Consensus Study Report
HIGHLIGHTS
October 2018

An Astrobiology Science Strategy for the Search for Life in the Universe

Are we alone in the universe? Astrobiology, the study of the origins of life in the universe and the search for life on other worlds, is a highly interdisciplinary and rapidly changing field at the intersection of biology, chemistry, geology, planetary science, and physics. Recent scientific advances have opened new doors for astrobiological inquiry including the discovery of thousands of new exoplanets, evidence of hydrothermal activity on Enceladus (a moon of Saturn), and life thriving in some of the most extreme conditions found on Earth. To chart a path forward and capitalize on current and upcoming missions, NASA and Congress asked the National Academies of Sciences, Engineering, and Medicine to develop a future research strategy for the field of astrobiology. *An Astrobiology Science Strategy for the Search for Life in the Universe* builds upon NASA's 2015 Astrobiology Strategy by highlighting recent technology advances and identifying the key scientific questions that will shape the future of the field. The report describes how space missions and ground-based telescopes should fit into the overarching astrobiology strategy and emphasizes opportunities for private, interagency, and international partnerships. This evaluation of astrobiology will inform upcoming decadal surveys in astronomy and planetary sciences and help guide agency priorities for the coming decade.

HABITABILITY IS NOT A YES OR NO QUESTION

Understanding what makes an environment habitable requires contributions from across a wide range of disciplines including physics, chemistry, biology, and geology. When well-integrated, these disciplines have the potential to reveal not only how life emerges, but also how life and its environment change together over time—a concept captured in the term "dynamic habitability." Planetary environments that may be habitable today or have been in the past are not necessarily the same as those that could have fostered the emergence of life. Earth, the only known inhabited planet, remains our best test case for both the emergence of life and the ways in which life and its environment coevolve.

As we seek to better identify the environmental conditions on early Earth that gave rise to life and how this life subsequently altered its environment, our understanding of how life and planetary environments are linked could help scientists compare habitability in environments within our solar system and beyond. Therefore, ***NASA and other relevant agencies should foster broad, interdisciplinary collaboration focused on characterizing dynamic habitability and the coevolution of planets and life.***

SPECIALIZED IMAGING TECHNOLOGIES ARE NEEDED FOR THE NEXT GENERATION OF EXOPLANET INSTRUMENTS

The search for life on planets around other stars has seen substantial progress in recent years. The Kepler mission has detected thousands of exoplanets, some of which fall within what is commonly considered the "habitable zone"—the region around a star where an Earth-like planet could support liquid water on its surface. In the near- to mid-term, the Transiting Exoplanet Survey Satellite (TESS), the Atmospheric Remote-sensing Infrared Exoplanet Large-survey (Ariel), and the James Webb Space Telescope (JWST) will focus on identifying and characterizing potentially habitable transiting exoplanets. Following these missions, the next step will be to build and operate instruments capable of directly imaging an Earth-like planet, as recommended in a recent report from the National Academies, Exoplanet Science Strategy. Whether observing from a space- or ground-based instrument, starlight suppression technologies, such as coronagraphs and starshades that block out the light from the parent star, will be essential for imaging Earth-like exoplanets. Therefore, ***NASA should implement high-contrast starlight suppression technologies in future space- and ground-based direct imaging missions***. If funded, the planned Wide Field Infrared Survey Telescope (WFIRST) will serve as a technology test bed for a coronograph, paving the way for its use on future missions.

THE SEARCH FOR LIFE SHOULD FOCUS BELOW THE SURFACE

Recent investigations focusing on organisms living in subsurface environments on Earth have expanded our understanding of what environments on other planets may be habitable. For example, if bacterial life can exist in cold, hypersaline (~10 times saltier than the ocean) environments on Earth, salty brines beneath the surface of Mars might also harbor life. Likewise, given that organisms on Earth can thrive far from the Sun's rays in sediments beneath the ocean floor and in the deep subsurface of Earth's landmasses, we should prioritize subsurface environments when seeking out signs of life. Other planets in the solar system do not have Earth's robust mechanisms for protecting its surface from radiation, making their surfaces less friendly to known forms of life. Given the breadth and diversity of life in Earth's subsurface, the discovery of subsurface fluids on Mars, and the potential habitats for life on ocean worlds, ***NASA's programs and missions should reflect a dedicated focus on subsurface habitability.***

A FRAMEWORK IS NEEDED TO CONFIRM POSSIBLE SIGNS OF LIFE

The search for life in this solar system and beyond hinges on the ability to identify and validate signs of life, or "biosignatures". Over the past few years, the astrobiology community has started to discuss under what conditions a biosignature might be measurable, how to identify false positives (i.e., biosignatures generated by non-biologic processes), and how we might recognize novel biosignatures generated by life with a substantially different molecular makeup than life on Earth. If possible, the community would benefit from identifying agnostic biosignatures— biosignatures created by life regardless of its molecular or genetic makeup—and ***NASA should support research into novel and agnostic biosignatures***. It is also necessary to understand the types of non-biologic processes that can cause false positives or alter true biosignatures. Therefore, ***NASA should focus on the range of abiotic phenomena that mimic biosignatures. NASA should also direct the astrobiology community to study how biosignatures can be preserved or destroyed within a planet's geologic record, including the conditions that could cause false negatives.***

Attaining community consensus on whether a biosignature represents a true sign of life will not be easy. Therefore, there is a need for a framework and a set of standards that would enable the astrobiology community to reach consensus on whether a purported biosignature on another planet is a true sign of life as we know it, a sign of life as we don't know it, a false positive, or a false negative. It is particularly important to resolve this challenge before potentially controversial results are returned from missions with astrobiological implications. Therefore, ***NASA should support the community in developing a comprehensive framework for assessment—including the potential for non-biologic signatures, false positives, and false negatives—to guide the testing and evaluation of in situ and remote biosignatures.***

NEW LIFE DETECTION TECHNOLOGIES CAN HELP ADDRESS KEY QUESTIONS IN ASTROBIOLOGY

Besides establishing criteria for biosignature detection to facilitate community consensus, overarching programmatic advances will be important in advancing the ability to detect biosignatures as part of future astrobiology missions. Because of the inherent ambiguity in many known biosignatures and the necessity of making multiple measurements on a sample, in situ detection of life can best be accomplished by instruments that can use multiple techniques to analyze the same sample. Current NASA instrument evaluation and selection policies tend to favor low technology risk, which in some cases adversely impacts scientific payoff. ***To advance the search for life in the universe, NASA should accelerate the development and validation of mission-ready, life detection technologies.*** In the past, the planning and implementation of planetary exploration missions focused on strategies developed with an eye toward geology science goals rather than astrobiology science goals. Instead, ***NASA should integrate astrobiological expertise in all mission stages, including inception and conceptualization, planning, development, and operations.***

PRIVATE, INTERAGENCY, AND INTERNATIONAL PARTNERSHIPS ARE ESSENTIAL FOR FUTURE ASTROBIOLOGY MISSIONS

The key scientific questions surrounding the search for life present immense challenges that will require partnerships with other agencies as well as private and international entities to overcome. For example, partnerships with the commercial sector could provide access to technologies being developed outside of the space industry such as artificial intelligence or biomedical devices. Philanthropic investment in the search for life is also increasing, not only for traditional award funding to individual investigators, but also for self-funded and crowd-funded missions that may be categorized as “high-risk/high-payoff”. Sharing assets and resources for large undertakings is even more important as missions increase in complexity, although barriers to effective cooperation still exist. ***NASA should actively seek new mechanisms to reduce the barriers to collaboration with private and philanthropic entities, and with international space agencies, to achieve its objective of searching for life in the universe.***

LEARN MORE AND SHARE YOUR INPUT ON THE FUTURE OF ASTRONOMY

The 2020-2030 Decadal Survey on Astronomy and Astrophysics is now underway. Learn more on the study website at **nas.edu/astro2020**.

Download past decadal surveys and midterm reviews using the links below:

New Worlds, New Horizons in Astronomy and Astrophysics - **nap.edu/12951**

New Worlds, New Horizons: A Midterm Assessment - **nap.edu/23560**

Vision and Voyages for Planetary Science in the Decade 2013-2022 - **nap.edu/13117**

Visions into Voyages for Planetary Sciences in the Decade 2013-2022: Midterm Review - **nap.edu/25186**

The recommendations in this report are closely tied to those of our recent report, *Exoplanet Science Strategy*. Download the report or watch the public briefing video at **nap.edu/25187**.

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