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FINAL TECHNICAL REPORT

NCC 2-336

**“Supporting Research and Technology Activities for
a Microwave Observing Program to
Search for Extraterrestrial Intelligence”**

SE 96/75

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SUMMARY OF RESEARCH NCC-2-336

OCTOBER 1, 1993–SEPTEMBER 30, 1995

BY

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INTRODUCTION

On October 1, 1993 the US Congress terminated funding for NASA's High Resolution Microwave Survey (HRMS), effectively putting the Agency out of the SETI business. One million dollars in termination funds were provided by the Congress and another one million dollars from FY'93 carryover funding was eventually provided by the Solar System Exploration Division at NASA Headquarters. The funds were allocated to permit an orderly termination of the long-term SETI research effort. Of these funds \$739,127 were provided to the SETI Institute under Cooperative Agreement #NCC 2-336 (supplement #s 43 and 44). Of this amount, \$120,000 were provided from the combination of the Solar System Exploration Division and the Educational Division at NASA HQ for the express purpose of fulfilling NASA's obligation to the third year of a joint NASA and NSF project to develop educational materials on the theme of Life in the Universe.

Funds provided for the termination of HRMS were expended by March 31, 1994 but this Cooperative Agreement (NCC 2-336) has remained in place on the basis of no-cost extensions to permit the final preparation of the educational materials for publication by Teachers Idea Press, Inc. The first three of the six Teachers Guides have now been published, and the rest will appear early in 1996. It is appropriate at this time to close out this Cooperative Agreement and report on the research completed. Annual renewal proposals for earlier years covered all previous work not reported on herein.

A. HRMS SCIENCE GOALS AND OBJECTIVES

Activities completed from November 1, 1993 through September 30, 1995 are reported under the categories identified in the Cooperative Agreement proposal.

Advocacy

R. Arnold, C. Neller and S. Shostak responded to increased demand for public information in the wake of Congressional termination of the HRMS. They generated information summary documents for distribution to the public and distributed the remaining supplies of posters, video tapes and other educational materials related to HRMS.

P. Backus assisted D.K. Cullers and other NASA Ames Civil Servants associated with the HRMS Project Office with documentation required to capture the essentials of the HRMS hardware and software in order to facilitate the transfer of the government developed technologies to the private sector.

TS Science Observations and Analysis

An informal meeting of the HRMS IWG, chaired by J. Tarter, was held during the Washington DC AAS meeting. All PIs presented the results of their research activities to date, and plans for publication. Where there was a question of support for graduate students and post-docs, the HRMS Project Office provided some partial support to facilitate project termination, and J. Tarter continued to provide supervision of this research. For the majority of the IWG PIs, no additional funds were allocated, but no-cost extensions were requested to permit publication of the completed research. Publication charges and venues were the responsibility of the PIs, but J. Tarter, J. Dreher, P. Backus and R. Stauduhar served as technical consultants to these publication efforts. P. Backus oversaw the termination of the software contract with Sterling Federal Systems Inc. that produced an archive of the HRMS observations at Arecibo and a detailed data wrapper explaining the circumstances under which the data were collected. A copy of this data archive was delivered to the HRMS Project Office as part of the termination activities. Numerous scientists supported by this cooperative agreement responded to academic and institutional requests to present colloquia on the Arecibo HRMS observations and the lessons learned from detailed investigation of the RFI environment encountered there. (See list of talks, page 12).

Science and Technical Advice

At the time of termination, the HRMS Targeted Search equipment was at Ames Research Center, having been completely disassembled, and was in the process of being modified and doubled in size. There was no functional system to show for all the years of taxpayer investment in HRMS. D. Harper, P. Backus, J. Tarter, and J. Dreher assisted the HRMS Project Office to make a detailed inventory of the HRMS equipment, including a board-level assessment of the status of every component of the system. This detailed inventory eventually formed the basis for a bailment agreement which effected the transfer of HRMS technologies to the private sector. Prior to December 1, 1994, the scientists listed above and the remaining contracted engineers worked on finalizing the documentation and restoring the system to the minimum configuration of the Arecibo deployment. Efforts to reconstruct this partial configuration were frustrated by a fire that occurred in one of the MCSA card cages in November of 1993, while the system was under power in the laboratory at Ames Research Center. Although none of the custom 9U boards were destroyed in the fire, the backplane for card cage #2 was completely destroyed, along with its power supplies. Extensive analysis of the damaged backplane by Surface Physics, Inc. failed to determine the cause of the fire. Although additional, unpopulated card cage #2 backplane boards were available in inventory, a replacement backplane was not manufactured due to concern over the intrinsic safety of the design.

While attempts were underway to reconstruct the HRMS Arecibo configuration, J. Tarter obtained formal agreement from the Directors of Arecibo Observatory and the ATNF (in Australia) to transfer the previously awarded observing time for HRMS Targeted Search observations to any private scientific organization that could show itself to be capable of continuing the observing program.

J. Tarter and J. Dreher assisted the HRMS Project Office in assessing the impact of cancellation of the NASA-ATNF MOA for SETI Observations at Parkes and Mopra. They verified the detailed costs claimed by ATNF that covered work already performed for the benefit of HRMS.

Drs. Tarter, Backus and Dreher assisted the HRMS Project Office in preparing both a Termination Plan and a final Termination Report, which were submitted to, and subsequently approved by, the Office of Solar System Exploration.

Scientific Meetings and Publications

Although an edited manuscript from the Workshops on Cultural Aspects of SETI was produced, it has proven impossible to find a suitable commercial publisher for this document. This is as much a result of the different expectations of the scholar/authors from different communities as it is the lack of funds for self-publication. In the absence of any new plans by NASA to produce this manuscript as a NASA Conference Proceedings, the SETI Institute will retain title of this manuscript and will continue to seek an opportunity for publication, perhaps in conjunction with an international meeting on the topic (financed by private sources).

Proceedings from the World Space Congress special symposium "SETI, A New Endeavor for Humankind" has been completed by P. Backus and C. Seeger and will be published as a special edition of Acta Astronautica.

When the text of this Cooperative Agreement was written, funds to support a series of Workshops on Advanced Signal Detection Technologies were anticipated from NASA Headquarters. These funds never materialized, and these tasks were not accomplished.

B. TSE GOALS AND OBJECTIVES

1) Targeted Search System Segment

(Note that parenthetical statements below refer to privately funded progress outside of the scope and financing of this Cooperative Agreement; i.e., work pursuant to the transfer of the technology to the private sector via bailment agreement.)

- (a) The MCSA Subsystem: P. Backus and J. Dreher provided oversight of contractors from Silicon Engines and John C. Reykjalín Inc. in attempts to reconstruct the 10 MHz dual-polarization configuration from the Arecibo deployment. The fire in card cage #2 frustrated these efforts, as already mentioned. (However, the documentation and design details were sufficiently well captured, that once private funding became available to continue supporting these efforts, a redesign of the MCSA [MCSA-lite] that eliminated the need for card cage #2 was successfully completed. A dual-polarization 20 MHz

system was eventually deployed [also with private funding] to Australia for six months of observing, thereby validating the transfer of the HRMS technologies to the private sector.)

- (b) The Signal Detection Subsystem: R. Stauduhar supervised contractors from John C. Reykjalin Inc. and Maxima Software in successful reconstruction of 10 MHz CW Detector, as deployed at Arecibo. He also supervised E. Pardo and A. Patrick in reconstruction of the 10 MHz Arecibo configuration for the Pulse Detector. Documentation for both systems was prepared for the HRMS Project Office. (Again, as with the MCSA, after the investment of private funding, it was possible to replicate both of these Signal Detectors to provide 20 MHz of dual-polarization coverage.)
- (c) The System Control Subsystem: P. Backus supervised the preparation of documentation for the SCS. A fully documented set of software, as deployed at Arecibo, was presented the HRMS Project Office.
- (d) The Radio Frequency Subsystem: J. Tarter and J. Dreher worked with the HRMS Project Office, the JPL HRMS Office and the Legal Counsel at Ames Research Center to implement a bailment agreement with the NSF, for the disposition of portions of the RFS. Two separate, incomplete, wideband receiver systems under construction at JPL for the HRMS Targeted Search were shipped to Cornell University. Under the terms of the bailment agreement, Cornell University (as the agent for the NSF) agreed to complete both these receivers and install them on the newly upgraded Arecibo Observatory, for use by the radio astronomy community and by any future private sector continuation of Targeted Search SETI observations.
- (e) System Engineering and Integration: As System Scientist, J. Dreher integrated and tested the various components of the TSS as they were reassembled or reconstructed at Ames Research Center.
- (f) TSS Verification System: R. Stauduhar, E. Pardo and A. Patrick documented plans for the Follow Up Detection Devices. Preliminary plans were presented to the HRMS Project Office.

2) Data Archive Segment

- (a) DAS Data Facility: With the termination of HRMS, no attempt was made to implement the Data Facility for support of external investigators. D. Harper completed an inventory of all data processing and LAN equipment that was presented to the HRMS Project Office and eventually put under the stewardship of the Space Sciences Division.

3) Information system and Utilization and Operations System

This segment of the TSE was never implemented. Equipment purchased in anticipation of its implementation was included in the data processing and LAN inventory listed above.

C. SETI EDUCATION GOALS AND OBJECTIVES

Teachers Ideas Press was selected as the commercial publisher for the Life In the Universe Teacher's Guides, videos, and posters. S. Shostak, C. Stoneburner and J. Tarter completed editing and galley corrections for the six Teacher's Guides. J. Lomborg produced the final slides and classroom posters for the project and assisted S. Shostak with the transfer of all slides to video format. S. Shostak modified the "Science Detectives" video to include more ethnic diversity. He also produced, field tested, and modified the "Project Haystack" video for the eighth grade. R. Arnold assisted in the above activities. Carl Sagan provided a forward to the Teacher's Guides and Teachers Ideas Press is predicting strong sales of these products. Copies of the Guides are being provided to all NASA Teacher Resource Centers. Attached as Appendix A is the final report to the NSF (co-funding agency for this effort) that includes a summary of the formal evaluation results from national field testing of the Life in the Universe curriculum materials.

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Publications for 1993, 94, and 95

(Note: Many 1994 and 1995 publications were actually produced under the auspices of Project Phoenix, which is the privately funded continuation of the former NASA HRMS targeted search. Such publications are listed here because they properly acknowledged HMRS funding prior to March, 1994.)

P.R. Backus, "The NASA SETI Microwave Observing Project Targeted Search", paper presented at the Third Decennial US/USSR Conference on SETI in Santa Cruz, CA, August, 1991. *ASP Conference Series*, Vol. 47, S. Shostak (ed.), Astronomical Society of the Pacific, San Francisco, pp. 322-333 (1993).

J. Billingham, "SETI Post-Detection Protocols: What Do You Do After Detecting A Signal?" Paper presented at the Third Decennial US/USSR Conference on SETI in Santa Cruz, CA, August, 1991. *ASP Conference Series*, Vol. 47, S. Shostak (ed.), Astronomical Society of the Pacific, San Francisco, pp. 416-424 (1993).

Billingham, J. and Tarter, J.C. "SETI (Search for ExtraTerrestrial Intelligence)." In *Space Biology and Medicine*, Vol. 1: *Space and its Exploration*. Ivanov, M., Kotelnikov, V., and Rummel, J., editors. American Institute of Aeronautics and Astronautics, Washington, DC, pp. 247-273 (1993).

D. Brocker and P.R. Backus, "The NASA Search for Evidence of Technological Civilizations in Space - Project HRMS." *The Search for Extraterrestrial Intelligence (SETI) in the Optical Spectrum*, Proceedings Vol. 1867, S. Kingsley (ed.), SPIE—The International Society for Optical Engineering, Bellingham, pp. 9-19 (1993).

D. K. Cullers, "An Application of One Measure of Search Merit to Optical SETI." *The Search for Extraterrestrial Intelligence (SETI) in the Optical Spectrum*, Proceedings Vol. 1867, S. Kingsley (ed.), SPIE—The International Society for Optical Engineering, Bellingham, pp. 156-160 (1993).

D. K. Cullers, "A New Method for Determining the Merits of SETI Search Strategies", paper presented at the Third Decennial US/USSR Conference on SETI in Santa Cruz, CA, August, 1991. *ASP Conference Series*, Vol. 47, S. Shostak (ed.), Astronomical Society of the Pacific, San Francisco, pp. 67-72 (1993).

F. Drake, "Conference Summary", paper presented at the Bioastronomy Symposium: Progress in the Search for Extraterrestrial Life, Santa Cruz, CA, August 1993. *ASP Conference Series*, Vol. 74, S. Shostak (ed.), Astronomical Society of the Pacific, San Francisco, pp. 582-585 (1995).

- D. Milne, C. Stoneburner, and S. Shostak, "Is Anybody Out There? The Search for Intelligent Extraterrestrial Life - the NASA HRMS Project." *Tennessee Teacher*, pp. 16-19; 29 (Jan./Feb. 1993).
- B.M. Oliver, "Search for Life Must Not Die", Commentary published in the *San Jose Mercury News*, (October 19, 1993).
- B.M. Oliver, "Fundamental Factors Affecting the Optimum Frequency Range for SETI", *The Search for Extraterrestrial Intelligence (SETI) in the Optical Spectrum*, Proceedings Vol. 1867, S. Kingsley (ed.), SPIE—The International Society for Optical Engineering, Bellingham, pp. 66-74 (1993).
- B.M. Oliver, "Symmetry in SETI", paper presented at the Third Decennial US/USSR Conference on SETI in Santa Cruz, CA, August, 1991. *ASP Conference Series*, Vol. 47, S. Shostak (ed.), Astronomical Society of the Pacific, San Francisco, pp. 66-72 (1993).
- B.M. Oliver, "Heron's Remarkable Triangle Formula", *The Mathematics Teacher*, Vol. 26, No. 2, pp. 161-163 (1993).
- B.M. Oliver, "Galactic Colonization and Other Flights of Fancy", *IEEE Potentials*, pp. 51-54 (August/September 1994).
- E. Pardo, D.K. Cullers, "Design of the Fast Fourier Transform Board in the SETI Follow Up Detection Device", paper presented at the 45th Congress of the IAF, Jerusalem, Israel (Oct. 1994). To be published in book of proceedings.
- T. Pierson, "SETI Institute: Summary of Projects in Support of SETI Research", paper presented at the Bioastronomy Symposium: Progress in the Search for Extraterrestrial Life, Santa Cruz, CA, August 1993. *ASP Conference Series*, Vol. 74, S. Shostak (ed.), Astronomical Society of the Pacific, San Francisco, pp. 432-444 (1995).
- J.C. Reykjalin, "A CW Detector for the NASA Targeted Search", paper presented at the Third Decennial US/USSR Conference on SETI in Santa Cruz, CA, August, 1991. *ASP Conference Series*, Vol. 47, S. Shostak (ed.), Astronomical Society of the Pacific, San Francisco, pp. 55-59 (1993).
- S. Shostak, "Ten-Year SETI Begins: NASA Listens for Cosmic Intelligence", *Spaceflight*, Vol. 35, pp. 116-118 (April 1993).
- S. Shostak, "Tuning In On The Extraterrestrials", *ISSOL Newsletter*, Vol. 20, No. 1 (Spring 1993).
- S. Shostak, "The Ultimate Motion Imaging System", *SMPTE Journal*, Vol. 102, No. 3, p. 202 (March 1993).
- S. Shostak, "An Astronomer's Astronomer", *Pacific Discovery Magazine*, p. 40 (Spring 1993).

- S. Shostak (ed.), *Third Decennial US-USSR Conference on SETI, ASP Conference Series*, Vol. 47, Astronomical Society of the Pacific, San Francisco (1993).
- S. Shostak, "The Search Goes On", *Mercury*, p. 22 (Sept./Oct. 1993).
- S. Shostak, "Robots Gear Up to Invade Mars!" *The World and I*, p. 196 (Feb. 1994).
- S. Shostak, "Junk in Space", *Pacific Discovery Magazine* (Spring 1994).
- S. Shostak, "Black Holes", to appear in *New World Encyclopaedia (Groliers)* (1994).
- S. Shostak, "Fossil Hunting on Mars", *The World and I*, p. 187 (Sept. 1994).
- S. Shostak, "De Jacht op Buitenaardse Intelligentie Gaat Door", *Zenit*, p. 296 (July/August 1994).
- S. Shostak, "Cracks in Heaven's Vault", *Pacific Discovery Magazine*, p. 35 (Fall 1994).
- S. Shostak, "From Marbles to Mario: Taking the High-Tech Trail", *Odyssey Magazine*, p. 27 (Nov. 1994).
- S. Shostak, "People of the Sun", *Astronomy Magazine*, p. 16 (April 1995).
- S. Shostak, "Do Not Disturb for Ten Thousand Years!" *Odyssey Magazine*, p. 8 (April 1995).
- S. Shostak (ed.), *Progress in the Search for Extraterrestrial Life*, Bioastronomy Symposium, Santa Cruz, August 1993, *ASP Conference Series*, Vol. 74, Astronomical Society of the Pacific, San Francisco (1995).
- S. Shostak, "SETI at Wider Bandwidths?" Paper presented at the Bioastronomy Symposium: Progress in the Search for Extraterrestrial Life, Santa Cruz, CA, August 1993. *ASP Conference Series*, Vol. 74, S. Shostak (ed.) San Francisco, pp. 446-454 (1995).
- S. Shostak, "Phoenix Rises: NASA SETI Project is Reborn", *Planetary Report*, Vol. XV, No. 3., p. 4 (May/June 1995).
- S. Shostak, "Op Zoek Naar Buitenaards Leven", *Kijk op de Kosmos*, Rene Genee and Theo Jurriens (eds.), De Fenix Pers, Meppel, The Netherlands, p. 93 (1995).
- S. Shostak, "Project Seeks True Voices Amid Interstellar Noise", *Insight*, p. 26 (June 1995).
- S. Shostak, "Project Phoenix Starts in the South", *SETIQuest*, Vol 1, No. 3, p. 7 (1995).
- S. Shostak, "Tuning In on Extraterrestrials", *The World and I*, p. 230 (June 1995).
- S. Shostak, "Let the Search Begin!" *Southern Sky*, p. 12 (May/June 1995).
- S. Shostak, "In Search of Extraterrestrials", *Topcat*, Vol. 28, p. 6 (July 1995).

- C. Stoneburner, "Life in the Universe: Bringing SETI into Elementary and Middle School Classrooms", paper presented at the 45th Congress of the IAF, Jerusalem, Israel (Oct. 1994). To be published in book of proceedings.
- J.C. Tarter, "The Current State of Searches for Extra-Solar System Planets", paper presented at the Third Decennial US/USSR Conference on SETI in Santa Cruz, CA, August, 1991. *ASP Conference Series*, Vol. 47, S. Shostak (ed.) San Francisco, pp. 166-173 (1993).
- J.C. Tarter, "SETI Concerns — Jill Tarter replies." Letter to the Editor, *Sky & Telescope*, p. 7 (March 1993).
- J.C. Tarter, "The NASA High Resolution Microwave Survey." *News Letter of the Astronomical Society of New York*, Vol. IV, No. 4. A.G. Davis Philip (ed.), L. Davis Press, Inc., pp. 5-12 (August 1993).
- J.C. Tarter, "Is It True That We Can't Afford Curiosity? The Search for Extraterrestrial Intelligence: A Case Study." To be published in *FORUM* (Winter 1995).
- J.C. Tarter and M.J. Klein, "HRMS: Where We've Been, and Where We're Going", paper presented at the Bioastronomy Symposium: Progress in the Search for Extraterrestrial Life, Santa Cruz, CA, August 1993. *ASP Conference Series*, Vol. 74, S. Shostak (ed.) San Francisco, pp. 456-469 (1995).
- J.C. Tarter, D. Milne, K. O'Sullivan, C. Stoneburner, et al., *The Evolution of a Planetary System, The SETI Academy Planet Project*. Teacher's guide for grades 5-6. Three more guides to be published in Fall 1995. Teacher Ideas Press, Englewood, Colorado (1995).

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Lectures and Colloquia

1993-1995

(Note: Many 1994 and 1995 lectures and colloquia were actually produced under the auspices of Project Phoenix, which is the privately funded continuation of the former NASA HRMS targeted search. Such lectures and colloquia are listed here because they properly acknowledged HMRS funding prior to March, 1994.)

Speaker	Date
Bob Arnold:	
Lecture to Precision Measurement Society	Jan. 12, 1993
Lecture to MENSA	Feb. 19, 1993
Lecture, West Valley Rotary Club of San Jose	Mar. 8, 1993
Lecture, De Anza College Science & Technology Speakers Series	Mar. 12, 1993
Invited talk at St. Nicholas School in Los Altos	Mar. 14, 1993
Lecture to scientific-technical interns from the Foothill-De Anza Community Colleges	May 25, 1993
Lecture at NASA Educational Workshops for Math and Science Teachers (NEWMAST)	Jul. 20, 1993
Vera Buescher:	
Talk at Mt. View Business & Professional Women's mtg.	Mar. 2, 1993
Seth Shostak:	
"The Search for Planets", course given for California Academy of Sciences, Golden Gate Park, San Francisco	Jan. 11, 18, 1993

“NASA Looks for Extraterrestrials”, for Instrument Society of America, Moffett Field, CA	Jan. 21, 1993
“SETI and Science”, Keynote Speech, First Annual Contra Costa County Math/Science/Technology Conference, Walnut Creek, CA	Jan. 30, 1993
Radio interview on NASA’s SETI project, station WHO (ABC affiliate), Des Moines, Iowa (Jan Michaels show).	Feb. 1, 1993
“NASA Searches the Galaxy for Intelligent Life”, Mid-Space Development Conference, Ames, Iowa.	Feb. 6, 1993
“Transportation: The Big Picture”, Leadership Mountain View, Alza Corporation, Mountain View, CA	Feb. 19, 1993
“Is Anyone Out There? NASA Searches for Extraterrestrials”, Golden Gate Institute, American Institute of Chemists, Newark, CA	Feb. 22, 1993
“The ‘I’ in SETI: How Intelligent Are the Aliens?” for Contact X, held at Biltmore Hotel, Santa Clara, CA	Feb. 27, 1993
“NASA Searches for Extraterrestrials”, San Jose Astronomical Society, Milpitas, CA	Mar. 6, 1993
“NASA Hunts for Extraterrestrials”, Sonoma County Astronomical Society, Santa Rosa, CA	Apr. 14, 1993
“NASA Searches for ET”, Mt. Tamalpais Interpretive Association, Mt. Tamalpais, CA	Apr. 24, 1993
“Where Are the Extraterrestrials Hiding?”, Tech Museum of Innovation, San Jose, CA	Apr. 29, 1993
“The Search for Extraterrestrials”, course for California Academy of Sciences, San Francisco, CA	May 5, 12, 19, 1993
“The Search for Extraterrestrials”, Rotary Club luncheon, Dublin, CA	May 11, 1993
“NASA Hunts for Aliens”, National Space Society, Mountain View, CA	May 13, 1993
“The Search for Extraterrestrials”, Kiwanis Club of Silicon Valley, Cupertino, CA	May 14, 1993

“The Search for Extraterrestrial Intelligence”, for Prof. Funaro’s anthropology class, Cabrillo College, Aptos, CA	May 18, 1993
“How Intelligent Are the Extraterrestrials, Anyway?”, Griffith Observatory public lecture, Los Angeles, CA	May 24, 1993
“NASA Hunts for Extraterrestrials”, International Space Devel. Conference, National Space Society, Huntsville, AL	May 28, 1993
“Radio Astronomy”, course given for California Academy of Sciences, Golden Gate Park, San Francisco, CA	Jun. 9, 16, 1993
“Astronomy in the Land of Oort”, Peninsula Astronomical Society, Los Altos, CA	Jun. 11, 1993
“The NASA Search for Extraterrestrial Life”, Rotary Club, Pebble Beach, CA	Jun. 15, 1993
“Update on the Search for Aliens”, Netherlands Consulate, San Francisco, CA	Jun. 17, 1993
“The NASA Search for Extraterrestrials”, Astronomy and Space Science Summer Institute, Berkeley, CA	Jul. 6, 1993
“NASA Searches for Extraterrestrials”, American Association of Physics Teachers, Boise, Idaho	Aug. 9, 1993
“Searching for Intelligent Life in the Universe”, Stockton Astronomical Society, Stockton, CA	Aug. 11, 1993
“NASA Searches for Extraterrestrials”, IISME, Moffett Field, CA	Aug. 13, 1993
“Some Bandwidth Considerations for SETI”, IAU Symposium, Commission #51, U.C., Santa Cruz, CA	Aug. 17, 1993
“Astrolab”, interactive astronomy course given for California Academy of Sciences, Golden Gate Park, San Francisco, CA	Sept. 15, 22, 1993
“NASA’s Continuing Search for Aliens”, Commonwealth Club, San Francisco, CA	Sept. 22, 1993
“ET Phone Us!: The NASA Search Continues”, Reuben H. Fleet Space Theater, San Diego, CA	Oct. 13, 1993

“Remnants of the Big Bang”, course given for California Academy of Sciences, Golden Gate Park, San Francisco, CA	Oct. 17, 25, 1993
“Is Anybody Out There?”, Bay Area Math Project, Berkeley, CA	Oct. 30, 1993
“Searching for Extraterrestrials”, Sunnyvale Presbyterian Church, Sunnyvale, CA	Nov. 6, 1993
“Space Cities”, local TV show appearance, Mountain View, CA	Dec. 20, 1993
Kent Cullers:	
Lecture at Ames Research Center for Stellar Program	Aug. 12, 1994
Seth Shostak:	
Seven Wonders of the Cosmos”, course given for California Academy of Sciences, Golden Gate Park, San Francisco, CA	Jan. 19, 26, 1994
“How to Find the Extraterrestrials”, for Mid Continent Space Development Conference, Ames, Iowa	Feb. 5, 1994
“SETI”, for 8th grade class, Graham Middle School, Mountain View, CA	Feb. 17, 1994
“Looking for Extraterrestrials”, for San Francisco Science Fair, Randall Museum, San Francisco, CA	Feb. 26 1994
“The Search for Extraterrestrials”, Science-Technology Conference, Explorer Scouts, San Jose, CA	Mar. 5, 1994
“Beam me up! A problem for Scottie and SETI”, Contact XI, Santa Clara, CA	18 Mar, 1994
“Federation Science”, course given for California Academy of Sciences, Golden Gate Park, San Francisco, CA	Mar. 7, 27; Apr. 7, 12, 24, 1994
“Air and Space: What Have We Learned?”, San Mateo County Office of Education, for Selby Lane Magnet School	Apr. 29, 1994
“Tribute to John Billingham”, retirement party, Sunnyvale Hilton Hotel	May 13, 1994
“The Search for Extraterrestrials”, Contra Costa Jewish Center Walnut Creek, CA	Jun. 7, 1994

“The Search for Extraterrestrials”, International Society for Hybrid Microelectronics, Sunnyvale, CA	Jun. 9, 1994
“Improving the Search for Extraterrestrials” (title uncertain), Universe '94, Astronomical Society of the Pacific, Flagstaff, AZ	Jun. 27, 1994
“Where are the Extraterrestrials Hiding?”, lunchtime colloquium, Dwingeloo Radio Observatory, Dwingeloo, The Netherlands	Jul. 8, 1994
“The Search for Extraterrestrial Life”, American Institute for Aeronautics and Astronautics, Family Space Fair, Santa Clara, CA	Jul. 15, 1994
“The Search for Extraterrestrial Life”, ASP Summer Course for Teachers, Berkeley, CA	Jul. 28, 1994
“Searching for Extraterrestrials”, Mtn. View Kiwanis Club, Mountain View, CA	Aug. 10, 1994
Interview for NOS Radio, “Met het Oog op Morgen” about IAU, SETI	Aug. 15, 1994
“Looking for Extraterrestrials”, popular lecture, The Museon, The Hague (Netherlands), in Dutch.	Aug. 17, 1994
SETI Update”, Peninsula Astronomical Society, Foothill College	Sept. 9, 1994
“When Worlds Collide”, Rotary Club, Dublin, CA	Sept. 13, 1994
“Film and Video”, course for Calif. Academy of Sciences, Golden Gate Park, San Francisco, CA	Sept. 13, 20, 1994
“SETI”, for ASTRO teachers’ program, San Mateo County Office of Education	Sept. 24, 1994
“SETI”, course for Elderhostel, San Francisco State, San Francisco	Sept. 26-30, 1994
“When Worlds Collide”, De Anza Kiwanis Club, Cupertino, CA	Oct. 21, 1994
“Death of the Universe”, course for Calif. Academy of Sciences	Oct. 25; Nov. 8, 1994
“When Worlds Collide”, for tour group, Macchu Picchu, Peru	Oct. 30, 1994
“Search for Extraterrestrials”, for tour group, Cuzco, Peru	Nov. 1, 1994

Jill Tarter:

Lecture to classroom (via telephone) in Kennebunk, Maine	Mar. 8, 1994
Colloquium at Interval Research Co.	Mar. 25, 1994
Interview with Sun West Media (Rachel McGuire)	Apr. 7, 1994
Filming of Haystack Education Video	Apr. 8, 1994
Taping for National Geographic TV Show (Nina Parmee)	Apr. 11, 1994
Physics Colloquium at Rice University, Texas	Apr. 14, 1994
Tele-interview with Lisa Breit	Apr. 14, 1994
Lecture at Symposium on Chemical Evolution at ARC	Apr. 25, 1994
Lecture at Occidental College (Laurie Fathe)	May 16, 1994
Trip to Japan - gave many lectures and interviews	May 23-28, 1994
Lecture at AAS meeting in Minneapolis	Jun. 2, 1994
Lecture at Mt. Tamalpais	Jun. 11, 1994
Lecture at Texas Instruments Colloquium	Jun. 16, 1994
Lecture at MIT	Jul. 6, 1994
Interview with NHK TV from Japan	Jul. 12, 1994
Lecture at The Tech Museum of Innovation in San Jose	Aug. 5, 1994
Presented paper at the IAU in The Hague, Netherlands	Aug. 17-24, 1994
Interview with "Good Morning America"	Sept. 26, 1994
Lecture at NSTA Conference in Portland, OR	Oct. 14, 1994
Lecture at Castilleja School, Palo Alto	Dec. 14, 1994
Interview with Mora Daily of KTEH, San Jose	Dec. 20, 1994
Peter Backus:	
Interview with Philip Dalkin (P. Backus, et al.)	Aug. 3, 1995

Presented paper at IAF Congress in Oslo, Norway	Oct. 6, 1995
Kent Cullers:	
Interview with David Elisco of WQED	Jun. 7, 1995
Lecture at San Jose State University	Jul. 11, 1995
SETI Lecture at Ames Research Center	Jul. 19, 1995
Interview with Ian Strano	Jul. 28, 1995
Lecture for Stellar Program at Ames Research Center	Aug. 11, 1995
Lecture at Eagle Club	Sept. 11, 1995
Lecture at IEEE meeting in Anchorage, AK	Sept. 16, 1995
Lecture at Braille Institute in Los Angeles	Sept. 19, 1995
Interview with Keay Davidson of SF Examiner	Oct. 12, 1995
Lecture at Goddard Space Flight Center	Oct. 24, 1995
John Dreher:	
Presented paper at IAF Congress in Oslo, Norway	Oct. 6, 1995
Seth Shostak:	
“Space Junk”, course for Calif. Academy of Sciences, San Francisco	Feb. 15, 22,
“SETP”, for Mid-Continent Space Development Conference, Ames, Iowa	Feb. 17, 1995
“Searching for Extraterrestrials”, East Bay Surgical Society, Oakland, CA	Feb. 28, 1995
“Destination: Mars!” course for Calif. Academy of Sciences, San Francisco	Mar. 2, 16,
“New Thoughts on SETP”, for Contact XII, Milpitas, CA	Mar. 11, 1995
“Searching for Extraterrestrials”, Space and Technology 1995	Mar. 11, 1995

(Explorer scouts), Almaden Research Center, IBM, South San Jose, CA

“Looking for Aliens”, La Entrada School, Menlo Park, California, 5th grade class Mar. 24, 1995

“New Strategies for Finding the Extraterrestrials”, Awahnee Lodge, Yosemite, CA, after-dinner talk for Pacific Planetarium Assoc. Apr. 1, 1995

“Looking for Extraterrestrials”, Santa Clara County Science Teachers Association, Moffett Club, Mountain View, CA Apr. 26, 1995

“The Scientific Search for Extraterrestrials”, Packard Foundation, Los Altos, California Apr. 28, 1995

“The Search for Extraterrestrials”, Student Teachers, Ames Research Center, organized by Juanita Ryan May 6, 1995

“The Search for Extraterrestrials”, NASA interns, Ames Research Center May 16, 1995

“The Hunt for Extraterrestrial Intelligence”, National Space Society of Australia, Sydney Observatory, Sydney, Australia Jun. 13, 1995

“Mars and the Search for Extraterrestrials”, Powerhouse Museum, Sydney, Australia Jun. 17, 1995

“The Search for ET”, course for Calif. Academy of Sciences, Golden Gate Park, San Francisco Aug. 7, 14, 21, 1995

“Searching for Extraterrestrials”, Los Altos Kiwanis, CA Sept. 10, 1995

Various talks for “Science Stars” event, Winston-Salem, North Carolina (with Jill Tarter) Sept. 25-27, 1995

“Strategies for SETI”, colloquium, NRAO, Charlottesville, VA Sept. 28, 1995

“The Next 10 Years”, for thirtieth anniversary of the 140-ft telescope, NRAO, Green Bank, W. Virginia Sept. 30, 1995

“Search for Extraterrestrials”, Elderhostel course, Tiburon, CA Oct. 30, 31; Nov. 1, 1995

“Search for Extraterrestrials”, Elderhostel course, Pacifica, CA Nov. 13, 14, 15, 1995

“The Hunt for Cosmic Company”, banquet talk for MODIS conference, NASA Greenbelt, Maryland	Nov. 16, 1995
“Project Phoenix”, for Society of Amateur Radio Astronomers, Mtn. View, CA	Nov. 18, 1995
“The Seven Wonders of the Cosmos”, course for Elderhostel, Tiburon, CA	Dec. 4,5,6, 1995
“Images: Electronic and Otherwise”, course for Calif. Academy of Sciences, San Francisco	Dec. 7, 14, 1995

Jill Tarter:

Was observing at Parkes radiotelescope in Australia for 6 months, during which time she gave dozens of interviews and lectures	Jan–June, 1995
Lecture at IRAS Conference on Star Island	July 29–Aug. 5, 1995
Interview with Ted Matsuo (Teleport USA)	Aug. 17, 1995
SETI talk at Lockheed, Palo Alto, CA	Sept. 14, 1995
Lectures and interviews for Science Stars in North Carolina	Sept. 25 - 27, 1995
Lecture at Barney Oliver Symposium, HP Labs	Oct. 24, 1995

APPENDIX A
FINAL PROJECT REPORT
TO
NATIONAL SCIENCE FOUNDATION
LIFE IN THE UNIVERSE – AN EXCITING VEHICLE FOR
TEACHING INTEGRATED SCIENCE

NATIONAL SCIENCE FOUNDATION

4201 Wilson Blvd.

Arlington, VA 22230

P/PI Name and Address

Dr. Jill Tarter
 2035 Landings Dr.
 Mt. View, CA 94043

NATIONAL SCIENCE FOUNDATION FINAL PROJECT REPORT

PART I - PROJECT IDENTIFICATION INFORMATION

1. Program Official/Org.	M. Patricia Morse
2. Program Name	Division of Materials Development, Research...
3. Award Dates (MM/YY)	From: Aug. 1, 1991 To: Dec. 31, 1994
4. Institution and Address	SETI Institute 2035 Landings Dr. Mt. View, CA 94043
5. Award Number	MDR-9150120
6. Project Title	LIFE IN THE UNIVERSE - AN EXCITING VEHICLE FOR TEACHING INTEGRATED SCIENCE

If Grant Conditions (Article 17, GC-1, and Article 8, FOP-11) require submission of a Final Project Report (NSF Form 98A) to the NSF program officer no later than 90 days after the expiration of the award. Final Project Reports for expired awards must be received before new awards can be made (NSF Grants Policy Manual Section 677).

Now, or on a separate page attached to this form, provide a summary of the completed projects and technical information. Be sure to include your name and award number on each separate page. See below for more instructions.

PART II - SUMMARY OF COMPLETED PROJECT (for public use)

A summary (about 200 words) must be self-contained and intelligible to a scientifically or technically literate reader. Without restating the project title, it should begin with a topic sentence stating the project's major thesis. The summary should include, if pertinent to the project being described, the following items:

- The primary objectives and scope of the project
- The techniques or approaches used only to the degree necessary for comprehension
- The findings and implications stated as concisely and informatively as possible

See attached.

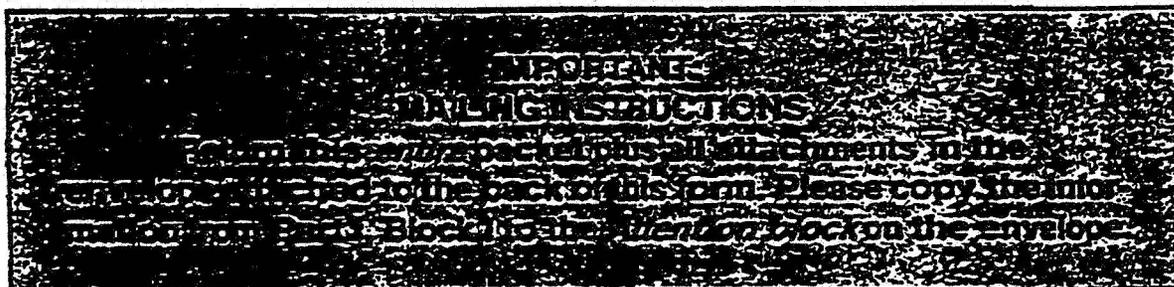
PART III - TECHNICAL INFORMATION (for program management use)

List references to publications resulting from this award and briefly describe primary data, samples, physical collections, inventions, software, etc. created or gathered in the course of the research and, if appropriate, how they are being made available to the research community. Provide the NSF Invention Disclosure number for any invention.

See attached.

I certify to the best of my knowledge (1) the statements herein (excluding scientific hypotheses and scientific opinion) are true and complete, and the text and graphics in this report as well as any accompanying publications or other documents, unless otherwise indicated, are the original work of the signatories or of individuals working under their supervision. I understand that willfully making a false statement or concealing a material fact in this report or any other communication submitted to NSF is a criminal offense (U.S. Code, Title 18, Section 1001).

Principal Investigator/Project Director Signature	Date



Part II - Summary of Completed Project

Curriculum materials based on the search for extraterrestrial intelligence (SETI) were developed for grades 3 through 9 science classes. The project was supported in part by NASA. Six teacher's guides, plus ancillary visuals, addressing topics in astronomy, biology, chemistry, geosciences, and physics as well as mathematics, social sciences, and language arts, were designed by a team of teachers, scientists, curriculum developers, and artists. First drafts were piloted by 10 design team teachers; revised drafts were field-tested by 109 teachers in 30 states. Extensive feedback from these teachers and their students and reviews by scientists were used to revise materials prior to submission to the publisher. The field-test teachers overall ranking of all guides (data from individual lesson feedback forms) was 4.31 on a one low to five high scale; 85% found the content appropriate to course and grade level and 75% indicated they had no reservations about using the materials again or recommending them to colleagues. The ratio of liked to disliked student responses (from 1305 student letters) was 70:30. Most recommendations from the teachers, students, and science reviewers were incorporated in the final versions for the guides, published by Libraries Unlimited/Teacher Ideas Press, 1995.

Part III - Technical information

Curriculum materials developed by the project:

SETI Institute. (1995). *The Science Detectives*. Englewood, CO: Libraries Unlimited/Teacher Ideas Press.

Students follow the travels of Amelia Spacehart, an astronaut and radio astronomer, who is searching the solar system for the source of a mysterious radio signal and sending back clues to her location via a video tape.. While students track her progress, they are led to explore features of the solar system, investigate states of matter, experiment with lenses and magnification, and perform large scale measurements. (Grades 3-4.)

The following Planet Project volumes (grades 5-6), can be used either as a series or individually. Students are invited to participate in a "SETI Academy" education and research program in which they act as scientists investigating Earth's history for clues to the possible existence of life beyond our solar system.

SETI Institute. (1995). *The SETI Academy Planet Project - Volume one: The Evolution of a Planetary System*. Englewood, CO: Libraries Unlimited/Teacher Ideas Press.

Students learn about the evolution of stars and planets. They apply what they learn to create a fictitious planetary system.

SETI Institute. (1995). *The SETI Academy Planet Project - Volume two: How Might Life Evolve on Other Worlds* Englewood, CO: Libraries Unlimited/Teacher Ideas Press.

Students study the evolution of plant and animal life. They apply what they learn to create fictitious animals. inhabiting a fictitious planet.

SETI Institute. (1995). *The SETI Academy Planet Project - Volume three: The Rise of Intelligence and Culture*. Englewood, CO: Libraries Unlimited/Teacher Ideas Press.

Student investigate the development of intelligence, culture, technology, and communication. They apply what they learn to create a technological civilization for a fictitious creature on a fictitious planet.

SETI Institute. (1995). *Life: Here? There? Elsewhere? The Search for Life on Venus and Mars*. Englewood, CO: Libraries Unlimited/Teacher Ideas Press.

Students investigate the characteristics of living things via an introduction to the interdisciplinary sciences of comparative planetology and exobiology. Students simulate conditions on Venus and Mars, and investigate various schemes for detecting life in the atmospheres and soils of Earth. They use what they learn from these activities to propose a spacecraft design for life detection on Mars or Venus. (Grades 7-8.)

SETI Institute. (1995). *Project Haystack: The Search for Life in the Galaxy*. Englewood, CO: Libraries Unlimited/Teacher Ideas Press.

Students consider whether extraterrestrial civilizations might exist, and if so where? How would they communicate with us and what would they say? How should we respond? Students are confronted with the scale and structure of the Milky Way Galaxy as they explore the cosmic "haystack" in their search for extraterrestrials. They build their own radio receiver, and use simple astronomical tools to solve some of the challenges of sending and receiving interstellar messages. (Grades 8-9.)

Papers

Coulter, G. R., Milne, D. H., O'Sullivan, K. A., & Stoneburner, C. A. (October, 1993). *The NASA HRMS Educational Outreach Program: Searching for Extraterrestrial Intelligence while Developing Extra Intelligent Terrestrials*. Paper presented at the 44th Congress of the International Astronautical Federation, Graz, Austria.

Milne, D., & O'Sullivan, K. A. (1994). Life in the universe: Foundation for Exciting Multidisciplinary Science Activities for Middle & Elementary School Classes. *Advances in Space Research*, 14(8), 451-458.

Milne, D., & Shostak, G. S., Stoneburner, C. A. (1993). Is Anybody Out There? *Tennessee Teacher*, 60(3), 16-30.

O'Sullivan, K. A. (April, 1995). *Evaluations in the Life In The Universe Curriculum Project*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco, CA.

Stoneburner, C. A. (October, 1994). *Life in the Universe: Bringing SETI into Elementary and Middle School Classrooms*. Paper presented at the 45th International Astronautical Congress, Jerusalem, Israel.

Stoneburner, C. A. (1994). SETI Seductive Hook for Science Curriculum. *SETI News*, 3(3), 4.

Summary of presentations and workshops:

American Association for the Advancement of Science Annual Meeting, San Francisco, CA 1994.

Astronomical Society of the Pacific, Annual Meeting: San Diego, CA 1993.

California Science Teachers Association Focus Institute: Los Angeles, CA 1993.

California Science Teachers Association State Conference: San Jose, CA 1992; Orange County, 1993; Palm Springs, 1994.

CMC-N, CSTA, SAME, SCATS, Superior Math Science, Regional Conference: Sacramento, CA 1994.

Comfortable Approach to Teaching Science (CATS) Program, NASA/JPL Teacher's Workshop: Pasadena, CA 1991.

Committee on Space Research (COSPAR) International Congress: Washington, DC 1992.

Contra Costa County Association of Math and Science Educators, Regional Conference: Concord, CA 1993.

Far West Labs, Regional Conference: Orange County, CA 1994.

Integrated Curriculum Conference, 1993

International Astronautical Federation/International Astronomical Union (IAF/IAU), International Congress: Montreal, Quebec 1991; Jerusalem, Israel 1994.

NASA's Educational Workshop for Elementary School Teachers (NEWEST): Mountain View, CA 1991 & 1992.

National Science Teachers Association National Conference: Boston, MA
1992; Kansas City, MO 1993; Anaheim, CA 1994.

National Science Teachers Association Regional Conference: Fort Worth,
TX, 1992; Charlotte, NC, 1992.

Phi Delta Kappa, Integrated Curriculum Conference, Regional Conference:
San Ramon, CA 1993.

San Diego Science Educators Association 8th Annual Conference:
San Diego, CA, 1992.

San Diego Science Educators Regional Conference: San Diego, CA 1992.

Space Agency Forum on the International Space Year (SAFISY),
International Congress: Orlando, FL 1991.

Space Agency Forum on the International Space Year (SAFISY), Regional
Conference: San Diego, CA 1992.

Superior Math/Science Conference, 1994

PART IV - FINAL PROJECT REPORT - SUMMARY DATA ON PROJECT PERSONNEL

(To be submitted to cognizant Program Officer upon completion of project)

The data requested below are important for the development of a statistical profile on the personnel supported by Federal grants. The information on this part is solicited in response to Public Law 99-383 and 42 USC 1885C. All information provided will be treated as confidential and will be safeguarded in accordance with the provisions of the Privacy Act of 1974. You should submit a single copy of this part with each final project report. However, submission of the requested information is not mandatory and is not a precondition of future award(s). Check the "Decline to Provide Information" box below if you do not wish to provide the information.

Please enter the numbers of individuals supported under this grant.
Do not enter information for individuals working less than 40 hours in any calendar year.

	Senior Staff		Post-Doctorals		Graduate Students		Under-Graduates		Other Participants ¹	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
A. Total, U.S. Citizens	1	2							25	18
B. Total, Permanent Residents									1	
U.S. Citizens or Permanent Residents ² :										
American Indian or Alaskan Native										1
Asian										
Black, Not of Hispanic Origin									1	2
Hispanic										
Pacific Islander										
White, Not of Hispanic Origin									24	15
C. Total, Other Non-U.S. Citizens										
Specify Country										
1.										
2.										
3.										
D. Total, All participants (A + B + C)	1	2							26	18
Disabled³										1

Decline to Provide Information: Check box if you do not wish to provide this information (you are still required to return this page along with Parts I-III).

¹ Category includes, for example, college and precollege teachers, conference and workshop participants.

² Use the category that best describes the ethnic/racial status for all U.S. Citizens and Non-citizens with Permanent Residency. (If more than one category applies, use the one category that most closely reflects the person's recognition in the community.)

³ A person having a physical or mental impairment that substantially limits one or more major life activities; who has a record of such impairment; or who is regarded as having such impairment. (Disabled individuals also should be counted under the appropriate ethnic/racial group unless they are classified as "Other Non-U.S. Citizens.")

AMERICAN INDIAN OR ALASKAN NATIVE: A person having origins in any of the original peoples of North America and who maintains cultural identification through tribal affiliation or community recognition.

ASIAN: A person having origins in any of the original peoples of East Asia, Southeast Asia or the Indian subcontinent. This area includes, for example, China, India, Indonesia, Japan, Korea and Vietnam.

BLACK, NOT OF HISPANIC ORIGIN: A person having origins in any of the black racial groups of Africa.

HISPANIC: A person of Mexican, Puerto Rican, Cuban, Central or South American or other Spanish culture or origin, regardless of race.

PACIFIC ISLANDER: A person having origins in any of the original peoples of Hawaii; the U.S. Pacific territories of Guam, American Samoa, and the Northern Marianas; the U.S. Trust Territory of Palau; the islands of Micronesia and Melanesia; or the Philippines.

WHITE, NOT OF HISPANIC ORIGIN: A person having origins in any of the original peoples of Europe, North Africa, or the Middle East.

DATA SHEET

Division of Materials Development, Research, and Informal Science Education

Institution: SETI INSTITUTE

PI/PO Name(s): JILL TARTER/DAVID MILNE/KATHLEEN O'SULLIVAN Phone 415-961-6633

Title of Project: LIFE IN THE UNIVERSE - AN EXCITING VEHICLE FOR TEACHING
INTEGRATED SCIENCE

NSF Request \$ 659,723

Non-NSF Contributions: \$ Pre-award 78949; during award period 379,749

Sources (in percent; percentages should sum to 100%)

Grantee Institution:	<u>100</u> %	Corporate:	<u>0</u> %
Other Foundations:	<u>0</u> %	Project-generated:	<u>0</u> %
Other (explain):	<u>0</u> %		

PROJECT EMPHASES

Content Areas		Level	
Astronomy	<u>10</u> %	Elementary	<u>0</u> %
Biology	<u>10</u> %	Middle	<u>0</u> %
Chemistry	<u>0</u> %	Secondary	<u>0</u> %
Computer Science	<u>0</u> %	Adult	<u>0</u> %
Earth Sciences	<u>10</u> %	TOTAL	100%
Engineering	<u>0</u> %		
Environmental Sciences			
Geography	<u>0</u> %		
Life Sciences	<u>10</u> %	Special Emphases	
Mathematics	<u>10</u> %	(Check those that apply)	
Physics	<u>10</u> %	Minorities	<u>0</u> %
Physical Sciences	<u>10</u> %	Women	<u>0</u> %
Social Sciences	<u>10</u> %	Disabled	<u>0</u> %
Technology	<u>10</u> %	Gifted	<u>0</u> %
Other (explain)	<u>10</u> %	Disadvantaged	<u>0</u> %
TOTAL	100%	Other (explain)	<u>0</u> %

For proposals from states that have elected to participate in the Intergovernmental Review of Federal Programs, indicate State Proposal Number: _____

*Our proposal is to design science activities founded on the subject of SETI (Search for Extraterrestrial Intelligence), which integrates the disciplines checked and links them naturally with certain other non-scientific subjects, including art, communication skills, and history.