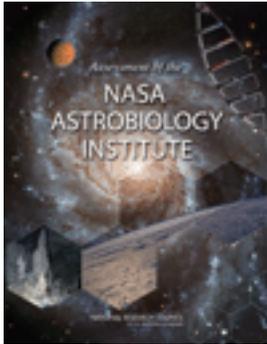


Free Executive Summary

Assessment of the NASA Astrobiology Institute



Committee on the Review of the NASA Astrobiology Institute, National Research Council

ISBN: 978-0-309-11497-4, 80 pages, 8 1/2 x 11, paperback (2008)

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Astrobiology is a scientific discipline devoted to the study of life in the universe - its origin, evolution, distribution, and future. In 1997, NASA established an Astrobiology program (the NASA Astrobiology Institute - NAI) as a result of a series of new results from solar system exploration and astronomical research in the mid-1990s together with advances in the biological sciences. To help evaluate the NAI, NASA asked the NRC to review progress made by the Institute in developing the field of astrobiology. This book presents an evaluation of NAI's success in meeting its goals for fostering interdisciplinary research, training future astrobiology researchers, providing scientific and technical leadership, exploring new research approaches with information technology, and supporting outreach to K-12 education programs.

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Executive Summary

Astrobiology is a scientific discipline devoted to the study of life in the universe—its origins, evolution, distribution, and future. It brings together the physical and biological sciences to address some of the most fundamental questions of the natural world: How do living systems emerge? How do habitable worlds form and how do they evolve? Does life exist on worlds other than Earth? As an endeavor of tremendous breadth and depth, astrobiology requires interdisciplinary investigation in order to be fully appreciated and examined.

As part of a concerted effort to undertake such a challenge, the NASA Astrobiology Institute (NAI) was established in 1998 as an innovative way to develop the field of astrobiology and provide a scientific framework for flight missions. Now that the NAI has been in existence for almost a decade, the time is ripe to assess its achievements.

At the request of NASA's Associate Administrator for the Science Mission Directorate (SMD), the Committee on the Review of the NASA Astrobiology Institute undertook the assignment to determine the progress made by the NAI in developing the field of astrobiology (Appendix A). It must be emphasized that the purpose of this study was not to undertake a review of the scientific accomplishments of NASA's Astrobiology program, in general, or of the NAI, in particular. Rather, the objective of the study is to evaluate the success of the NAI in achieving its stated goals of:

1. Conducting, supporting, and catalyzing collaborative interdisciplinary research;
2. Training the next generation of astrobiology researchers;
3. Providing scientific and technical leadership on astrobiology investigations for current and future space missions;
4. Exploring new approaches, using modern information technology, to conduct interdisciplinary and collaborative research among widely distributed investigators; and
5. Supporting outreach by providing scientific content for use in K-12 education programs, teaching undergraduate classes, and communicating directly with the public.

The committee's assessment of the NAI's progress in these five areas is presented in Chapters 2 to 6, respectively. In evaluating the success of the NAI in achieving these five goals, the committee was requested to address the following considerations:

- a. Has the NAI developed, as envisioned, as an evolving experiment in cutting-edge, distributed, collaborative science and education in astrobiology?
- b. Does the NAI provide a unique and useful complement to other Astrobiology program support mechanisms (e.g., individual grants to principal investigators), and if improvements need to be made in this area, what are they?
- c. Are the research, training, and public educational activities of the NAI appropriately balanced in terms of investments and outcomes, services to NAI members and external partners, and activities that engage and support the wider astrobiology community and the needs of young professionals?
- d. What other activities or roles not currently undertaken by the NAI might be appropriate in the future?

The committee's responses to these four criteria can be found in subsections in Chapters 2 to 6. Specific recommendations and suggestions as to how the recommendations might be implemented can be found in the final subsection of each of the same chapters.

Information on the origins of NASA's Astrobiology program and the NAI; a summary of comments on the role, status, and scientific importance of astrobiology from previous NRC reports; and some information on the budgetary history and the impact of recent cuts to the Astrobiology budget can be found in Chapter 1.

FINDINGS AND RECOMMENDATIONS

Overall, the committee is unanimous in finding that the NAI has fulfilled its original mandate. The NAI has played a key role in supporting the development of astrobiology and has positively affected NASA's current and future missions. The committee recommends that the NAI should continue to be supported. Specific findings and recommendations are organized according to the five goals and four criteria listed above

NAI Goal 1—Interdisciplinary Research

Although the committee was not charged to undertake a review of the NAI's scientific contributions, it is difficult to evaluate the NAI's success in conducting, supporting, and catalyzing collaborative interdisciplinary research without some brief mention of the NAI's scientific achievements. Consideration of the NAI's major scientific contributions reveals that some are highly interdisciplinary but that some are not. In the committee's view, interdisciplinarity must be viewed as the orientation and emergent quality of an overall enterprise and not as a requirement or expectation levied on every piece of work produced by that enterprise. Thus, with respect to the goal of conducting, supporting, and catalyzing collaborative interdisciplinary research, the committee finds that the NAI has:

- Successfully promoted interdisciplinary science;
- Stimulated many scientific achievements;
- Successfully integrated life sciences into NASA programs;
- Often effectively leveraged ongoing and new research;
- Contributed to the establishment of new astrobiology programs worldwide; and
- Supported programs that are widely distributed throughout the United States.

The committee makes the following recommendations:

- The NAI should institute better measures of performance and progress to improve the accountability of its nodes in promoting astrobiology as a field of interdisciplinary and collaborative study;
- The NAI should improve the tracking and critical assessment of its publications; and
- The NAI should encourage and cultivate interactions with non-NAI astrobiology teams and organizations throughout the world.

Suggestions as to how these recommendations might be implemented can be found in Chapter 2.

NAI Goal 2—Training the Next Generation of Astrobiologists

The NAI's commendable effort to train the next generation of astrobiologists faces many challenges. The continuation of funding beyond the 5-year lifetime of NAI teams is not guaranteed. Young researchers seeking to establish themselves outside the protective environment of NAI teams face particular challenges when trying to accomplish interdisciplinary research within the highly discipline-oriented organization of research universities. The pool of resources for training new researchers is limited. Nevertheless, with respect to the goal of training the next generation of astrobiology researchers, the committee finds that the NAI has:

- Trained graduates who are now employed in academic and other positions;
 - Promoted the establishment of new programs and faculty positions in astrobiology at several universities;
- and
- Not been sufficiently proactive in countering the negative effects on training and education programs caused by recent cuts to NASA's Astrobiology budget.

The committee recommends that the NAI should work toward developing more consistent educational and training opportunities. In addition, the NAI should ensure more stable support of graduate students and postdoctoral researchers in astrobiology. Suggestions as to how this recommendation might be implemented can be found in Chapter 3.

NAI Goal 3—Leadership for Current and Future Space Missions

Although the NAI has not played a significant role in the selection or execution of NASA missions, the field of astrobiology provides the intellectual and scientific foundation for much if not all of NASA's current robotic solar system exploration missions and many of its astrophysical activities relating to the search for and characterization of extrasolar planets. The NAI's influence has been indirect and has come through the actions of individual scientists affiliated with NAI teams. This is probably the most appropriate vehicle for the NAI's involvement in NASA's flight program. Thus, with respect to the goal of providing scientific and technical leadership on astrobiology investigations for current and future space missions, the committee finds that the NAI has:

- Encouraged astrobiologists to provide needed recommendations and expertise to NASA for mission planning;
- Promoted the participation of astrobiologists in the science teams for current and future missions;
- Organized activities, such as focus groups, that have strongly influenced NASA missions; and
- Identified astrobiology questions that underpin most of NASA's current flight programs.

The committee believes that the NAI must remain clearly focused on supporting NASA's spaceflight missions, and so its highest-priority recommendation is as follows: Because its most critical function is to ensure that its research activities clearly contribute to NASA's current and future spaceflight activities, the NAI should be more proactive in identifying future astrobiology missions. In addition, the NAI should actively encourage a partnership between astrobiologists and their engineering counterparts to help define future NASA missions.

The committee also recommends that in selecting new nodes, the NAI should give more weight to the potential contribution of the proposed research to future NASA missions.

Suggestions as to how these recommendations might be implemented can be found in Chapter 4.

NAI Goal 4—Use of Information Technology

The NAI experience with information technology has been mixed. Those aspects of the application of information technology within the control of NAI Central—e.g., its extensive and informative Web page with its archive

of astrobiology seminars and research results—are second to none in NASA. But those aspects of the utilization of information technology outside the direct control of NAI Central—e.g., the use of collaborative work tools by the researchers affiliated with NAI teams—has been less successful. The lack of success most likely results from social rather than technical factors. Thus, with respect to the goal of exploring new approaches using modern information technology to conduct interdisciplinary and collaborative research among widely distributed investigators, the committee finds that:

- The substantial efforts by NAI Central to improve communications among NAI members have achieved some significant successes; and
- The NAI has been less successful in promoting the use of collaborative work tools by the researchers affiliated with its participating teams.

The committee recommends that the NAI should vigorously pursue new approaches using modern information technologies to increase the effectiveness of the NAI nodes. In particular, additional efforts by NAI Central are needed to ensure that new communications tools are used to enhance the effectiveness of interdisciplinary and collaborative research and training. Suggestions as to how this recommendation might be implemented can be found in Chapter 5.

NAI Goal 5—Education and Outreach

The public's interest in the subject matter of astrobiology has enabled the effective leveraging of funds, partnerships, and expertise far greater in scope than those made available by the NAI itself. Thus, with respect to the goal of supporting outreach by providing scientific content for K-12 education programs, teaching undergraduate classes, and communicating directly with the public, the committee finds that the NAI has:

- Successfully promoted astrobiology as a field with broad-based public appeal;
- Developed effective programs for outreach to the general public; and
- Enabled minority educational activities.

The committee makes the following recommendations:

- The NAI should be more strategic in exploiting synergies among nodes in K-12 education, minority education, and teacher training; and
- The NAI should address the specific requirements for teaching astrobiology at the undergraduate level.

Suggestions as to how these recommendations might be implemented can be found in Chapter 6.

Assessment of the

NASA ASTROBIOLOGY INSTITUTE

Committee on the Review of the NASA Astrobiology Institute

Space Studies Board

Division on Engineering and Physical Sciences

NATIONAL RESEARCH COUNCIL
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This study is based on work supported by the Contract NASW-01001 between the National Academy of Sciences and the National Aeronautics and Space Administration. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the agency that provided support for the project.

International Standard Book Number 13: 978-0-309-11497-4

International Standard Book Number 10: 0-309-11497-7

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Preface

In a letter sent to Space Studies Board (SSB) Chair Lennard Fisk on January 11, 2007, Mary Cleave, NASA's associate administrator for the Science Mission Directorate (SMD), requested that the Space Studies Board (SSB) of the National Research Council (NRC) conduct a review to evaluate the progress made by the NASA Astrobiology Institute (NAI) in developing the field of astrobiology, both from the perspective of NAI members and from that of the larger community of NASA-supported scientists. The goal of this review is to help guide NASA in assessing and shaping the future of the NAI, particularly in its preparation of a solicitation issued to help select future teams to carry the NAI into a second decade.

NASA's Astrobiology program is the scientific outgrowth of the public and scientific excitement generated by a series of new results from solar system exploration and astronomical research programs in the mid-1990s, together with parallel advances in the biological sciences. Instituted in 1997, NASA's Astrobiology program focuses on research activities designed to understand the origin, evolution, and distribution of life in the universe. The program consists of four distinct elements: (1) grants programs designed to support individual investigators; (2) technological activities aimed at the development of new scientific instrumentation; (3) technological activities aimed at the field-testing of new scientific instruments; and (4) the NASA Astrobiology Institute, a consortium of geographically dispersed research groups ("lead centers" or "nodes") conducting interdisciplinary research.

The first three elements of the Astrobiology program are quite traditional in that they are designed to fund individual researchers following the peer-review of proposals written in response to annual announcements of opportunity. The NAI, however, was intended to be an experiment in the management of research efforts. The goal behind the creation of the NAI was to broaden and transform NASA's preexisting activities related to the search for life in the universe. The NAI was to promote the formation of interdisciplinary teams that would address cross-cutting questions in novel ways that were deemed not practicable within the constraints of the existing grants program. The NAI was formed to produce the highest-quality research results while ensuring the infusion of astrobiology objectives into NASA missions, to build a coherent astrobiology community, and to provide associated education and outreach efforts to enable public access to and benefit from NASA-supported astrobiology research. Since its founding, the NAI has placed special emphasis on encouraging collaborative research among scientists, as well as providing insights to educators from a variety of different backgrounds.

In response to a mandate contained in Section 314 of the NASA Authorization Act of 2000 and a subsequent request from NASA, the Space Studies Board and the Board on Life Sciences undertook a study in 2001 to assess NASA's Astrobiology program. In particular, the study looked at the relationship between NASA's Astrobiol-

ogy program and related activities funded by other federal agencies (e.g., the National Science Foundation, the National Institutes of Health, and the Department of Energy) and also research activities conducted by other public and private scientific institutions in the United States and overseas. The resulting report, *Life in the Universe: An Assessment of U.S. and International Programs in Astrobiology*,¹ gave a generally favorable review of the NASA Astrobiology program. However, the study committee concluded that insufficient time had elapsed to adequately address the key issue of whether or not the scientific contributions of the NAI were greater than the sum of its parts. In other words, did the unique organizational arrangements of the NAI represent a net plus or minus for science relative to what could be achieved if NAI's funding were distributed among more traditional grants programs? The report recommended that "NASA should undertake a comprehensive review of the scientific and educational results of its Astrobiology program in general, and of the NASA Astrobiology Institute (NAI) in particular, at the end of a decade of activity, in order to assess the longer-term effects of the founding of the new program and the new institute on the research area. This review would include analysis of the significant scientific contributions that have arisen from the program. It should be undertaken no later than 2008, when the NAI is a decade old" (p. 3).

Following the receipt of funding from NASA in late-May 2007 to undertake the study requested by Dr. Cleave, the Space Studies Board established the ad hoc Committee on the Review of the NASA Astrobiology Institute in June 2007. The committee's activities began with a conference call held on July 13 and continued at a meeting held in Sunnyvale, California, on July 25-27. Presentations and deliberations continued at a meeting held in Washington, D.C., on August 16-18 and concluded at a third and final meeting held in Costa Mesa, California, on August 31-September 1. In addition to presentations and discussions at its meetings, the committee solicited comments from all of the NAI's current and former principal investigators and from leading astrobiologists at international organizations associated or affiliated with the NAI. In addition, the committee solicited input from past and present NAI postdoctoral fellows.

A draft report was completed during the first week of September and sent to external reviewers for commentary in mid-September. A new draft responding to the reviewers' comments was completed in late October, and the report was approved for release on November 20.

The work of the committee was made easier thanks to the important presentations and comments provided by numerous individuals from a variety of public and private organizations. These include the following: Shige Abe, Marco Boldt, Wendy W. Dolci, David Morrison, Carl B. Pilcher, and Daniella Scalice (NASA Astrobiology Institute); James L. Green, Michael Meyer, and John D. Rummel (NASA, Science Mission Directorate); Jeffrey Bada (University of California, San Diego), John Baross (University of Washington), Baruch Blumberg (Fox Chase Cancer Center), Andre Brack (European Exo/Astrobiologie Network Association), David Des Marais (NASA Ames Research Center), David Deamer (University of California, Santa Cruz), Edna Devore (SETI Institute), Pascale Ehrenfreund (Leiden University), Todd Gary (Tennessee State University), Scott Hubbard (Stanford University), Bruce Jakosky (University of Colorado), Clark Johnson (University of Wisconsin, Madison), Andrew Knoll (Harvard University), Jonathan Lunine (University of Arizona), Rocco Mancinelli (SETI Institute), Michael Manga (University of California, Berkeley), Marcia McNutt (Monterey Bay Aquarium Research Institute), Victoria Meadows (University of Washington), Michael Mumma (NASA Goddard Space Flight Center), Hiroshi Ohmoto (Pennsylvania State University), Tullis C. Onstott (Princeton University), Anatoli Pavlov (Russian Astrobiology Center), John Peters (Montana State University), Francois Raulin (Groupement de Recherche en Exobiologie), Bruce Runnegar (University of California, Los Angeles), Timothy Slater (University of Arizona), Mitchell Sogin (Marine Biological Laboratory), Sean Solomon (Carnegie Institution of Washington), Woodruff T. Sullivan III (University of Washington), Roger Summons (Massachusetts Institute of Technology), Carol Tang (California Academy of Sciences), Catherine Tsairides (Lockheed Martin), Margaret Turnbull (Space Telescope Science Institute), Malcolm Walter (Australian Center for Astrobiology), and Neville J. Woolf (University of Arizona).

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the authors and the NRC in making

¹ National Research Council, *Life in the Universe: An Assessment of U.S. and International Programs in Astrobiology*, The National Academies Press, Washington, D.C., 2003.

its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

The committee wishes to thank the following individuals for their participation in the review of this report: Sidney Altman (Yale University), Paul Falkowski (Rutgers University), Andrea Ghez (University of California, Los Angeles), Charles Kennel (University of California, San Diego), Eugene Levy (Rice University), H. Jay Melosh (University of Arizona), Kenneth Nealson (University of Southern California), Maxine Singer (Carnegie Institute of Washington), and David Spergel (Princeton University).

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Larry L. Smarr (University of California, San Diego). Appointed by the NRC, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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