held in Boston, USA June 18-21, 1984, i.e. in less than two years from the establishment of the new Commission.

III. IAU SYMPOSIUM 112

IAU Symposium 112 - The Search for Extraterrestrial Life: Recent Developments was hosted by Boston University, the home institution of the President of Commission 51, who will also be the Editor of the Proceedings of the Symposium (Papagiannis [4]). It was financially and morally supported by the IAU, NASA and Boston University, to all three of which we express our deepest appreciation. It was cosponosored by four other IAU Commissions: 15. Physical Study of Comets, Minor Planets, and Meteorites; 16. Physical Study of Planets; 24. Photographic Astrometry; 40. Radio Astronomy. It was also cosponsored by four other major international organizations with which IAU Commission 51 has established close working relationships. These four International Organizations were:
COSPAR (ISCU Committee on Space Research)
IAF/IAA (International Astronautical Federation/Intern.Acad. of Astronautics)
ISSOL (International Society for the Study of the Origin of Life)

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IUBS (International Union of Biological Sciences)

The Scientific Organizing Committee, which included representatives of the above four organizations plus NASA, consisted of the following: M.D. Papagiannis (Chairman), J. Billingham (NASA), D. DeVincenzi (COSPAR), F.D. Drake, J. Jugaku, N.S. Kardashev, G. Marx, R. Pesek (IAF/IAA), C. Ponnamperuma (ISSOL), C. Sagan, O. Solbrig (IUBS), and V.S. Troitsky.

The Local Organizing Committee, on the other hand, was made up of faculty members from Harvard University, MIT, and Boston University. It consisted of the following: Philip Morrison (MIT) and Edward M. Purcell (HU) Co-Chairmen, Tom Bania (BU), Stephen Jay Gould (HU), Paul Horowitz (HU), Edward Lilley (HU), Michael D. Papagiannis (BU), and David Staelin (MIT). The Symposium was attended by about 150 participants from 18 different countries. Actually the Soviet participants, though they had preregistered, in the last minute they were not able to attend. They have sent in, however, their papers for the volume of the Proceedings, which will be published by D. Reidel Publ. Co. in their IAU Symposia Series, and will include more than 65 contributions. The scientific program of the Symposium consisted of seven half-day Sessions, the titles and Chairmen of which were:

I. THE SEARCH FOR OTHER PLANETARY SYSTEMS
Co-chairmen: Carl Sagan and Jun Jugaku

II. PLANETARY, INTERPLANETARY AND INTERSTELLAR ORGANIC MATTER
Co-Chairmen: William M. Irvine and Donald L. DeVincenzi

III. UNIVERSAL ASPECTS OF BIOLOGICAL EVOLUTION
Co-Chairmen: Lynn Margulis and John Billingham

IV. RADIO SEARCHES - RECENT OBSERVATIONS
Co-Chairmen: Edward M. Purcell and Edward Lilley

V. TECHNOLOGICAL PROGRESS IN RADIO SEARCHES
Co-Chairmen: Frank D. Drake and George Marx

VI. THE FERMI PARADOX AND ALTERNATIVE SEARCH STRATEGIES
Chairman: Philip Morrison

VII. SUMMARY AND CONCLUSIONS
Chairman: Harlan J. Smith

In addition there were several special events during the Symposium including: a welcoming reception at the Castle of Boston University hosted by Dr. G. Bannister the Dean of Arts and Sciences at Boston University, the Symposium Banquet in the new Hall of Flags of Boston University, with Carl Sagan as the Banquet Speaker, a special event at Boston's Museum of Science in which we honored Philip Morrison, and a visit by many of the participants to the Harvard-Smithsonian Oak-Ridge Observatory, about 40 miles (65 km) from Boston, where Prof. Paul Horowitz of Harvard is using its 84 ft radiotelescope as a SETI dedicated facility running a continuous, 24 hours per day search called "Project Sentinel".

The event at the Museum of Science was organized to honor Prof. Morrison for the 25th anniversary since the publication of the historic Cocconi and Morrison paper in NATURE. After a nice reception, Philip Morrison gave a thought provoking talk in which he reminisced about the difficulties int the beginning, expressed gratification on how far we have advanced in these 25 years, and shared with us some thoughts and ideas about the future. After his talk, IAU Commission 51 honored him with a commemorative plaque on which it was inscribed:

ON THE 25TH ANNIVERSARY OF THE HISTORIC PAPER
BY G. COCCONI AND P. MORRISON
"SEARCHING FOR INTERSTELLAR COMMUNICATIONS"
IAU COMMISSION 51 - SEARCH FOR EXTRATERRESTRIAL LIFE
AWARDS THIS PLAQUE TO PROFESSOR PHILIP MORRISON
IN RECOGNITION
OF INSPIRING LEADERSHIP AND OUTSTANDING CONTRIBUTIONS
IAU SYMPOSIUM 112 - BOSTON USA - JUNE 1984

Figure 2 shows Philip Morrison, who is holding the plaque in his hands, with the President, Michael D. Papagiannis, and the Vice President, Frank D. Drake, of IAU Commission 51, immediately after the presentation.

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IV. HIGHLIGHTS OF RECENT DEVELOPMENTS

It is generally agreed that planets represent the cosmic wombs where life may start and develop, sheltered in the hospitable, rich in nutrients, protective environments of certain planets. It is also agreed that carbon is the most suitable chemical element to produce the complex molecular structures required by life, and water is the best agent to act as the medium for the chemistry of life. Though one might be accused of chauvinism for extrapolating into the whole Universe our own experience, and though several alternatives have been proposed in both the scientific and in the the science fiction literature, the fact remains that on many objective criteria a carbon based life on a planet with liquid water seems to be by far the most likely combination to occur in the Universe. As a result our search for extrasolar planetary systems and our work on the formation of organic compounds not only on Earth but also in other parts of our Solar System as well as in the interstellar space, are critical steps in our efforts to understand how common life might be.

In recent years there has been a lot of excitement in the search for other planetary systems. The Infra-Red Astronomy Satellite (IRAS), which was launched on January 25, 1983, was able to detect particle envelopes around a considerable number of young stars, possibly indicating planetary formation from preplanetary disks. The first such star found by the IRAS (Aumann, et al [5]) was Vega (alpha Lyrae, 25 l.y.), which was soon followed by Fomalhaut, epsilon Eridani and beta Pictoris. For this last one, Bradford Smith and Richard Tenile were able to obtain some high resolution pictures using a coronogrpah and a CCD camera with the 100-inch telescope of the Las Companas Observatory in Chile. When these pictures were computer enhanced they showed that the particle envelope around beta Pictoris was actually a tilted preplanetary disk. Preplanetary disks have also been detected using speckle interferometry and image processing techniques around several T-Tauri stars, such as HL Tauri (Beckwith, et al [6]). A disk was also discovered around the infrared source IRS 5 L1551 with the 45m Nobeyama radiotelescope of Japan. Another important discovery was made by Donald McCarthy, Frank Low and Ronald Probst, who using infrared speckle interferometry were able to observe a massive object called a brown dwarf, 20-50 times the mass of Jupiter, around the star Van Biersbroeck 8.

Meanwhile the Allegheny Observatory of the University of Pittsburgh is completing the installation of a new objective lens and several other improvements to their astrometric telescope. Combined with their multichannel Astrometric Photometer (MAP) it is expected to reach an accuracy of 0.002 arcsec and start in 1985 a systematic search for Jupiter-like planets in 100-200 stars in the neighborhood of our Sun. Several other groups are perfecting instruments and techniques to detect planets from the motions they induce to their central star. Promising is also the possible use of the Space Telescope in the search for extrasolar planets. The Faint Object camera of the ST, which will have a coronographic finger of 0.8 arcsec and an apodizing mask, might be used for the direct detection of planets. The fine Guidance System and the Wide Field/Planetary Camera might be used for astrometric planetary detection studies. The main problem with the Space Telescope is likely to be the lack of adequate time, because the requests already exceed the available time by a factor of 15. Planetary searches, however, are finally entering a new era and this field is likely to become one of the most exciting astronomical topics in the coming 10-20 years.

The study of organic matter in our Solar System and in the interplanetary space is beginning to confirm that the formation of complex organic molecules of importance to life is a rather common phenomenon in the Universe. R.D. Brown and his colleagues at Monach University in Australia have developed computer programs that can predict quite accurately the abundances of different organic compounds in interstellar space. They have also searched for glycine (Brown, et al [7]), the simplest amino acid, but without success. They feel, however, that they might have a better chance looking for glycinonitrile ($H_2N.CH_2.CN$). The study of interstellar grains and the accretion of complex organic compounds is actively pursued by J. May Greenberg [8] at the University of Leiden in Holland. When dark molecular clouds condense to form solar systems it seems that a significant fraction of these organic compounds can survive the process becoming incorporated in comets and in carbonaceous chondrite asteroids. C. Ponnamperuma [9] and his colleagues at the University of Maryland were able to detect the presence of all five Nitrogen bases, the key building blocks of DNA and RNA, in the Merchison meteorite, which is a carbonaceous chondrite meteorite that fell in Victoria, Australia on September 28, 1969.

Titan, the giant moon of Saturn, seems to be a very interesting example for the synthesis of complex organic compounds in our Solar System (Sagan and Thompson, [10]). It has a thick nitrogen atmosphere with a considerable admixture of methane, and probably oceans of liquid hydrocarbons on its surface. Irradiation of a simulated Titanian atmosphere produces complex organic solids, called tholins, which make the atmosphere of Titan opaque and give it its orange-reddish color. Tholins, which laboratory simulations show that they contain many of the organic building blocks central to life on Earth, precipitate and probably form thick deposits in the bottom of the hydrocarbon oceans of Titan. It is possible that Titan is preserving in deep freeze the products of the chemical evolution that led to the origin of life on Earth, which some day we might be able to study by landing on Titan.

We also learn a lot about the origin and evolution of life from our own planet. We now have clear evidence from sites in Western Australia and South Africa (Knoll and Barghoorn, [11]) that life was present on our planet 3.5 billion years ago and probably started a few hundred million years earlier. Since it took several hundred million years for our planet to undergo chemical differentiation, for its surface to cool off, and for the oceans to form, it seems almost surprising that life appeared so soon after that. As Stephen Jay Gould said at the Symposium, "we find life in the first rocks capable of holding it". Extremely interesting is also the work on molecular replication of Leslie Orgel of the Salk Institute. He is actually focussing on template-directed, non-enzymatic synthesis of oligonucleotides that are complementary to the template. He has succeeded, e.g., in using CCGCC to direct the synthesis of GGCGG with a 20% yield.

We still have a long way to go before we have adequate statistics on extrasolar planets, especially on small, solid planets like the Earth which are much harder to detect, and thus to be able to say how common planets with liquid water might be. The indications, however, are that life will rapidly originate on such planets because the processes of chemical evolution leading to prebiotic organic compounds such as sugars, aminoacids, etc., are of universal applicability. We also do not know yet what fraction of planats where life might originate are able to maintain this hospitable environment for billions of years (Papagiannis [12]) so that life may be able to follow its painfully slow process of biological evolution to an advanced civilization. Run-away glaciations or run-away green house effects might terminate prematurely the presence of life in a considerable number of such planets. If conditions hold, however, biological evolution is likely to produce forms that fit all available niches and then forms that are not restricted to any particular niche.

It is interesting that the biological evolution might be assisted by major astronomical catastrophies, such as major impacts by comets or asteroids (Alvarez, et al [13]), which produce the extinction of a large number of species thus making room for the appearance of new ones. In the case of the Earth there is evidence of a series of such extinctions (Raup and Sepkoski [14]) with a periodicity of about 26 million years. The most impressive of them was the one that occurred about 65 million years ago at the Cretaceous-Tertiary border which wiped out the dinosaurs and opened the road for the expansion and rapid evolution of mammals. It has been proposed that such periodic extinctions might be produced by a small companion star to our Sun for which the name Nemesis, an ancient Greek goddess of divine vengence and destruction, has been proposed (Davis, Hut and Muller [15]).

V. TECHNOLOGICAL PROGRESS IN SETI WORK

Assuming that sites for the origin and evolution of life are relatively common in the Galaxy, it is reasonable to expect that there might be a significant number of advanced technological civilizations interested to communicate with other fellow stellar civilizations. The number N of such advanced civilizations in our Galaxy has been the subject of extensive debates (see e.g. articles in [3]) and estimates vary from N =1, i.e. only ourselves, to many billions if the colonization of the Galaxy has taken place. The initial estimates, which were obtained with the so called Drake Equation, were of intermediate values placing N in the range of 10^5-10^6, i.e., approximately one civilization per million stars. On this basis many searches have been undertaken, primarily in the radio domain, though there have also been some searches in the optical and in the infrared. In the radio domain most searches have been at the 21 cm line of Hydrogen, though several other "magic frequencies" (radio spectral lines or their arithmatic combinations) have also been used. According to Jill Tarter [16], who maintains a log-book of all the SETI efforts around the world, from the first radio search by Frank Drake in 1960 to 1984, there have been 46 different searches, half of them in the last six years. The number, the sophistication, and the international participation in this effort have been increasing steadily. Radio searches have now been undertaken in the USA, USSR, Australia, Canada, France, Germany, and Holland, with Japan getting ready to join the group with its new Nobeyama millimeter radio telescope. It is estimated that more than 100,000 hours have been spent in these 46 search projects.

Radio searches today can be divided into three general categories: Directed, Shared and Dedicated. Directed searches usually employ one of the larger radio telescopes of the world for a specific SETI project of relatively short duration and most often are carried out in one or more of the "magic frequencies". Shared searches involve either the re-analysis of old data for SETI signals using data tapes that had been obtained for other purposes, or the parasitic on line analysis for SETI signals of the data obtained while the radio telescope is conducting an unrelated astronomical program. In this category belongs the SERENDIP II system developed by S. Bowyer and D. Werthimer of U.C.- Berkeley (Werthimer, et al [17]) which consists of an automated device that performs a real time search for narrow-band SETI signals, and can be attached in a parasitic mode to any radio telescope. Finally in the Dedicated category belong searches which are carried out by observatories fully committed to SETI work. These facilities are usually automated and are thus able to collect data continuously and on a 24 hour basis. There are two such professional observatories now in operation. The oldest is the Ohio State University Radio Observatory which has been a SETI dedicated facility since 1973 and is now under the direction of Robert Dixon [18]. The other is the Harvard-Smithsonian Oak Ridge Radio Observatory, near Boston, where Project Sentinel of Paul Horowitz [19] has been in operation since March 1983. In the last two years amateur groups have also built amateur-SETI dedicated facilities, two in the United States and one in Canada. Let us hope that they will be as successful with SETI as they have been in their searches for comets.

Important progress is also being made in the technological and planning aspects of SETI. In the hardware area two different 8 million channel spectrum analyzers are now being built. The one being constructed at Harvard by Paul Horowitz and his colleagues [20], for their Project Sentinel at the Oak Ridge Radio Observatory, is an 8.4 million channel ultra-narrowband spectrum analyzer. It will cover a range of 420 kHz with a resolution of 0.05 kz per channel, and will be using a swept receiver to cancel the effects of the Earth's rotation. It will extend the present frequency coverage by a factor of 200, thus alleviating the present strict requirements that the transmitting civilizations corrected their signals. for all possible Doppler shifts. It is expected to become operational within 1985.

The other megachannel spectrum analyzer is being built at Stanford for NASA by Allen Peterson, Kok Chen and Ivan Linscott [21]. It will have 8.25 million channels and a spectral bandwidth of about 8 MHz. The output bandwidths will be 1 Hz, 32 Hz, 1024 Hz and 74 KHz, and the output will consist of either complex samples or of power (sqaure-law-detected) samples. It will also have an accumulater to integrate the power of the output bands for periods up to 1000 seconds. A prototype unit with 74,000 channels has now been completed and will be undergoing tests in 1985. The entire system is expected to be completed by the end of this decade. This system will improve by a factor of 100 what has been available for SETI up to now, and will also be of significant value to radioastronomical work in general.

There are also active research and development programs for SETI related software. Signal recognition algorithms, to be used with the megachannel spectrum analyzer discussed above, are now being developed at the NASA-Ames Research Center by Berny Oliver, Kent Cullers, John Wolfe, and others. To detect an intelligent signal in the data coming out from the MCSA, the data must be searched by different algorithms particularly sensitive to signals concentrated in frequency and/or time, and also algorithms capable of detecting frequency drifts due to Doppler effects. Due to the extremely large quantities of data that will be pouring out from the MCSA, it is important to do most of the analysis in real time. The high sensitivity signal recognition techniques now under development at NASA-Ames (Cullers [22]) are also likely to find applications in many other areas, including some that are remote to Astronomy such as brain research.

NASA now has a very active SETI group concentrated mostly at its Ames Research Center, Moffett Field, California. SETI work started at NASA-Ames in 1970 and has continued ever since with lecture series, work shops, project studies such as Project Cyclops (Oliver and Billingham [23]), workshops, meetings of advisory groups, publications of volumes and reports, as well as experimental SETI work through observational programs and equipment development programs. John Billingham, who was the head of this group, and his colleagues deserve a lot of credit for keeping the flame for SETI burning on practically a shoestring during the difficult years of the 1970's and the early 1980's when the US Congress was adamantly opposed to any funding for SETI.

They did persevere, however, and finally won, because Congress at last withdrew in 1982 its opposition to SETI and starting with the fiscal year 1983 NASA is spending approximately 1.5-2.0 million dollars per year for SETI research and development. This supports the work on the MCSA at Stanford, an equally fine SETI group at the Jet Propulsion Laboratory in Pasadena, California, internal work at Ames, and finally NASA has started funding a few external projects on SETI, one of which was our IAU Symposium 112. SETI at NASA-Ames, which is still under the Extraterrestrial Research Division headed by John Billingham, has now a new Director, Dr. Bernard Oliver [24], a highly respected pioneer in this field with great technological and administrative experience (a past Vice President for Research of the Hewlett-Packard Co). In summary NASA-Ames has unquestionably become the world's center for SETI research.

Besides the development of hardware and software, NASA through its Ames and JPL groups has developed a comprehensive search program which will go into full gear with the completion of the MCSA now being built for NASA and Stanford. The search for intelligent radio signals is a multidimensional problem which is affected by several parameters (sky coverage, frequency coverage, sensitivity, etc.). To optimize the chances of success, NASA has developed a two component program. In the first one, called the Targeted Search, the emphasis is on sensitivity, while in the second called the All-Sky survey, the emphasis is on a much broader sky coverage at a much lower sensitivity. In both cases the idea of "magic frequencies" is given up in favor of a more comprehensive frequency coverage in the 1-10 GHz range. This, of course, will become possible thanks to the MCSA now under developments.

The Targeted Search (Seeger and Wolfe [25]) will examine about 800 targets (the 773 F, G, and K main sequence stars contained in the RGO catalogue, some additional stars with peculiar spectra, and possibly some galaxies), using radiotelescopes all around the world since these targets are scattered over the

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whole sky. The frequency range to be covered will be approximately from 1.2 GHz to 2.0 GHz, which is centered around the so-called "water hole" between the hydrogen (H)-line at 1.4 GHz and the hydroxyl (OH)-lines around 1.65 GHz. This region, on objective criteria, seems to be the most attractive for interstellar communications and might also have some additional significance since OH and H form water which probably is a basic ingredient for life throughout the Universe. This frequency range will be analyzed with a resolution of 1 Hz and an observing period of about 1,000 seconds per target. With only one MCSA with a bandwidth of 8 MHz, this project will take 5-10 years. The time, of course, can be shortened substantially if more than one MCSA were available, which seems quite possible because duplicating a successful instrument is much faster and much cheaper than developing the first one.

The All-Sky Survey (Klein and Gulkis [26]), will cover the entire sky but with a much lower sensitivity. It will also have a broader frequency coverage, ranging from about 1 GHz to approximately 10 GHz. The frequency resolution will probably be 32 Hz. This survey will probably use primarily smaller telescopes, which have broader beams. This speeds up the survey, at the expense of course of sensitivity. It is estimated that the All-Sky Survey will also take approximately 5 years. In both cases of course the biggest problem will be availability of telescope time and availability of additional units of the MCSA. An estimate of what time fractions of existing radiotelescopes might be available, including stations of the Deep Space Network in the United States, Australia and possibly Spain, indicates that with the availability of 2-3 MCSA's the entire project could be completed in less than 10 years and possibly in only 5 years.

VI. DISCUSSION ON STRATEGIES

It is fair to say that during the late 1970's there was a sort of a revolt within the SETI community, sparked primarily by a paper by Michael Hart [27]. It was based on the realization by a significant number of scientists that interstellar voyages at V = 0.01-0.05c, with large, self-sustained space colonies, will probably be within the capabilities of advanced technological civilizations. As a result a colonization wave could sweep through the entire galaxy in only about 10 million years, which is a very short period compared to the billions of years that our Galaxy has been capable of harboring advanced civilizations. It was also difficult to see how the complete colonization of the Galaxy, including our own Solar System, could have been avoided, if indeed our Galaxy had harbored close to one billion civilizations during the past 5 billion years, each with an average life-time of approximately one million years, as estimated by the proponents of the Drake equation.

The galactic colonization concept, however, leads to the question: "But then, where are they?", which is often called "the Fermi Paradox" because supposedly this question was first posed by the great nuclear physicist Enrico Fermi. Some have extended this argument to conclude that since they don't seem to be here, the colonization of the Galaxy must have not taken place simply because there was no one there to initiate it. Hence we must be alone in the entire Galaxy. Others argued that the galactic colonization has either not occurred because it is too expensive to be of any use [28], or that it has not yet been completed because it is a very slow process [29]. Others, on the other hand, have argued that extraterrestrials might have colonized our own Solar System, living probably in far away space colonies, but for certain reasons [30],[31] they have chosen not to make their presence known.

The important outcome from our IAU Symposium 112 was the realization and the acceptance that none of us can be certain of how civilizations far more advanced than ours are likely to act and to behave. Hence, though these debates are interesting and in many ways valuable, we must not allow them to slow down the momentum we have gained with so much effort. Instead we must forge ahead having one or two key search projects, such as the one developed by NASA, as the

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cornerstones of our search effort, but encouraging also the expression of alternative points of view through parallel experimental searches. This multiple-path approach or mixed strategy, as people called it at the Symposium, is a very healthy development for SETI which can only get stronger with a broader participation and with the exploration of several different paths toward the common goal.

VII. PLANS FOR THE FUTURE OF COMMISSION 51

During our symposium, IAU Commission 51 formulated several plans for the future [32], which were communicated to the Executive Committee of the IAU with a very favorable overall response. They include the following:

1. The next IAU Symposium of Commission 51, at the invitation of the Hungarian Academy of Sciences, will be held in Hungary in June 1987.
2. The next President of Commission 51 for the period 1985-88 will be Frank D. Drake.
3. The next Vice President of Commission 51 will be George Marx of Hungary.
4. The new 10 member Organizing Committee of Commission 51 will consist of the following: R.D. Brown (AUSTRALIA), P. Connes (FRANCE), G.D. Gatewood (USA), J. Jugaku (JAPAN), P. Feldman (CANADA), J. Mayo Greenberg (HOLLAND), N.S. Kardashev (USSR), P. Morrison (USA), M.D. Papagiannis (USA), and V.S. Troitsky (USSR).
5. Eight prominent scientists from other fields who are now serving as Consultants to our Commission will be elected full members of the IAU. They are: John Billingham, Donald DeVincenzi, Paul Horowitz, Anthony R. Martin, Bernard M. Oliver, R. Pesek, Cyril Ponnamperuma, and Edward M. Purcell.
6 Incorporate in the title of our Commission the name BIOASTRONOMY, which we feel describes in a concise and scientific manner the goals of our Commission, namely the astronomical search for life (bios) in the Universe.

VIII. CONCLUSIONS

IAU Commission 51, the youngest of IAU commission, which was established only in 1982, has made great strides forward in these three years and has acted as a catalyst and as a coordinator for the more cohesive expression of the many exciting new developments that are happening in this new field. The volume of the Proceedings [4] of our recent IAU symposium 112 will be a compendium and an excellent reference source for all these new developments. We look forward into the future of our new IAU Commission and of our young discipline with enthusiasm and great anticipation.

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FIGURE 1. A group of key IAU Symposium 112 participants. Left to right, Edward M. Purcell and Philip Morrison co-Chairmen L.O.C., Carl Sagan the Banquet Speaker, Michael D. Papagiannis President and Frank Drake Vice-President IAU Commission 51.

FIGURE 2. Philip Morrison holding the 25-th Anniversary Commemorative Plaque presented to him during the IAU Symposium 112. Standing by are the President Michael D. Papagiannis and the Vice-President Frank Drake of IAU Commission 51.

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