NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

OAST SPACE THEME WORKSHOP

VOLUME II

THEME SUMMARY

III. SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE (#9)

A. Theme Statement

B. April 26, 1976, Presentation

C. Summary

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Held at the
Langley Research Center
April 26-30, 1976

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Foreword

The attached material represents the working papers from the OAST Space Theme Workshop held at the Langley Research Center, April 26-30, 1976, and contains a quick-look analysis of the proceedings. The material is unedited and intended for further use by the participants of the workshop and the planning elements of NASA concerned with space mission research and technology. It should be understood that the data do not represent official plans or positions but are part of the process of evolving such plans and positions.

Nearly 100 of the Agency's top technologists and scientists joined with another 35 theme specialists to produce this working document - a document that provides a technical foundation, including research and technology base candidates, for each of the six space themes.

The material in this report is considered essential to the development of Center initiatives in support of these themes. Copies of the report will be made available to the Center Management Board and the individuals at the Centers responsible for the FY'78 program planning cycle. The timing of this planning activity has caused us to distribute this document in this unedited form. Thus, it possibly contains errors, hopefully, more of a typographical rather than a technological nature. Nonetheless, the information contained is of a high professional level, reflecting the efforts of the workshop participants and will be invaluable to the planning and successful execution of the Agency's near- and far-term advanced technology program.

Stanley R. Sadin
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Chairman
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Office of Aeronautics and
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THEME #9

THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE

SETI

THEME SUMMARY
WORKING GROUP DIRECTIVE

I. UNIQUE CONSIDERATIONS

SETI offers the means to disclose the existence of extraterrestrial civilizations - an event that might be the most profound in all human experience. Preliminary studies indicate that the required technology can be developed to support a creditable exploration program in this decade. This task entails the detection of signals by use of large antenna collector areas and sophisticated signal processors. Phase I effort will utilize a smaller ground-based approach while design and concept studies for future systems including ground, space and lunar based alternatives will proceed concurrently.

The search for extraterrestrial intelligence (SETI) is a new thrust in the exploration of space, and by definition falls within the mandate of the Agency as specified in the NASA Charter.

Questions relating to extraterrestrial life, and the possibilities for interstellar communication, are discussed at some length in the report entitled, "Future Space Programs 1975", prepared in September 1975, by the Subcommittee on Space Science and Applications for the Committee on Science and Technology of the U.S. House of Representatives. Corresponding discussions took place during the Hearings before the Subcommittee. Recommendation D in the Subcommittee Report reads: "In determination of space program composition over the next decade, adequate weight needs to be given to the widest possible range of longer term opportunities to assure that the scientific and technological base has been developed to support them." One of the six longer term programs identified is "Extraterrestrial communication systems". In consonance with this Congressional recommendation, the proposed theme is the development of the technological base for a program to search for extraterrestrial intelligent life.

The proposed program also falls within the Programs and Specific Objectives of OAST: a major portion of the work envisaged in Fiscal Years 1978 through 1981 is advanced system technology in general, and advanced communications technology in particular. As will be described later, one of the principal options for the implementation of a SETI system is a space-borne radiotelescope incorporating advanced technology of various kinds. It is important to point out that the entire effort has great intrinsic value with regard to the developed technology that would have broad application in many other fields.

II. BACKGROUND

A. Theme Description

A program to search for signals of extraterrestrial origin should be initiated now and expanded over the next decade into one of the major thrusts of our total space program.

Although such a program, if it enjoyed stable support, would in fact expand more or less continuously into a mature long-term effort, it is convenient to describe the program as having three distinct phases: (1) a preliminary phase, (2) an intermediate phase, and (3) a longterm search phase. These phases involve progressive increases in sensitivity, hardware complexity, system capability and cost. Extraterrestrial intelligent signals may be detected at any time, with the a priori probability being small at the start of Phase I, and growing in proportion to the system sensitivity and number of targets searched. Each phase serves to gather experience useful in the design of the larger scale efforts of the next phase, should these be required. Below is outlined what is conceived to be the content and time periods of the phases.

1. The Preliminary Phase (1977-1983)

This is essentially the system analysis and prototype construction phase during which the most likely search strategies are evaluated, the trade-offs between system parameters are studied, and prototype hardware to implement selected search strategies is designed, constructed and tested. Existing equipment, supplemented with the prototypes as these come "on-line", is used to conduct initial wide area and wide frequency band surveys (SETI Mark I) for high powered (beamed) signals. Existing observatories will examine selected areas and targets over especially likely frequency bands. Although sky survey efforts should cover as much of the radio spectrum as possible, the present search strategy indicates that the low end of the microwave window should be given high priority. The receivers and data processors proposed for Phase I will achieve at least a ten thousand-fold increase in sensitivity over existing systems, at a cost that is negligible compared with a thousand-fold increase in collecting area. In addition, steps must be taken during this period to protect the selected portion or portions of the spectrum against interference that would destroy the effectiveness of the search. Finally, it appears desirable during this period to define and design certain ancillary programs needed to give further confidence in the probability of success of a search, and to identify the targets to be searched.

2. The Intermediate Phase (1982-1988)

This phase continues the search for extraterrestrial intelligence while building the first dedicated search system incorporating the best ideas that have evolved during the preliminary phase, and

uses this system to refine the earlier techniques and strategy. It is also the phase during which the nature of a large search system and of the ancillary systems is resolved. The intermediate phase efforts are expected to involve space as well as earth based antennas (SETI Mark II) and will utilize the technology developed during the preliminary phase.

3. Long-Term Phase (1989-)

Since the nature of large-scale systems (SETI Mark III and IV) depend upon decisions to be arrived at during the preliminary and intermediate phases, only general comments ca be given at this time:

a. This phase may be unnecessary, or at least greatly altered if detection has already been achieved.

b. Here a "long-term" search is defined as the examination of something on the order of 10^6 likely stars with system parameters appropriate to this task, as determined by prior studies.

c. The required search time is expected to be on the order of two to three decades if only one observation is made per star. During this time it would be prudent to search the relatively few nearby stars several times.

d. The long search times make it imperative that the system be largely automatic.

e. If the decision is to build a system in space or on the moon, an initial size commitment or a series of sizes for successively larger systems must be decided upon. If an earth-based array is chosen it becomes necessary to expand the pilot antenna by 2 - 3 orders of magnitude over perhaps a 20-year period. The overriding consideration in the final decision of antenna location is expected to involve the question of radio frequency interference (RFI).

4. Schedule (see Figure 1)

B. Theme Advocacy Issues

1. Rationale

There is widespread and growing interest in the whole subject of extraterrestrial life, and particularly of extraterrestrial intelligent life. This interest is evident from the rapidly increasing numbers of scientific publications in the area, from the corresponding increase in the numbers of popular books and magizine articles, and from the general level of public interest as reflected in

AMES SETI PROGRAM PLAN

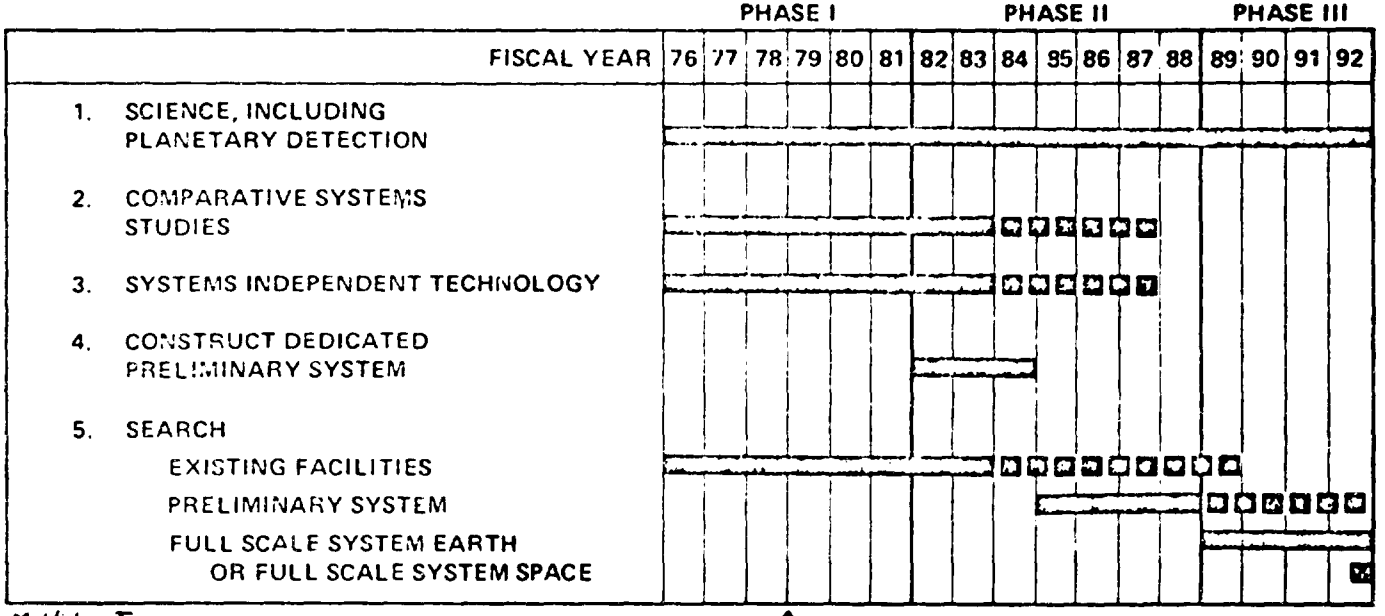


Figure 1

Congressional inquiries and testimony.

NASA has provided the major existing stimulus for the search for extraterrestrial life in its research programs in exobiology and in the Viking program. If Viking should discover microbial life on Mars, our confidence that life is widespread in the universe will be substantially improved, and the argument for SETI given a powerful impetus. If, on the otherhand, the results of Viking are clearly negative, it may be that the only way of detecting extraterrestrial life will be to search for signals of intelligent origin. In either case, the Agency should initiate a SETI program now so that the momentum of Exobiology programs and missions can be maintained. In view of the timing of the Viking landing, a SETI program should actually be initiated in FY77.

The electromagnetic spectrum is rapidly becoming saturated. It is important to begin the program as soon as possible so that good use can be made of the spectrum, and protection from radio frequency interference can be provided most economically.

It is possible that the SETI program will be shown to be most efficiently and economically carried out with a space-borne system. Should this in fact be the result of the systems studies carried out in the preliminary phase, the space system could then become a major user of the Space Shuttle and associated space transportation systems in the second phase of a SETI program after 1984.
In view of the lead times involved for projects involving Shuttle use, the first phase of the program should begin as soon as possible.

The Soviets have a major interest in SETI programs and are already conducting preliminary searches. A Soviet long-range program plan, comprehensive in nature, has been published in "Soviet Astronomy", and describes extensive ground based and space systems. While their system designs do not appear to be as sophisticated as those envisaged here, it would seem to be important to maintain the U.S. lead.

Political circumstances may lead at any time to a demand for a bold and imaginative new element of our national space program. Political circumstances could also lead to the demand for an international space program, and in particular for a joint US-USSR venture as a follow-on to the Apollo-Soyuz mission. In either case a SETI program could be a promising candidate. An early start on the development of the science and technology base, in FY77 or FY78, is indicated in the interest of preparedness.

2. Benefits

Although the benefits of a SETI program cannot be estimated in dollar terms, they do fall into five major categories:

a. The discovery of extraterrestrial civilizations would have enormous benefits that greatly exceed those of any other venture ever undertaken by the human race. The potential gain in knowledge in the arts and sciences and in technology are incalculable. In addition, knowledge of the pathways taken by extraterrestrial cultures, which allowed them to achieve long-term stability, may indeed be essential to our own longevity.

b. Whether or not signals of intelligent origin are found, major discoveries will surely be forthcoming in the science of radio-astronomy.

c. The data processing systems that will be developed would have a major impact in a number of fields where multichannel spectral processing is required.

d. The detection of extrasolar planets is of fundamental scientific interest quite apart from its importance for SETI.

e. The stellar census, giving an automated record of all star types, locations, magnitudes and distances down to 14th magnitude, will be of enormous value to the astronomical community.

3. Problem Areas

With the possible exception of the RFI question, no insuperable technological hurdles are foreseen. There will be, however, a great challenge in carrying out the advanced technology development required, particularly for the space or lunar based systems.

III. TECHNOLOGY NEEDS

A. Justification

It is generally recognized that in the search for signals of extraterrestrial intelligent origin, the key requirement is a highly sensitive search system. The three most important parameters which relate to the system sensitivity are the effective collecting area, the system noise temperature and the frequency resolution bandwidth or bin width. Substantial improvement in effective collecting area, over that presently available, is by far the most expensive and is highly dependent on unknowns such as antenna design, location and RFI compatibility. On the other hand, vast improvements (40-60 db) over present instrumentation in system noise temperature and bandwidth resolution is well within the state-of-the-art and could be achieved at relatively modest costs. The hardware thus developed could then be utilized with existing antennas (Arecibo, DSN, etc.) to begin an active SETI effort to look for signals from fortuitously close civilizations, or equivalently, civilizations at greater distances but of higher effective radiating power. Concurrently, the questions with regard to antenna design, location and RFI compatibility have to be addressed by in-depth studies in order to provide the information required to enable a confident final decision on the construction of a more sensitive search system that will be both cost effective and reliable. Finally there is a strong expectation that the signals of interest will originate on or near planets of solar type stars. Within 1000 light years there are far fewer of these stars than there are separate pointing directions on the sky for even a single 100 meter antenna. Therefore, a catalog of likely targets is required if the signal search duration is to be minimized. Present star catalogs contain about 10^{-3} of the solar type stars believed to be within 1000 light years of the earth. It is necessary to carry out a stellar census of the sky down to the 14th - 15th apparent magnitude so that a reasonably complete target list can be prepared for the search.

B. System Independent Technology

1. Multichannel Spectrum Analyzer (MCSA)

The optimum architecture for a 10^6 to 10^9 bin Fourier Transform Processor, or MCSA, is now being studied by simulation on the Ames 7600 computer. A 10^6 bin unit, using off-the-shelf chips, would be constructed for on-air testing by the start of FY78. Economical special LSI chip designs will be required in FY 77-78 along with the architecture of an MCSA design expandible to 10^9 and more bins. A prototype subunit of the final 10^9 MCSA design should be completed and tested in FY79. The construction of the final 10^9 MCSA would then start at the end of FY79.

2. Low Noise Receiver

It is vital to carry out realistic, operational tests of the new electronic components during development, and to characterize

the spectral range of prime interest. JPL can fabricate a MASER (tunable over this spectral range, having an instantaneous bandwidth 20-40 Mhz; 2-3K equivalent terminal temperature) for these tests by extrapolating the design of the DSN S-band MASER. This will improve the sensitivity of the tests by about 10 db over the better L-band receivers now in use. It should be completed in time for use with the first experimental models in the multichannel spectrum analyzer and pattern recognition analyzer development.

Following this, it will be necessary to proceed to study and develop a wide band (≈ 300 MHz) low noise input amplifier system. A final prototype design should be available by the beginning of FY80.

3. Pattern Recognition Analyzer

Two types of analyzers are required in order to study the spectral data developed by the MCSA. These should be developed in parallel over FY 77-80. The first is a scanning, zoom-type display optimized for human pattern recognition capability. This unit will be used for diagnostic purposes, on-air tests, and to assist in determining the precise characteristics required for the second, or automatic analyzer. In addition, other data processing approaches require examination.

The automatic analyzer is required to deal effectively (at a sufficiently low false-alarm rate) with the enormous data rate provided by the MCSA, sorting out possible intelligent signals, interfering signals due to both human activities and astronomical phenomena, and monitoring the overall system performance.

The knowledge of experienced researchers in visual and automatic pattern recognition systems and in data processing should be applied in the development of these analyzers. Both the analyzers and the MCSA should be major advances in the state of the art and of great value in areas outside SETI.

4. Stellar Census System

After preliminary examination of the relevant problems, it is believed that an optical telescope system equipped and fully automated for multi-color photographic photometry can provide a stellar census from which target priority lists can be constructed. Further detailed study is required in order to verify this belief. (If the photographic approach should prove inadequate, an alternate type system; probably photo-electric, will have to be developed.)

Assuming the photographic approach is reasonable, it is planned to complete the detailed system design (already begun) by the

end of FY79. The system envisaged involves developing the following major characteristics:

a. Identical telescopic systems located at suitable sites at roughly 30N and 30S latitudes.

b. The moderate field telescopes will be equipped with a fully automatic calibration, exposure, and plate development system for multicolor photometry.

c. The nature of the color system has yet to be established. This must be determined. Stellar classification is expected to be on the MK system, but further study is planned in this connection.

d. All plates will be measured on computer-controlled measuring machines, and the computer will provide best estimates of spectral type, luminosity etc.

e. The stellar census will consist of magnetic storage containing nearly all objects in the sky down to perhaps 15th apparent magnitude, all classified by a uniform, well defined color system. Unless unforseen problems arise, detailed system design should be complete by FY80.

Telescopes having apertures on the order of 60 inches are envisioned. Construction at good northern and southern hemisphere sites should take two or, at the most, three years, starting in FY80.

5. Extrasolar Planetary Detection

It is important to the fundamental arguments for SETI that a program be implemented for the design and development of an extrasolar planetary detection system. The first step should be the design of dedicated astrometric telescope and a concurrent detailed feasibility study of promising new techniques such as space telescope apodization, IR and radio VLBI astrometry and photometric and radial velocity determination.

Detailed design studies of new techniques should follow the conclusion of the feasibility study, completed by January 1980. The design study may interact with the similar study on a dedicated astrometric telescope, as some of the potential new techniques (radial velocity) could use the same telescope systems.

C. Antenna Design/Location Technology

1. Comparative System Studies

In order to assist the decision on whether to build a large system on earth, or in space, or on the far side of the moon, more accurate cost, feasibility, and risk evaluation data are required than are available at the of FY76. The SRI study asserts that a space system may be comparable in cost with a ground-based system.

A decision on where to site a large interstellar search system should be made only when hard estimates of cost, feasibility, risk, and capability associated with the basic alternatives are available.

Three separate parallel studies are required to develop this information in a reasonable time. An effort will be made to see that each study is carried out by capable proponents of the design study entrusted to them. At least two years, and perhaps six or more years, may be required to develop sufficient basic data for a sound decision, whether to base a large search system (if still required) on earth, in space, or on the moon; and what the optimum form of each system should be.

2. Earth Based Systems

For ground-based operation, an array similar to that of the Cyclops study is the system of choice at the present time. Studies and technical developments since Cyclops, particularly in materials technology, show that an earth-based array system can be developed at a cost appreciably less than projected in the 1971 study.

It is planned to refine the proposed earth-based system by studies and model exercises until the design reaches the state-of-the-art and projected costs are understood to a precision of 10 to 15%. These studies will be carried on at a moderate level of effort for the next three to six years, or until a point of diminishing returns is clearly evident. These studies will be of value in areas outside SETI.

3. Space Based Systems

For space-based systems, the SRI study shows a shielded, multi-feed, large spherical antenna to be the system of choice. But costs, feasibility and risk are most uncertain. Therefore, a major study should be carried out, starting in FY77 and continuing until a clear decision can be made. This study will involve at least these major items:

a. development of long lived, light weight, low thermal coefficient of expansion materials, or, alternatively, the use of a sun shield to stabilize the system at a low temperature;

b. antenna design alternatives;

c. transportation methods;

d. space assembly, operations and maintenance;

e. the satellite relay systems required to line the data flow with earth operations;

f. the optimum division of the electronic system between space and earth.

The increase in sensitivity for space based systems is expected to occur in a step-wise fashion with an increase in antenna aperture on the order of a factor of ten for each successive system.

Table 1 outlines important parameters of three space antenna systems suitable for SETI, VLBI, and general physical studies that represent the successive steps in a possible search strategy starting with small and intermediate size systems in Phase 2 and the large system for Phase 3. Mark II is based on a Boeing design, III & IV on a Lockheed design. Further explanatory comments are:

a. Assembly (or unfurling) and tests are assumed to take place in low Earth orbit (275 km). Then, systems are ferried to synchronous altitude or to L-4(5) lunar position (or beyond). One or two manned visits per decade should be sufficient for routine service, replacement of consumables, and repair.

b. Due to rapid motion relative to ground stations, low earth orbit appears highly impractical for either SETI or VLBI. A geostationary orbit is nearly ideal for SETI since the earth blocks only about 0.6% of the sky. VLBI would need an orbit giving large variation in apparent RA and DEC, and in range from VLBI earth stations.

c. Space advantages are: for SETI, complete sky coverage with one system, ability to hold a desired signal without interruption, low maintenance, automatic operation, multiple feeds, and the ability to search over a very wide frequency range: for VLBI, greater resolution and good coverage of the o-v transform plane.

d. Space disadvantages: for SETI, chiefly the RFI problem: for VLBI, no problem if operation is in frequency bands solely allocated to radio astronomy. VLBI requires an accurate

range measuring system.

e. SETI and VLBI require essentially the same pointing accuracy.

f. A SETI system in space needs either greater RFI allocation protection (than on earth), or an RFI shield. Such a shield needs to be appreciably larger than the SETI antenna and held close to it. A shield diminishes the advantages mentioned in (c) above. It complicates the links-to-earth and the solar power problems. A shielded system is best placed at lunar distance, to avoid interference from satellites. A good shield does allow complete freedom of choice in operating frequency.

g. A shield for a SETI system in space is technically possible. It is certain to be a major cost item, both capital and operating.

h. At synchronous altitude, a direct link with the earth signal processing system is possible. At other altitudes, two relay satellites are required. In Mark III and IV, where the feeds are physically independent of the main reflector system, a third relay is required. The shield also complicates the solar power supply system because of shaddowing.

i. The multiple feed arrangement of Mark IV, triples the data processing system costs while cutting the search time to perhaps one-third.

j. In all systems it is assumed all data processing is on earth. Signal collection is straightforward. Besides the collector and feed, it requires only low noise amplifiers, atomic frequency standards, frequency synthesizers, and a relay system to earth. For the foreseeable future, the data processing system must be on earth or in a stable space colony of considerable capability.

k. A shielded Mark II system has much to recommend it now. It can look for strong signals over the entire microwave window; and its value to radio astronomy is considerable. This is because of its atmosphere-free spectral coverage and resolution, as well as its VLBI potential. Nothing on earth could match it for broad frequency capability. It would have a long life time independent of SETI.

TABLE 1

CHARACTERISTIC	MARK II	MARK III	MARK IV
1. Diameter (M)	30	300	3000
2. Antenna system	off-axis rigid parabolic cassegrain	maypole soft spherical	maypole soft spherical
3. Surface tolerance (mm)	0.05	1	1
4. Nominal maximum frequency (GHz)	300	15	15
5. 3 db beamwidth/pointing precision			
f = 1.5 GHz	24'/2.5'	2.5'/15"	15"/1.5"
15. "	2.5'/15"	15"/1.5"	1.5"/0.1"
300. "	7.2"/0.7"	NA	NA
6. Feed(s) pointing control range	NA	± 2°	± 7°
7. Number of feeds/Secondary diameter	1 ; 6m	1 ; 30m	3 ; 130m
8. Slew time: collector	10^2	10^3	10^6
feed(s) (sec)	NA	10^2	10^2
9. Mass of antenna (kg)	10^4	10^6	10^7
10. Mass of RFI shield (kg)	NA	10^6	10^7
11. Electrical power requirements. (kw)		(TO BE ADDED)	
Receivers, Data link(s), Control telemetry, Figure monitor(s), Figure servos	2	2	6
Collector ion thrustors (If required)	10	30	1500
RFI shield thrustors (may be chem.)	5	15	700
12. Circular polarization channels	2	2	6
13. Total data link bandwidth (MHz)	600	600	1800
14. System noise temperature (K)	5 - 100	5 - 10	5 - 10
15. Frequency resolution (min. bin width)	0.1 Hz	0.1 Hz	0.1 Hz
16. Equivalent isotropic power sensitivity (dbW/Hz minimum in 1000 seconds)	-255	-255	-255
17. Lifetime: antenna & shield	10	10	30
subsystems	3	3	5
18. Operational Date	1984	1990	1995

4. Lunar Based Systems

A search system based on the far side of the moon has some obvious advantages stemming chiefly from the shielding from the earth provided by the moon itself.

The SRI study determined a Cyclops-type array as the system of choice for this site. Extrapolating soft engineering and cost data, they estimated the lunar site could be exploited perhaps by FY 2000 or later. Lunar colonization would be required and could be developed by then.

It is clear that more detailed studies are required in order to soundly evaluate the possibility of a lunar site for SETI.

D. Radio Frequency Interference (RFI)

RFI blocks access to that part of the electromagnetic spectrum occupied by the interfering signal. If the signal is strong enough, it can paralyze the low noise input amplifiers of any search system, thus putting the entire system out of operation.

RFI System Studies are underway in FY76 because it is clear Phase I activities will require protection by suitable frequency allocation procedures. Further, protective allocation procedures are required for any earth-based search system regardless of size and siting; they are required for a space system unless a separate and adequate shield is provided--a costly matter. For an Interstellar Search System (ISS) based on the far side of the Moon, allocation procedures are required only for space vehicles launched on trajectories going beyond the lunar orbit.

A major effort in RFI system studies is planned for FY77-78. This will have two aspects: (1) how the contemplated search systems may be designed and operated to be least susceptible to RFI, and (2) what frequency allocation procedures are required by a search system while at the same time least restrictive with respect to other uses of the same portion of the spectrum.

E. Schedule

The detailed schedule is given in Figures 2, 3, 4, 5 and 6.

F. Resources

The resources requirements for phase 1 are given in Figure 7.

SYSTEM INDEPENDENT TECHNOLOGY DEVELOPMENT

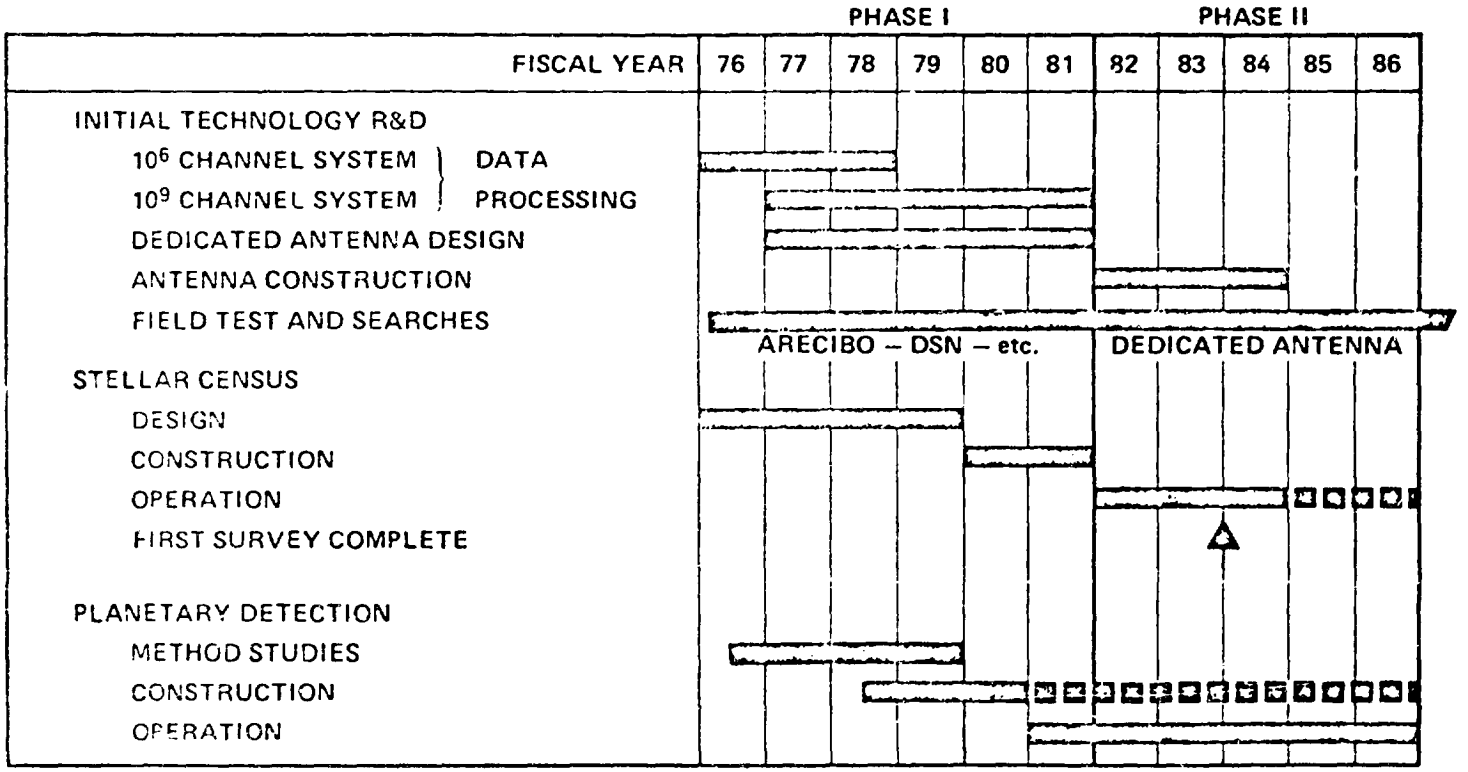
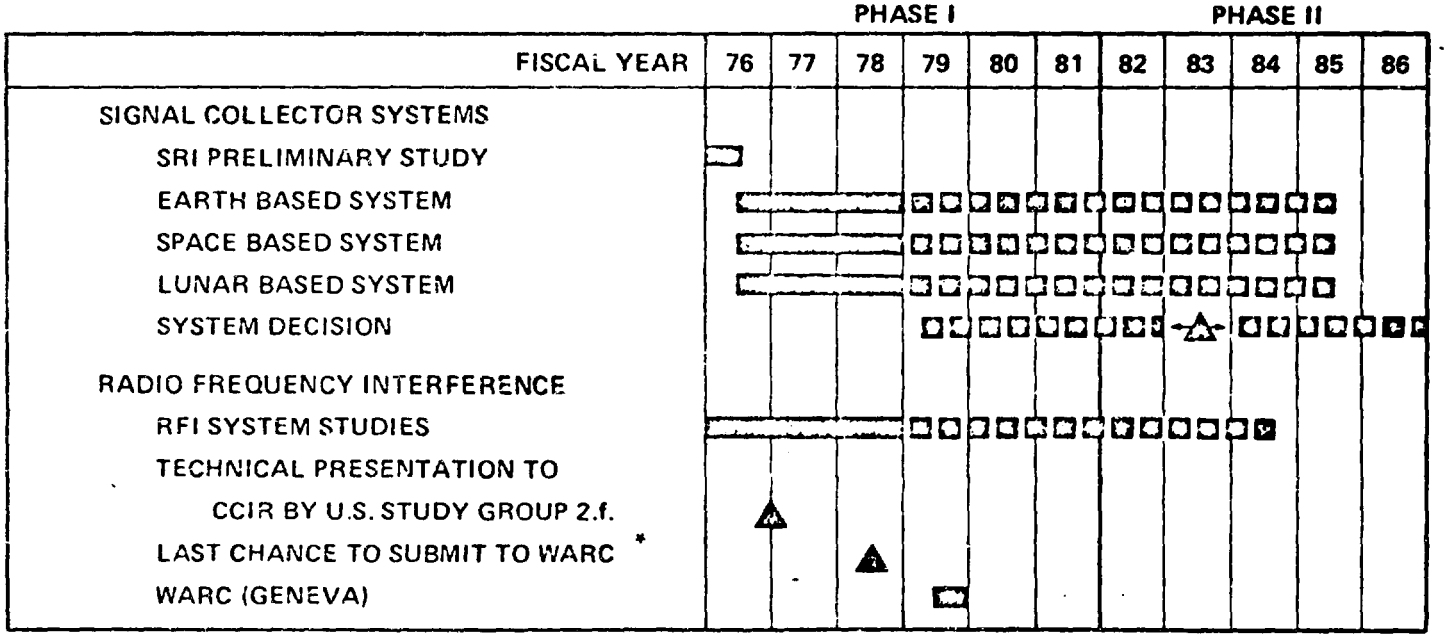


Figure 2

COMPARATIVE SYSTEM STUDIES



*World Administrative Radio Conference

Figure 3

SEARCH SYSTEM DEVELOPMENT

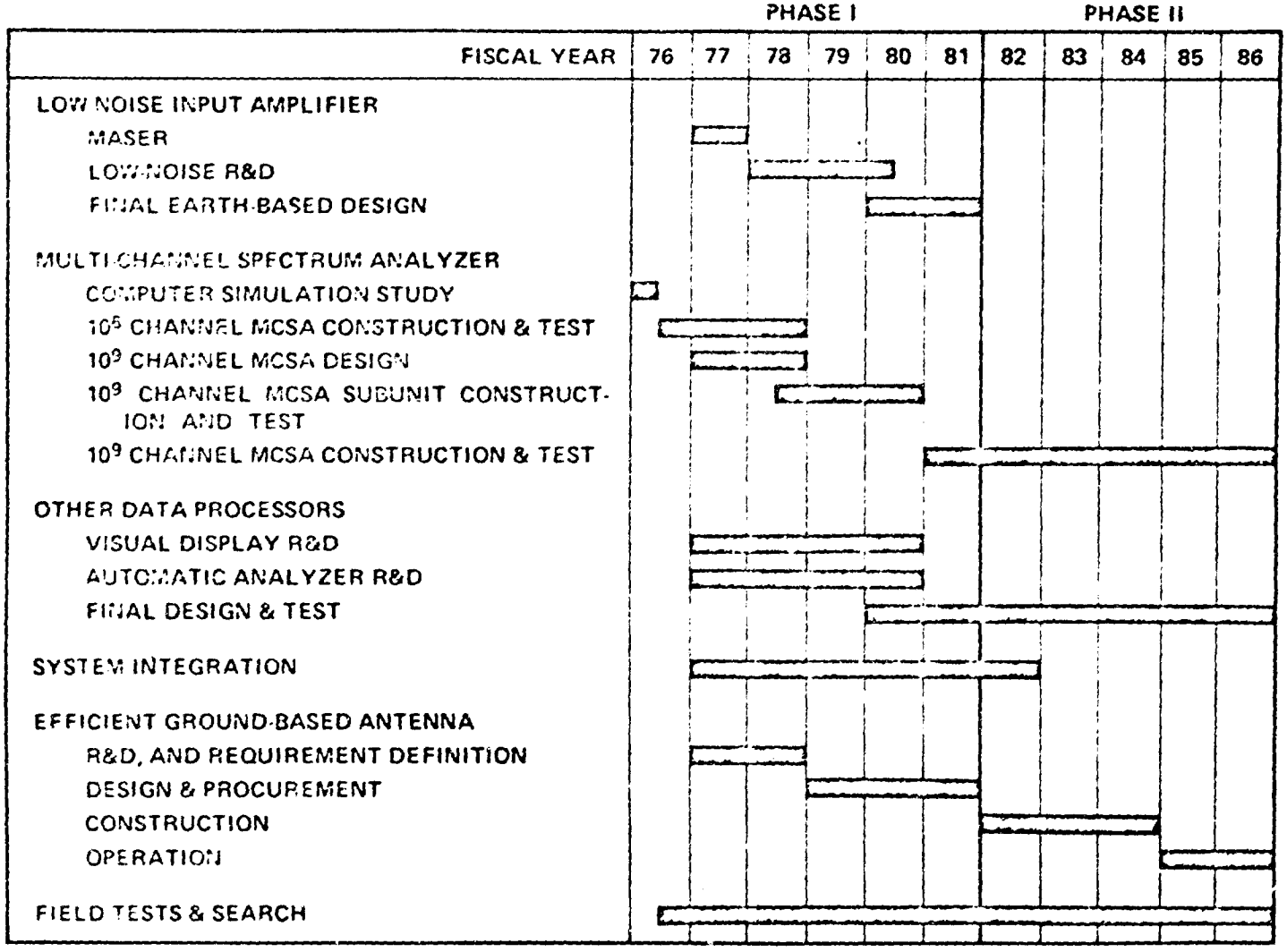
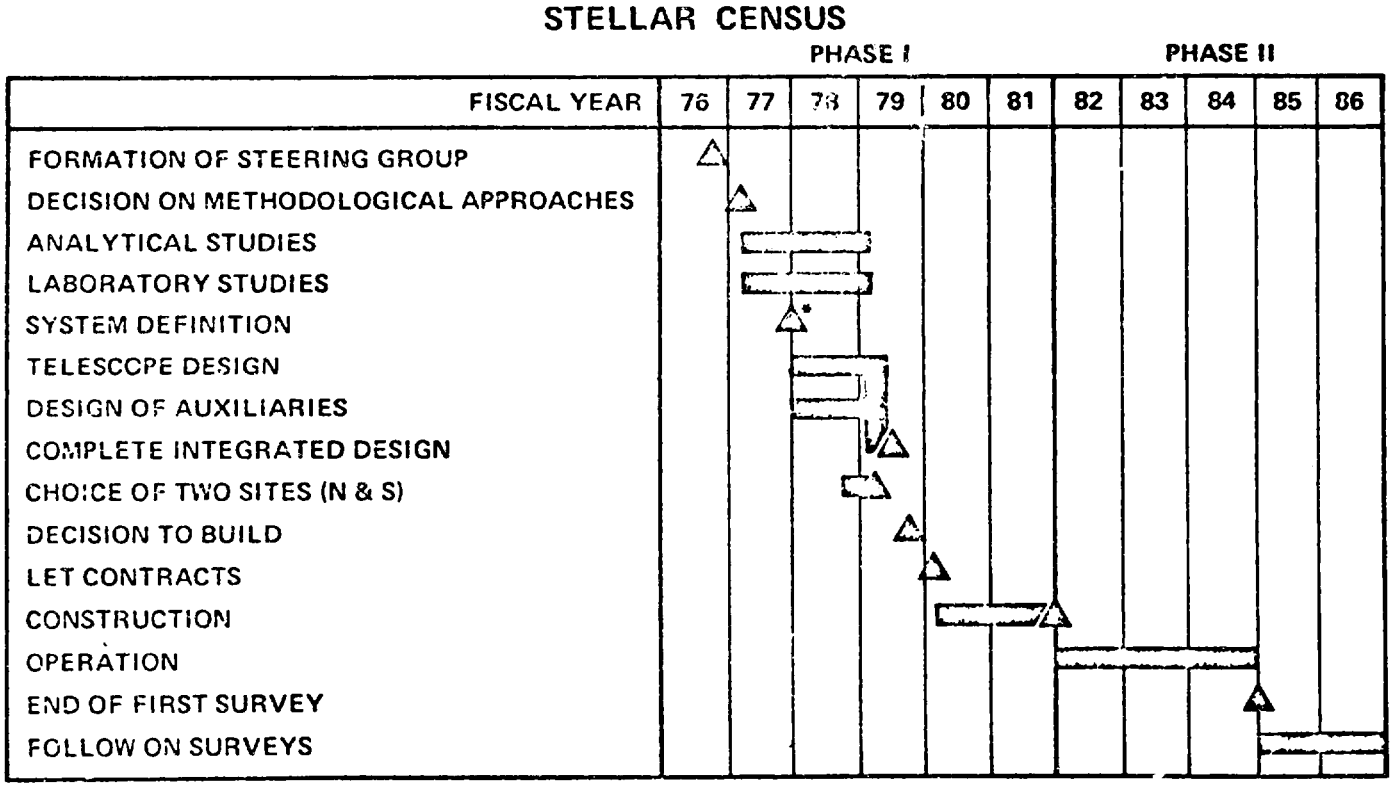


Figure 4


STELLAR CENSUS
PHASE I
PHASE II
FISCAL YEAR
76
77
78
79
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83
84
85
86
FORMATION OF STEERING GROUP
DECISION ON METHODOLOGICAL APPROACHES
ANALYTICAL STUDIES
LABORATORY STUDIES
SYSTEM DEFINITION
TELESCOPE DESIGN
DESIGN OF AUXILIARIES
COMPLETE INTEGRATED DESIGN
CHOICE OF TWO SITES (N & S)
DECISION TO BUILD
LET CONTRACTS
CONSTRUCTION
OPERATION
END OF FIRST SURVEY
FOLLOW ON SURVEYS
*IF PHOTOGRAPHIC, GO. IF NEW DEVICE NEEDED, DEVELOP IT, THEN GO.

Figure 5

EXTRASOLAR PLANETARY DETECTION PROGRAM

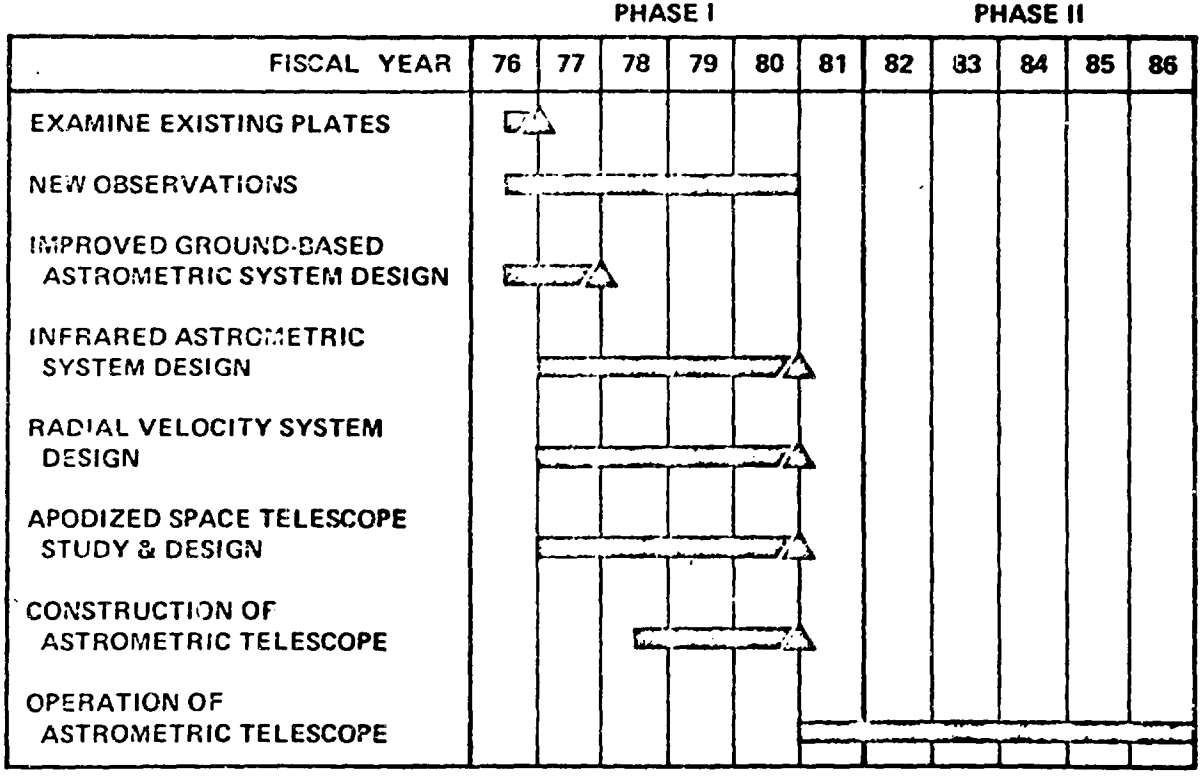


Figure 6

AMES SETI PROGRAM PLAN
PHASE I COSTS *

	MILLIONS OF FY' 76 DOLLARS						TOTAL
	76	77	78	79	80	81	
COMPARATIVE SYSTEM STUDIES							
SRI PRELIMINARY	0.12						0.12
EARTH BASED		0.2	0.3	0.4	0.3	0.2	1.4
SPACE BASED		0.7	1.0	1.4	1.4	0.7	5.2
LUNAR BASED		0.3	0.4	0.5	0.4	0.2	1.8
RFI EVALUATION		0.1	0.2	0.2			0.5
SYSTEM INDEPENDENT TECHNOLOGY DEVELOPMENT							
STELLAR CENSUS	0.02	0.3	0.6	0.9	2.5	2.5	6.8
PILOT MODEL RECEIVER AND DATA PROCESSOR	0.14	0.9	2.5	5.0	10.0	10.0	28.5
DEDICATED SINGLE ANTENNA		0.3	0.4	0.5	0.5	10.0	11.7
SCIENCE, INCLUDING PLANETARY DETECTION	0.03	0.3	0.4	0.6	0.9	1.5	3.7
IMPACT STUDIES		0.1	0.1	0.1	0.2	0.2	0.7
TOTAL	0.31	3.2	5.9	9.6	16.2	25.3	60.5
		0.6	2.2	0.3	0.3	0.3	

*Plus for observational program using existing antenna facilities

Figure 7

SUPPORTING PROPOSALS -- #9 SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE SUPPORTING INITIATIVES

		N.I. NO.	
o DIRECT SUPPORT	1.	110	SETI (PHASE 1)
o GENERICALLY OR PARTLY RELATED	2.	103	CCD-UNIFIED DATA PROCESSOR * (10)
	3.	104	DEXTEROUS MANIPULATOR * (11)
	4.	105	ATTITUDE CONTROL OF STRUCTURES * (11)
	5.	111	THERMAL SYSTEM DESIGN *
	6.	114	LARGE AREA SPACE STRUCTURES * (8)
	7.	115	CCD-ON BOARD PROCESSOR * (10)
	8.	118	SPHINX C * (7)
	9.	127	STEV/MIPTOL * (8)
	10.	128	ATL *
	11.	129	HELIUM CRYOGENICS/SPACE *
	12.	130	ORBITAL DEMONSTRATING OF LARGE STRUCTURES *
	13.	301	AUTONOMOUS GUIDANCE AND NAVIGATION *

FIGURE 8

IV. WORKING GROUP DIRECTIVE

A. Priorities

Priorities have been established within the following three major research areas:

1. System Independent Technology

The highest priority efforts in the development of the system independent technology are the design and fabrication of the prototype MCSA and the low noise maser. This technology must be available as early as possible since the use of the prototype hardware on existing antennas allows an early preliminary search/survey effort and will address, in a timely fashion, many of the downstream technology requirements.

2. System Studies

By far, the greatest technology development effort at the Workshop should be directed toward a space located antenna, rather than Earth or Lunar options. A great deal of work has already addressed the large-scale Earth based system (Cyclops) and, with the possible exception of new signal handling and materials considerations, the system concept is fairly well established. The space systems, on the other hand, have received only modest attention and, therefore, present the greatest unknowns. Preliminary studies tend to indicate that a lunar based search system would be cost prohibitive. Further studies of lunar possibilities seem warranted, however, before sound decisions can be made.

3. Radio Frequency Interference (RFI)

In recognition of the rapidly advancing national preparations for the 1979 general World Administrative Radio Conference (WARC), it is essential that the SETI position on RFI protection be established as soon as possible. This is extremely important since, with the exception of the lunar system, RFI will directly impact the feasibility and costs of any SETI concept regardless of design and location.

B. Intrinsic Value

The Working Groups are asked to assess the intrinsic value of the SETI developed technology. In particular, it is necessary to determine, as soon as possible, which specific SETI technical advances would apply to other fields of endeavor, with the various specific applications clearly identified.

C. Related and Supporting Proposals

Those proposals and activities which relate to, and would be supportive of, the SETI initiative are listed in Figure 8. As shown, only one new initiative currently submitted, totally supports SETI but specific tasks in others are of value to the SETI program.

D. Workshop Participation

The expected involvement of the various Theme Workshop Working Groups is detailed in Figure 9. This chart is only provided as a guide - it is expected that other technology needs and Working Group involvements will be identified.

SETI THEME TEAM

NASA HQ	NASA CENTERS	EXTERNAL
OAST	J. Billingham (ARC)	P. Morrison (MIT)
S. Sadin (Chairman)(RX)	(Lead Center)	B. Oliver (H.P.)
W. Gilbreath (RX)	J. Wolfe (ARC)	F. Drake (ARECIBO)
C. Schwenk (RR)	C. Seeger (ARC)	
H. Alsberg (RE)	G. Pieper (GSFC)	
	R. Edelson (JPL)	
PROGRAM OFFICES	H. Davis (JSC)	
I. Rasool/R. Young (SS)		
R. Freitag/L. Fero (MT)		
F. Bryant (TS)		

EXPECTED WORKSHOP INVOLVEMENT

	NGC	COMM. AND DATA HANDLING	SENSORS	SOFTWARE	PROPULSION	POWER	MATERIALS	STRUCTURES DYNAMICS
SYSTEM INDEPENDENT TECHNOLOGY								
MCSA		X		X				
LOW NOISE RECEIVERS		X						
PATTERN RECOGNITION ANALYZER		X		X				
STELLAR CENSUS SYSTEM		X	*	X				
EXTRASOLAR PLANETARY DETECTION			*	X				
EARTH BASED SYSTEMS								
ANTENNA DESIGN		X					X	X
SIGNAL HANDLING		X		X				
SPACE BASED SYSTEMS								
ANTENNA DESIGN	X	X	X		X	X	X	X
SHIELD DESIGN	X	X	X		X	X	X	X
FEED SPACECRAFT	X	X	X		X	X		
RELAY SPACECRAFT	X	X	X		X	X		
LUNAR BASED SYSTEMS								
ANTENNA DESIGN		X					X	X
LOGISTICS					X	X		
RFI		X						

*Was not addressed fully by working group

CRITERIA FOR SEARCH

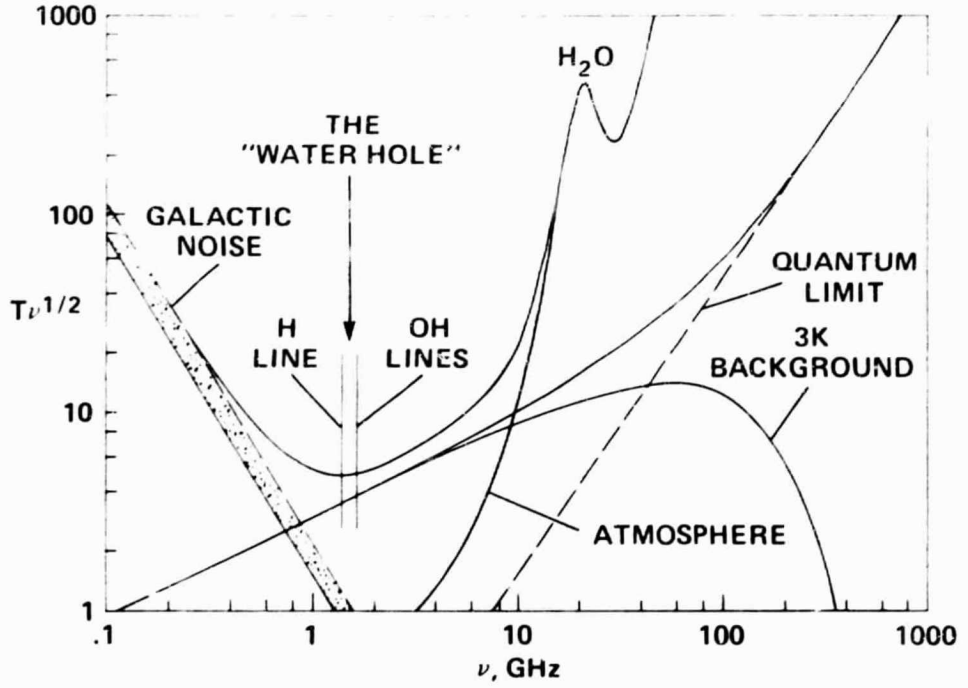
- USE EXISTING FACILITIES WHERE POSSIBLE
- START WITH MODEST SYSTEM AND EXPAND
- HAVE REASONABLE CHANCE OF SUCCESS WITHIN A DECADE OR TWO AFTER ACHIEVING A SIGNIFICANT SEARCH CAPABILITY
- HAVE THE LEAST COST FOR GIVEN PROBABILITY OF SUCCESS
- PRODUCE VALUABLE SCIENTIFIC RESULTS

MICROWAVE WINDOW

- MINIMUM NOISE SPECTRAL DENSITY
- GREATEST RANGE FOR GIVEN TRANSMITTED POWER

LOW END OF MICROWAVE WINDOW

- COLLECTING SURFACE CHEAPEST PER UNIT AREA
- LOWER DOPPLER DRIFT RATES PERMIT NARROWER BANDWIDTHS
- BROADER BEAMS
- HYDROGEN AND HYDROXYL LINES


1000
100
10
1
$T_\nu^{1/2}$
.1
1
10
100
1000
ν, GHz
H_2O
THE
"WATER HOLE"
GALACTIC
NOISE
H
LINE
OH
LINES
QUANTUM
LIMIT
3K
BACKGROUND
ATMOSPHERE

DETECTION PROBABILITY = 0.95

COMMUNICATIVE SPECIES IN GALAXY	LIGHT YEAR RADIUS OF VOLUME SEARCHED	NUMBER OF 100m DISHES REQUIRED
10^5	808	1,613
10^7	174	75
10^9	38	4
(2.2×10^9)	(43)	(ARECIBO)

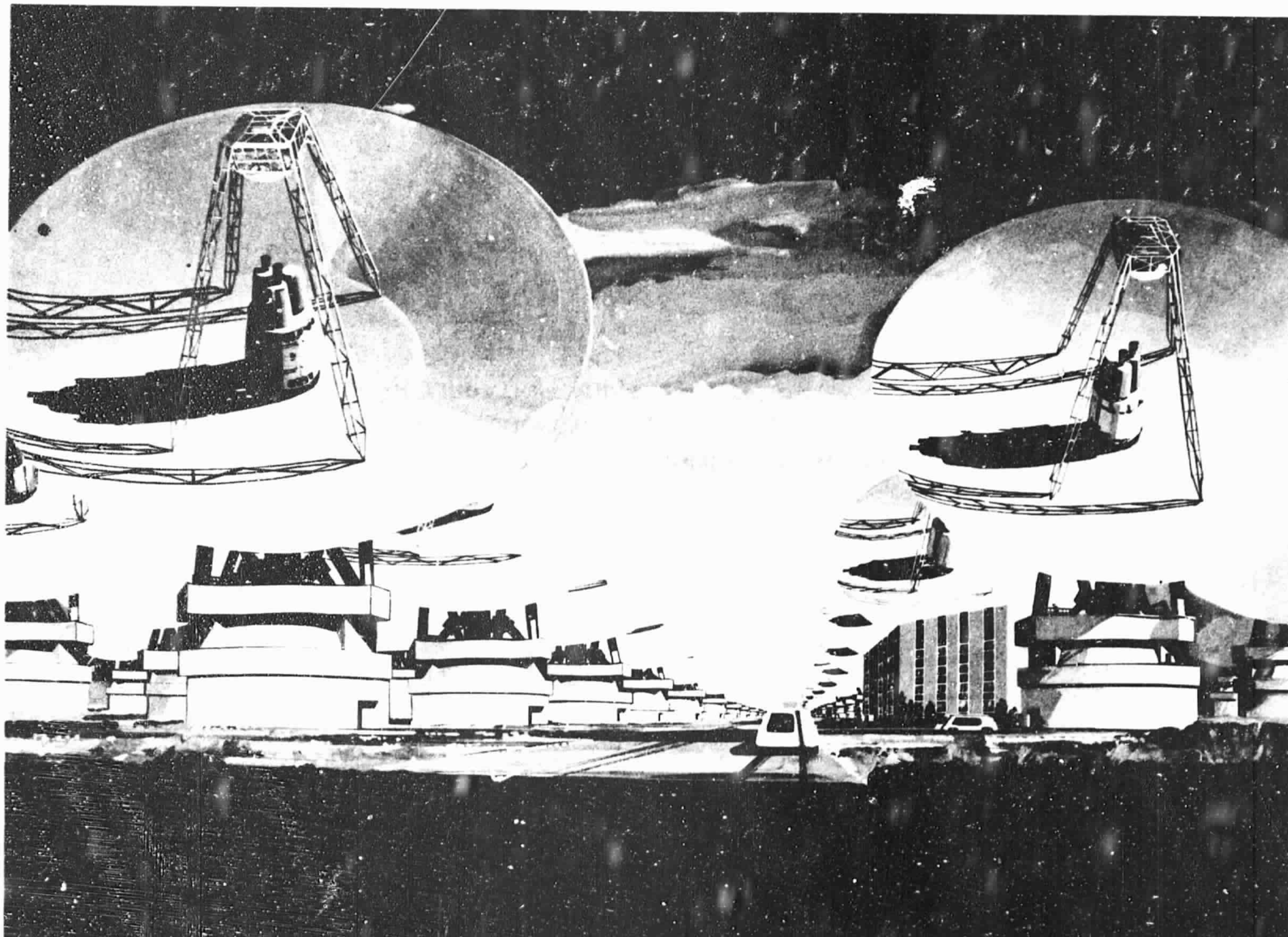
ASSUMING:
$P_t g_t = 10^9 W$ T = 10K B = 0.1 Hz t = 1000 sec

SEARCH STRATEGY

- LISTEN RATHER THAN TRANSMIT
- CONCENTRATE ON LOW END OF MICROWAVE WINDOW
- BEGIN NOW WITH EXISTING ANTENNAS
- OPERATE MODEST PILOT SYSTEM WHILE CONTINUING TO INCREASE SENSITIVITY
- MULTI-CHANNEL SPECTRAL ANALYSIS
- EXTRA SOLAR PLANETARY DETECTION
- DEVELOP SEARCH PRIORITIES
  - SUITABLE STARS OUTWARDS FROM EARTH
  - RANDOM IN GALACTIC PLANE
  - OTHER GALAXIES
- NEED PROTECTION OF OPTIMUM FREQUENCY BAND
- MAKE AVAILABLE PART TIME FOR RADIOASTRONOMY

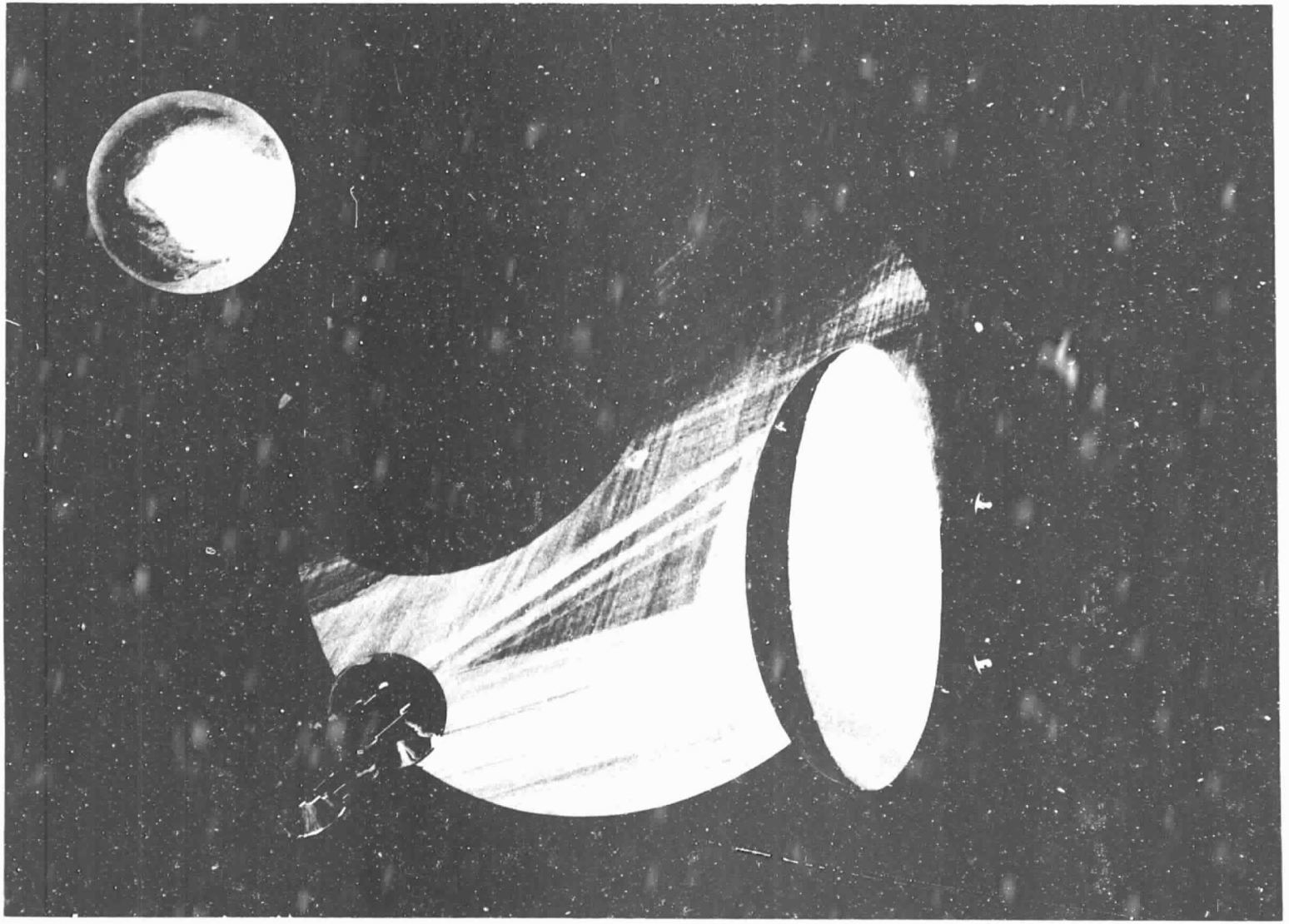
PROJECT CYCLOPS

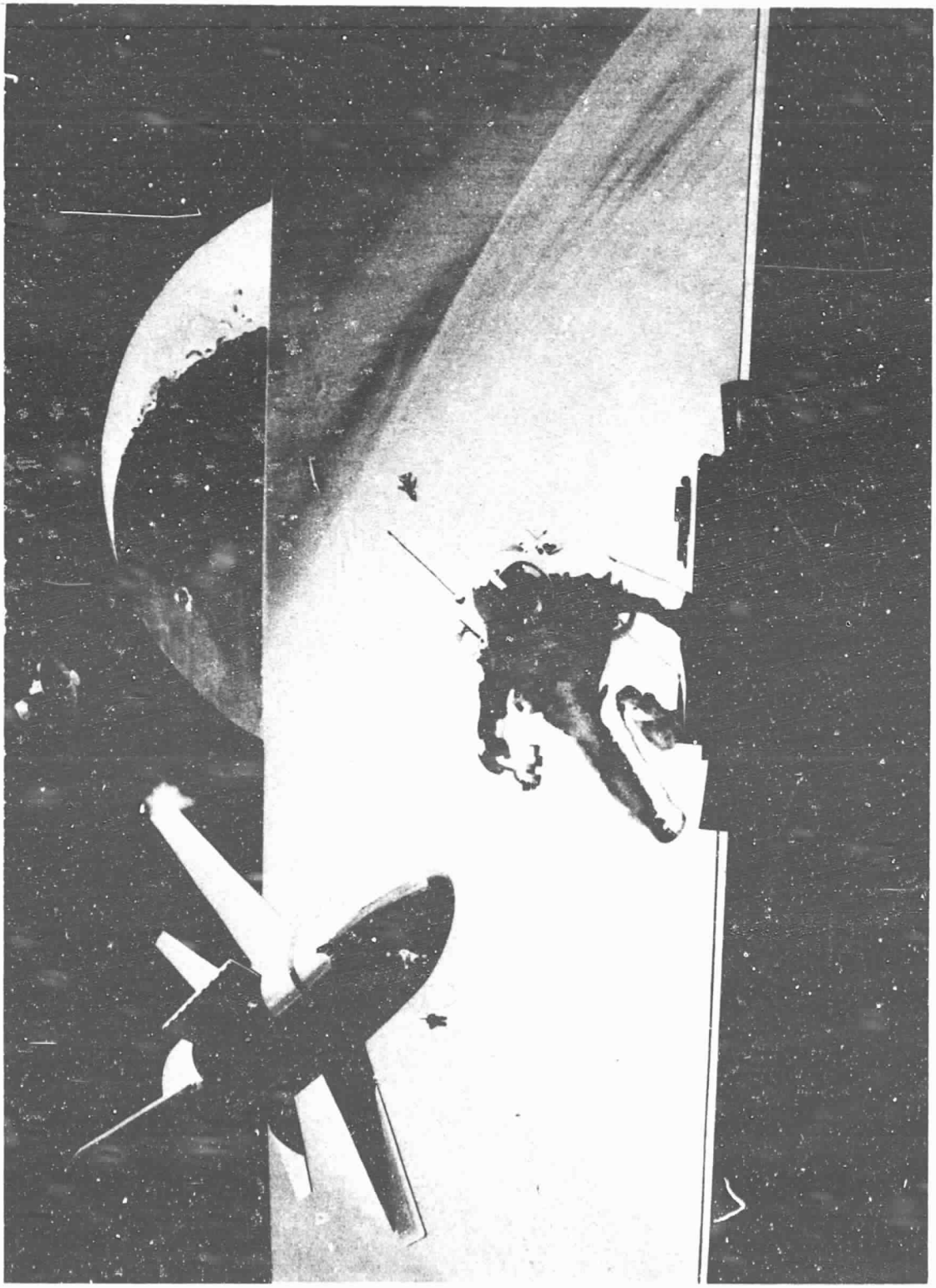
- TERRESTRIAL SYSTEM
- PHASED ARRAY OF 100m ANTENNAS
- START WITH MODEST SYSTEM AND EXPAND
- OPTICAL SIGNAL PROCESSING
- 1971 TECHNOLOGY



SPACE SETI SYSTEM

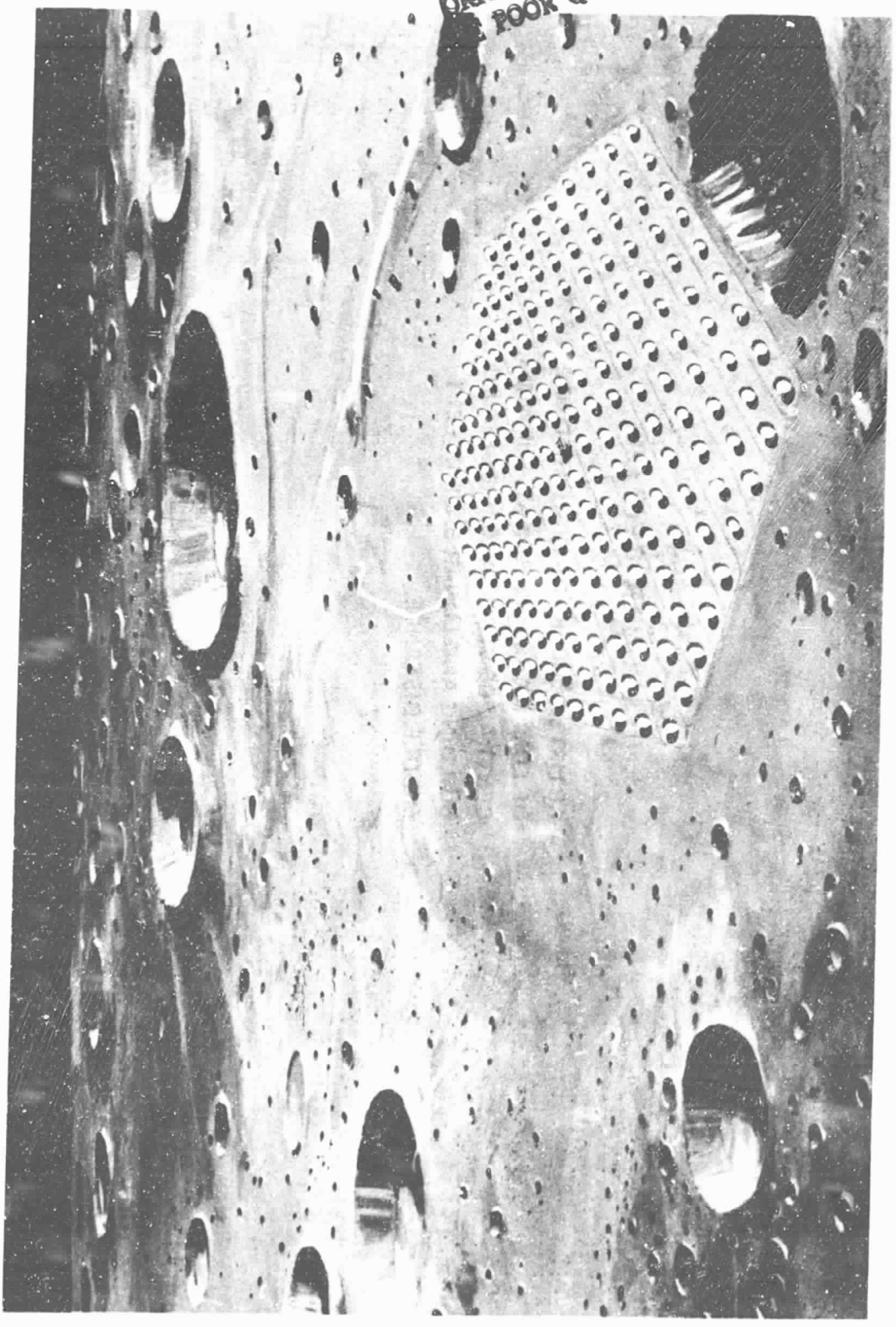
ARTIST's CONCEPT OF SPHERICAL SPACE SETI SYSTEM ANTENNA AND TWO FEEDS, SHOWING RELAY SATELLITE AND RADIO FREQUENCY INTERFERENCE SHIELD: LOCATED AT LUNAR LIBRATION POINT L4.





LUNAR CYCLOPS

ARTIST's CONCEPT OF HIGH ALTITUDE VIEW OF LUNAR CYCLOPS ARRAY, SHOWING CENTRAL CONTROL AND PROCESSING BUILDING AND LUNAR BASE IN LEFT MIDDLE DISTANCE.



COMPARISONS OF INTERSTELLAR SEARCH SYSTEMS

ANTENNA CONCEPT / PARAMETER	CYCLOPS TYPE ARRAY ON EARTH	SPACE SYSTEM SPHERICAL REFLECTOR		CYCLOPS TYPE ARRAY ON THE MOON
		WITH 1 BEAM	WITH 3 BEAMS	
SYSTEM TEMPERATURE, °K	10	7	7	7
ANTENNA EFFICIENCY, percent	80	72	46	84
SKY COVERAGE, percent	82	100	100	94
MAXIMUM SEARCH RANGE, light years	405	379	379	387
AREA, km^2	4	3	4	2
SEARCH TIME, years	8	17	4	8
OVERALL COST, billions of 1975$	6	6	9	14

ASSUMPTIONS:
- 10^6 CIVILIZATIONS IN THE GALAXY WITH 1 GW EFFECTIVE RADIATED POWER
- 95% PROBABILITY OF RECEIVING AN INTELLIGENT SIGNAL
- 10% OF TIME ALLOCATED TO RADIO ASTRONOMY

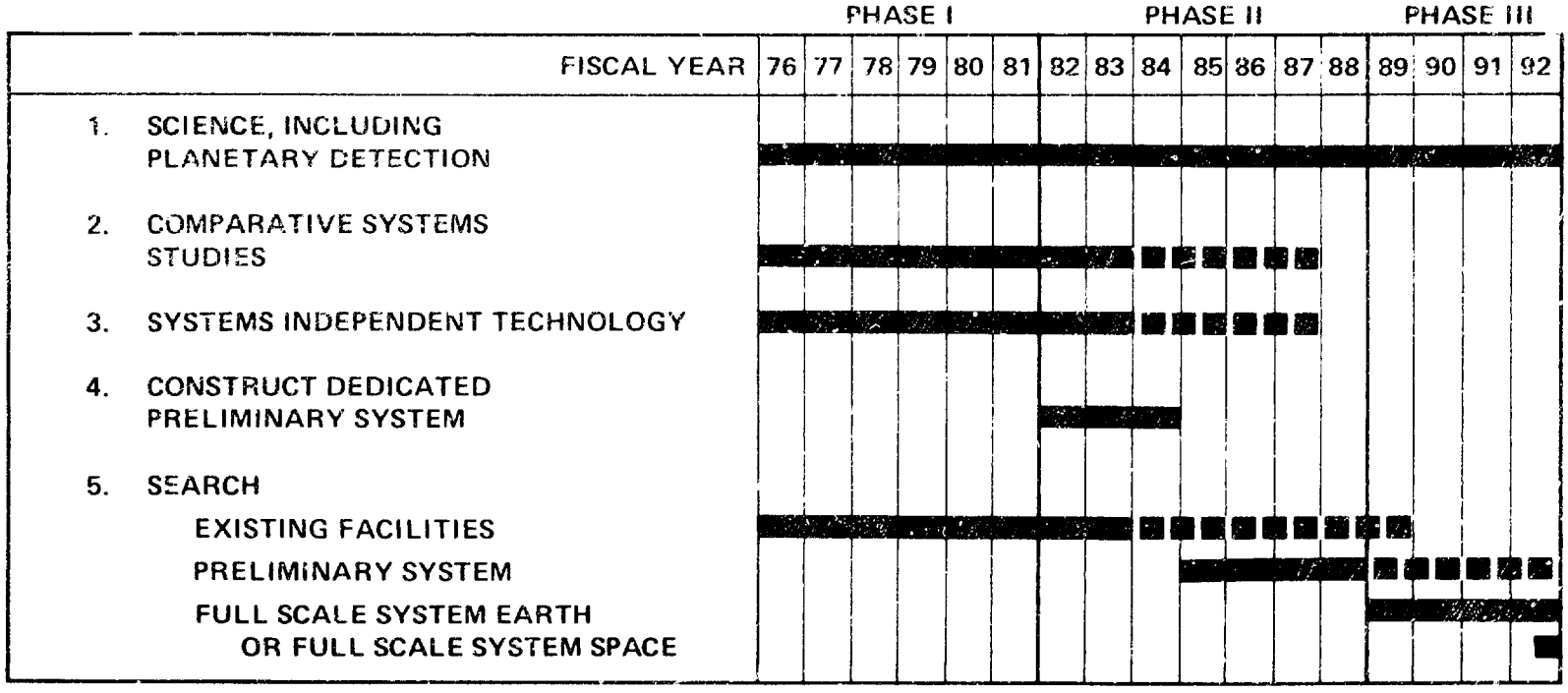
RADIO-FREQUENCY INTERFERENCE (RFI)

- PREFERRED BANDS FOR DETECTING SIGNALS
  - 1.400 TO 1.427 GHz (HYDROGEN LINE)
  - 1.427 TO 1.727 GHz (NOISE MINIMUM)
- CERTAIN TRANSMISSIONS IN THESE BANDS, PARTICULARLY FROM SATELLITES, WILL MASK SIGNALS AND PREVENT THEIR DETECTION
- LEGAL PROTECTION NECESSARY FOR SUCCESSFUL SEARCH
- DEGREE OF PROTECTION REQUIRED DEPENDS ON SEARCH SYSTEM USED

RFI PROTECTION

SYSTEM	DEGREE OF LEGAL PROTECTION REQUIRED (IMPACT ON SPECTRUM USE)	IMPACT ON SETI SYSTEM HARDWARE
EARTH – PRELIMINARY	MODERATE	NONE
EARTH – FULL SCALE	MODERATE	NONE
SPACE – UNSHIELDED	MAJOR	NONE
SPACE – SHIELDED	INSIGNIFICANT	CONSIDERABLE
MOON	INSIGNIFICANT	NONE

AMES SETI PROGRAM PLAN



AMES SETI PROGRAM PLAN
PHASE I COSTS

	MILLIONS OF FY' 76 DOLLARS						TOTAL
	76	77	78	79	80	81	
COMPARATIVE SYSTEM STUDIES							
SRI PRELIMINARY	0.12						0.12
EARTH BASED		0.2	0.3	0.4	0.3	0.2	1.4
SPACE BASED		0.7	1.0	1.4	1.4	0.7	5.2
LUNAR BASED		0.3	0.4	0.5	0.4	0.2	1.8
RFI EVALUATION		0.1	0.2	0.2			0.5
SYSTEM INDEPENDENT TECHNOLOGY DEVELOPMENT							
STELLAR CENSUS	0.02	0.3	0.6	0.9	2.5	2.5	6.8
PILOT MODEL RECEIVER AND DATA PROCESSOR	0.14	0.9	2.5	5.0	10.0	10.0	28.5
DEDICATED SINGLE ANTENNA		0.3	0.4	0.5	0.5	10.0	11.7
SCIENCE, INCLUDING PLANETARY DETECTION	0.03	0.3	0.4	0.6	0.9	1.5	3.7
IMPACT STUDIES		0.1	0.1	0.1	0.2	0.2	0.7
TOTAL	0.31	3.2	5.9	9.6	16.2	25.3	60.5

EXPECTED WORKSHOP INVOLVEMENT

	NGC	COMM. AND DATA HANDLING	SENSORS	SOFTWARE	PROPULSION	POWER	MATERIALS	STRUCTURES DYNAMICS
SYSTEM INDEPENDENT TECHNOLOGY								
MCSA		X		X				
LOW NOISE RECEIVERS		X						
PATTERN RECOGNITION ANALYZER		X		X				
STELLAR CENSUS SYSTEM		X	X	X				
EXTRASOLAR PLANETARY DETECTION			X	X				
EARTH BASED SYSTEMS								
ANTENNA DESIGN		X					X	X
SIGNAL HANDLING		X		X				
SPACE BASED SYSTEMS								
ANTENNA DESIGN	X	X	X		X	X	X	X
SHIELD DESIGN	X	X	X		X	X	X	X
FEED SPACECRAFT	X	X	X		X	X		
RELAY SPACECRAFT	X	X	X		X	X		
LUNAR BASED SYSTEMS								
ANTENNA DESIGN		X					X	X
LOGISTICS	X				X	X		
RFI		X						

SETI - THEME #9

WORKING REPORT

- SPACE TECHNOLOGY WORKSHOP -

LANGLEY RESEARCH CENTER

APRIL 26-30, 1976

A. SUMMARY

1. SETI THEME PROGRAM OUTLINE

The goal of SETI is the detection of radio signals of extraterrestrial intelligent origin. As outlined in the SETI Theme Summary/Working Group Directive (see [illegible] ___), the SETI Theme Program Plan consists of three phases: (1) A preliminary or near-term phase, (2) an intermediate phase, and (3) a long-term phase.

Phase One employs modest improvements on available technology in the areas of radio frequency signal detection and processing and utilizes existing facilities (radio antennas) to initiate a preliminary search (defined as MARK I Search Systems) and to address future technology need and requirements.

Phase Two continues the search while building the first dedicated, small scale search systems (one earth-based and one spaceborne) incorporating all of the knowledge gained in Phase One. These dedicated facilities have been defined as MARK II Search Systems and are envisioned to be a 100-meter diameter ground system and approximately 30-meter diameter space system. Phase Two also resolves the nature of intermediate (MARK III) and large-scale (MARK IV) search systems and their ancillary requirements.

Phase Three is the long-term phase which may never be required if signals of extraterrestrial intelligent origin are detected during Phase One or Phase Two. If necessary, however, Phase Three calls for the detailed design and construction of large search systems of ever increasing sensitivity and will involve either a large, expanding earth based array of 100-meter dishes or spaceborne dishes with equivalent diameters in the 300- to 3000-meter class.

The results of the Space Technology Workshop have not changed the key elements of the SETI Theme Program Plan. The Workshop has, however, provided the technological interchange necessary to identify the specific technology needs and initiatives required to implement a serious SETI effort. The SETI Theme Team feels that the Workshop experience has been invaluable in setting priorities for a realistic program plan and search strategy based on sound step-by-step technology advancements.

2. MAJOR TECHNOLOGY NEED/INITIATIVES - SETI

A. - New Initiatives Plan *

N.I. Priority	Item	Center	
		N.I.	RTOP
1	Antenna Independent Technology	JPL	
	a. Low Noise Front End		
	i. 40 MHz Bandwidth ii. 300 MHz Bandwidth iii. Parametric Upconverters iv. Spaceborne cryostat		
	b. Receiver		
	c. Data processing		
2	Multichannel Spectral Analyzer and Pattern Analyzer	ARC	
	a. 10^6 channel b. 10^9 channel		
3	World Administrative Radio Conference	ARC	JPL
4a	Preliminary Searches Using Mark I Systems - Sky Survey	JPL	
4b	Preliminary Searches Using Mark I Systems - Targeted Search	ARC	
5	Mark II Systems (Phase A Study)	ARC	
	a. Spaceborne		ARC/Contractor
	b. Ground		JPL
6	Data Relay and Communications Systems	JPL	
	a. Space		
	b. Ground		
7	Archival System	MSFC	

* For more complete description see Appendix C

2. MAJOR TECHNOLOGY NEED/INITIATIVES - SET? (Continued)

A. - New Initiatives Plan *

N.I. Priority	Item	Center	
		N.I.	RTOP
8	Radio Frequency Interference	ARC	
	a. Studies and Design (Receiver Protection)		JPL
	b. Hardware Test and Evaluation (Receiver Protection)		JPL
	c. Shield Requirements		ARC
9	Antenna Design (Space) Mark III & IV	ARC	
	a. Reflector		LARC/MSFC
	b. Feed		JPL
	c. Shield		LARC/MSFC
	d. Transportation		JSC
	e. Stabilization and Control		GSFC
10	Antenna Arraying Techniques	JPL	
11	Stellar Census	ARC	
12	Comparative Systems Studies (Trade-off Mark II, IV)	ARC	
13	Planetary Detection	ARC	
14	Science of SET I	ARC	
15	Impact Studies	ARC	

*For more complete description see Appendix C

2. MAJOR TECHNOLOGY NEED/INITIATIVES - SETI (Cont'd)

NI's	B. -ASSOCIATED TECHNOLOGY NEED
1	E2/4,13,14,27,E3/19,E4/1,2,6,9,13,M1/4
2	E2/4,6,13,14,E4/1,2,6,9,13
3	E3/16
4	None
5	E1/3,15,19,E2/1,28,41,M1/2,8/M2/1,10/M2/1,12/M2/3,P2/PC-2,P2/EI-2,ES-1
6	E2/29,38,39
7	E2/14,E4/1,2
8	E2/22
9	E1/7,13,14,18,21,23,E2/1,2,28,E3/67,68,E4/9,M1/2,1 8/M2/2,8/M2/4,9/M2/1,9/M2/2,10/M2/1,12/M2/3,12/M2/6 P1/EVERYTHING,P2/PC-2,ES-7,ES-8,PP-1,S-6,S-2,PP-5,EI-3,EI-2 P2/TE-3,ES-1,PC-4,PC-6
10	E2/40,E3/68,E4/9,12/M2/3,P2/PP-1
11	E3/27
12	NONE
13	E3/32 E4/13
14	NONE
15	NONE
R&T BASE	E2/10,E3/40A,E4/5,10,12,18,19,P2/PC-3,PC-8,PC-9

PARTIAL DESCRIPTIONS

MAJOR REQUIRED NEW INITIATIVES

THEME 9

SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE

Priority 1

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Antenna Independent Technology for the SETI **DATE** 4/30/76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE
To develop low noise front ends, receiver, and data processing technology required for the Search for Extraterrestrial Intelligence

JUSTIFICATION
~~(TBS)~~

TECHNICAL APPROACH/PLAN
Low Noise Front Ends: 40 MHz Bandwidth tunable from 1.4 to 1.7 GHz; 300 MHz Bandwidth tunable from 18 to 25 GHz with parametric upconverters development to obtaining a tunability from 1.4 to 25 GHz; construct a space-borne closed cycle cryostat appropriate to cryogenic maser use. Wideband Receiver for application with front ends. Data processing for ETI signal detection

SCHEDULE

SCHEDULE ITEM (FY)	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK																				
(TBS)																				
MANPOWER (M-Y)																				
INHOUSE																				
CONTRACT																				
FUNDING (10^6 $)																				
INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Jet Propulsion Laboratory

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT
Request development of New Initiative from recommended lead center probable commonality with other efforts.

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Multichannel Spectral Analyzer (MCSA) and Pattern Analyzer **DATE** 4 / 30 / 76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE

Develop the technology of multichannel spectral analysis and pattern analysis for the purpose of searching for signals of extraterrestrial ~~intelligent origin.~~

JUSTIFICATION

(TBS)

TECHNICAL APPROACH/PLAN

Develop a 10^6 channel analyzer for use in preliminary search activities. Following the experience gained in the building of this device proceed to develop a 10^9 channel device. Perform studies and technology development in pattern recognition and analysis appropriate for use with the above device.

SCHEDULE FY

SCHEDULE ITEM	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y)																				
)USE																				
ITRACT																				
FUNDING (10^6 $)																				
INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Ames Research Center

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT

Request development of New Initiative from recommended lead center probable commonality with other efforts.

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Frequency Protection for the SETI by Preparation for the WARC **DATE** 4 / 30 / 76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE

Perform studies and write papers required for obtaining at the 1979 general World Administrative Radio Conference the frequency protection required for the SETI

JUSTIFICATION

(TBS)

TECHNICAL APPROACH/PLAN

(TBS)

SCHEDULE

SCHEDULE ITEM	FY 76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y) INHOUSE																				
CONTRACT																				
FUNDING (10^6 $) INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Ames Research Center with support from the Jet Propulsion Laboratory

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT

Request development of a New Initiative from recommended lead center.

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Observational Program to Search for Radio Signals from Extraterrestrial Intelligence Through the Use of Existing Facilities - Sky Survey **DATE** 4 / 30 / 76 **TT NO.** 9 **OR WORKING GROUP NO.** _____

OBJECTIVE
Perform systems integration required and perform preliminary searches for continually present signals using existing antenna facilities with a broad-band, sky survey strategy.

JUSTIFICATION
(TBS)

TECHNICAL APPROACH/PLAN
Perform searches over the entire sky visible from the chosen location through use of existing antenna facilities and the equipment developed in other New Initiative on SETI. Characterize natural and man-made RF, gather concurrent radio astronomical data and develop technology through experience gained.

SCHEDULE

SCHEDULE ITEM (FY)	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y)																				
)USE																				
/TRACT																				
FUNDING (10^6 $)																				
INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Jet Propulsion Laboratory

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT
Request development of a program plan from recommended lead center direct to appropriate NASA office.

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Preliminary Searches for Extraterrestrial Intelligence using Mark I Systems - Targeted Search **DATE** 4 / 30 / 76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE

Perform preliminary SETI using existing radio astronomical facilities through the use of transportable SETI equipment

JUSTIFICATION

(TBS)

TECHNICAL APPROACH/PLAN

Perform searches over the frequency band from 1.4 to 1.7 GHz to very high frequency resolution by observing near-by stars. Characterize the effects of natural and man-made RFI. Develop technology through experience gained. Utilize equipment developed in other New Initiatives on SETI.

SCHEDULE

SCHEDULE ITEM (FY)	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y) INHOUSE																				
CONTRACT																				
FUNDING (10^6 $) INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Ames Research Center

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT

Request development of New Initiative from recommended lead center direct to appropriate NASA office.

Priority 5

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Mark II Systems (Phase A Study) **DATE** 4 / 30 / 76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE
Perform a Phase A Study of the Mark II systems both Spaceborne and Ground located for the SETI.

JUSTIFICATION
(TBS)

TECHNICAL APPROACH/PLAN
eg. 30m, 300 GHz dedicated spaceborne antenna
eg. 100m, 15 GHz dedicated ground antenna

SCHEDULE

SCHEDULE ITEM	FY 76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y)																				
INHOUSE																				
CONTRACT																				
FUNDING (10^6 $)																				
INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Ames Research Center; Space system study performed by ARC and Contractors; Ground system study performed by JPL

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT
Request development of New Initiative from recommended lead center probable commonality with other efforts

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Data Relay and Communications Systems **DATE** 4 / 30 / 76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE

Study, design and develop broadband phase preserving transponders for data transmission and relay for spaceborne and ground SETI systems

JUSTIFICATION

(TBS)

TECHNICAL APPROACH/PLAN

(TBS)

SCHEDULE

SCHEDULE ITEM	FY 76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y)																				
OUSE																				
TRACT																				
FUNDING (10^6 $)																				
INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Jet Propulsion Laboratory

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT

Request development of New Initiative from recommended lead center probable commonality with other efforts

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Archival System for use with SETI **DATE** 4 / 30 / 76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE
Develop mass memory techniques for archival storage of SETI data, and associated RFI and radio astronomical data

JUSTIFICATION
(TBS)

TECHNICAL APPROACH/PLAN
(TBS)

SCHEDULE

SCHEDULE ITEM	FY 76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y)																				
INHOUSE																				
CONTRACT																				
FUNDING (10^6 $)																				
INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Marshall Space Flight Center

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT
Request development of New Initiative from recommended lead center

probable commonality with other efforts

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Investigation of RFI problems and solutions for a SETI system **DATE** 4 / 30 / 76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE

Study, design, develop and test methods of RFI protection and elimination in support of the SETI

JUSTIFICATION

(TBS)

TECHNICAL APPROACH/PLAN

a. Studies and design for receiver protection

b. Hardware test and evaluation for receiver protection

c. Requirements for shielding of spaceborne SETI systems

SCHEDULE

SCHEDULE ITEM	FY 76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y)																				
INHOUSE																				
CONTRACT																				
FUNDING (10^6 $)																				
INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Ames Research Center: support from JPL for tasks a. and b.

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT

Request development of New Initiative from recommended lead center probable commonality with other efforts

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Spaceborne Antenna Design for Mark III and IV **DATE** 4 / 30 / 76

SETI Systems **TT NO.** 9 **OR WORKING GROUP NO.** _____

OBJECTIVE

Study the requirements and achievement of very large spaceborne antennas for the SETI

JUSTIFICATION

(TBS)

TECHNICAL APPROACH/PLAN

Study Categories	Center for RTOP
a. Reflector	LaRC/MSFC
b. Feed	JPL
c. Shield	LaRC/MSFC
d. Transportation	JSC
e. Stabilization and Control	GSFC

SCHEDULE

SCHEDULE ITEM (FY)	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y) INHOUSE																				
CONTRACT																				
FUNDING (10^6 $) INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Ames Research Center with support from other Centers as shown above

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT

Request development of New Initiative from recommended lead center probable commonality with other efforts.

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Antenna Arraying Techniques for Multi-element Broadband Arrays **DATE** 4 / 30 / 76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE

Study, develop and test techniques for phase-preserving, very-large, multi-element, broadband arrays

JUSTIFICATION

(TBS)

TECHNICAL APPROACH/PLAN

(TBS)

SCHEDULE

SCHEDULE ITEM	FY 76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y)																				
INHOUSE																				
CONTRACT																				
FUNDING (10^6 $)																				
INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Jet Propulsion Laboratory

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT

Request development of New Initiative from recommended lead center

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Technology for the Performance of a Stellar Census to Assisting a Targeted SETI **DATE** 04 / 30 / 76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE

Develop the required technology for performing a Stellar census out to approximately 1000 light years for a targeted SETI

JUSTIFICATION

(TBS)

TECHNICAL APPROACH/PLAN

(TBS)

SCHEDULE

SCHEDULE ITEM (FY)	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y) INHOUSE																				
CONTRACT																				
FUNDING (10^6 $) INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Ames Research Center

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT

Request development of New Initiative from recommended lead center

PRIORITY 12

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Comparative Studies of SETI Systems of the Mark III, IV Class **DATE** 04 / 30 / 76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE

Perform comparative studies on the relative merits of various configurations for large SETI systems

JUSTIFICATION

(TBS)

TECHNICAL APPROACH/PLAN

(TBS)

SCHEDULE

SCHEDULE ITEM	FY 76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y)																				
)USE																				
ITRACT																				
FUNDING (10^6 $)																				
INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Ames Research Center

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT

Request development of New Initiative from recommended lead center

PRIORITY 13

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Technology development for the Detection of Extrasolar Planetary Systems **DATE** 04 / 30 / 76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE

Develop the technology required for the detection of extrasolar planetary systems

JUSTIFICATION

(TBS)

TECHNICAL APPROACH/PLAN

(TBS)

SCHEDULE

SCHEDULE ITEM	FY 76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y) INHOUSE																				
CONTRACT																				
FUNDING (10^6 $) INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Ames Research Center

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT

Request development of New Initiative from recommended lead center

SPACE TECHNOLOGY ADDITIONAL INITIATIVE — FORM IV

TITLE Studies of Scientific Basis of the SETI — DATE 04 / 30 / 76

TT NO. 9 — OR WORKING GROUP NO. ____

OBJECTIVE

Perform scientific studies into the background assumption of the SETI

JUSTIFICATION (TBS)

TECHNICAL APPROACH/PLAN

Theoretical aspects of stellar and planetary formation

SCHEDULE

SCHEDULE ITEM	FY 76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y)																				
OUSE																				
ITRACT																				
FUNDING (10^6 $)																				
INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Ames Research Center

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT

Request development of program plan from recommended lead center direct to appropriate NASA Office

PRIORITY 15

SPACE TECHNOLOGY ADDITIONAL INITIATIVE **FORM IV**

TITLE Studies of the Impact of Detection of Extraterrestrial Intelligence **DATE** 04 / 30 / 76

TT NO. 9 **OR WORKING GROUP NO.** _____

OBJECTIVE

Perform studies to assess the various aspects of the detection of extraterrestrial intelligence on the human race

JUSTIFICATION

(TBS)

TECHNICAL APPROACH/PLAN

(TBS)

SCHEDULE

SCHEDULE ITEM	FY 76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
TASK (TBS)																				
MANPOWER (M-Y)																				
INHOUSE																				
CONTRACT																				
FUNDING (10^6 $)																				
INHOUSE																				
CONTRACT																				

PROPOSED LEAD CENTER Ames Research Center

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT

Request development of program plan from lead center direct to appropriate NASA Office

OVERALL THEME TECHNOLOGY RANKING AND INITIATIVE ACTION

TT-9 SETI

FORM V
PAGE 1
DATE 4/30/76

TECHNOLOGY NEED NO		OVERALL T.T PRIORITY	INITIATIVE ACTION		
			REVISE EXISTING INITIATIVE	DRAFT NEW INITIATIVE*	NONE REQUIRED
SETI Receiver	E2/27				
Low Noise Microwave Receivers	E3/19	1		*	
Pattern Recognition	E4/6	2		*	
Pattern Recognition Analyzer	E2/13	3		*	
Data Set Selection	E2/4	4		*	
High Vol. Data Buff.	E4/2	5		*	
Large Cap. Ground Data Stor.	E2/14	6		*	*See SETI New Initiative Plan
Multidimensional Data Systems	E4/1	7		*	
Long-Life Space Cryogenics	M1/4	8		*	
Sys. Integrity SW	E4/9	9		*	
Algorithms/Num. Analysis	E4/13	10		*	
Multichan. Spec. Analyzer	E2/6				
10^9 Chan. Spec. Analyzer	E3/16	11		*	
SETI Antenna	E2/28				
Large Antenna Struc.	M1/2	12		*	
Space Deployed Lrg. Struc.	8/M2/1				

OVERALL THEME TECHNOLOGY RANKING AND INITIATIVE ACTION

TT -9 SETI

FORM V
PAGE 2
DATE 4/30/76

TECHNOLOGY NEED NO		OVERALL T.T PRIORITY	INITIATIVE ACTION		
			REVISE EXISTING INITIATIVE	DRAFT NEW INITIATIVE *	NONE REQUIRED
Low Cost, High Perf. Ground Antenna	E2/41	13		*	
Precision S/C Pointing	E1/3	14		*	*See SETI New
End-To-End Data Mgt.	E2/1	15		*	Initiative Plan
Attitude, Figure Control	E1/15	16		*	
Envir. Charging	P2/E1-2	17			✓
Computer-Aided Design	E1/19	18		*	
Radiation Resistant Sol. Cells	P2/PC-2	19		✓	
NDE Techniques	12/M2/3	20			✓
Solar Sail Structure	10/M2/1	21			✓
Battery Perf. and Life	P2/E5-1	22			✓
Transponders	E2/29				
SETI Transponder	E2/38	23		*	
SETI Relay	E2/39	24		*	

OVERALL THEME TECHNOLOGY RANKING AND INITIATIVE ACTION

TT -9 SETI

FORM V
PAGE 3
DATE 4 / 30 / 76

TECHNOLOGY NEED NO		OVERALL T.T PRIORITY	INITIATIVE ACTION		
			REVISE EXISTING INITIATIVE	DRAFT NEW INITIATIVE *	NONE REQUIRED
RFI	E2/22	25		*	*See SETI New
Orbital Assembly	8/M2/4	26		✓	Initiative Plan
Extra Acc. Lrg. Ant. Struc.	9/M2/1				
Space Assembled Lrg. Struc.	8/M2/2	27		*	
Large Aperture Ant.	E3/68				
Antenna Feed Design	E3/67	28		*	
Lrg. Area for RFT Protect.	M1/1				
Shield Struc.	9/M2/2	29		*	
Auto. Stationkeeping	E1/7	30		*	
Long-Life Att. Control	E1/21	31		*	
Low Thrust NGC	E1/13	32		*	
Damage Tolerance	12/M2/6	33		✓	
Arraying Technology	2/40	34		*	

OVERALL THEME TECHNOLOGY RANKING AND INITIATIVE ACTION

TT - 9 SETI

FORM V
PAGE 4
DATE 4 / 30 / 76

TECHNOLOGY NEED NO		OVERALL T.T PRIORITY	INITIATIVE ACTION		
			REVISE EXISTING INITIATIVE	DRAFT NEW INITIATIVE	NONE REQUIRED
Solid Prop. Motor	P1/4				
Elec. Prop. For OTV	P1/13				
Ion Thruster for On-Orbit CPS	P1/49	35			✓
MPD Thruster	P1/12				
Air Aug. Earth to Orbit	P1/19				
H_2-O_2 Reusable for OTV	P1/1				
Cryo. Fluids in Space	P1/7				
LH_2-LO_2 Att. Contr. For LV	P1/20	36			✓
Low Cost Prop.	P1/21				
Adv H_2-O_2 Prop. For LV	P1/22				
Mixed Mode OTV	P1/2				
Earth Stor. Propellants	P1/9				
H_2-O_2 Engine	P1/17	37			✓
Prop. For Boosters	P1/30				
Dual Fuel Eng. For Boosters	P1/31				
Monopropellant Station Keep	P1/51				

OVERALL THEME TECHNOLOGY RANKING AND INITIATIVE ACTION

TT -9 SETI

FORM V

DATE 4/30/76

TECHNOLOGY NEED NO		OVERALL T.T PRIORITY	INITIATIVE ACTION		
			REVISE EXISTING INITIATIVE	DRAFT NEW INITIATIVE	NONE REQUIRED
Prop. For OTV	P1/3				
H_2-O_2, Att. Control	P1/8				
H_2-O_2, Prop. For LV	P1/23	38			✓
Att. Contr. For LV	P1/25				
Reusable Prop. Sys.	P1/26				
Self Test and Repair	E1/18				
Auton. Data Handl.	E2/2	39		*	*See SETI New Initiative Plan
Auton. Rendezous and Docking	E1/14	40		*	
Robotics and Teleops.	E1/23	41		*	
H/O Fuel Cell	P2/E5-8	42			✓
Fuel Cell Regeneration	P2/E5-7	43			✓
Power Conditioning	P2/PP-1	44			✓
Light-weight Solar Cells	P2/PC-4				
Light-weight Solar Cells	P2/PC-6	45			✓
Oasis	P2/5-6	46			✓
Power Sys. Mgt.	P2/5-2	47			✓

OVERALL THEME TECHNOLOGY RANKING AND INITIATIVE ACTION

TT -9 SETI

FORM V
PAGE 6
DATE 4/30/76

TECHNOLOGY NEED NO		OVERALL T.T PRIORITY	INITIATIVE ACTION		
			REVISE EXISTING INITIATIVE	DRAFT NEW INITIATIVE	NONE REQUIRED
Remote Power Controller	P2/PP-5	48			✓
Sphinx B/C	P2/E1-3	49		✓	
Nuclear Power Module	P2/TE-3	50		✓	
Resistojet	P1/11				
Solar Heated H_2 Thruster	P1/15				
Laser Prop. For OTV	P1/16	51			✓
Booster Prop.	P1/24				
Composite Eng. Techn.	P1/32				
Solar Sailing Techn.	P1/44				
Metallic H Prop.	P1/6	52			✓
CCD Array	E3/27	53		*	
Radial Vel. Spectrom.	E3/32	54		*	