National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

Reply to Attn of: Science Mission Directorate/DAAR

APR 16 2019

Dr. Fiona Harrison
Space Studies Board
National Academies of Science, Engineering, and Medicine
500 5th Street, NW
Washington, DC 20001

Dear Dr. ~~Harrison~~: Fiona

I would like to express my appreciation for the September 2018 delivery of the pre-publication "An Astrobiology Strategy for the Search for Life in the Universe" report. I thank you and the members of the Astrobiology Strategy for the Search for Life in the Universe Study Team for their hard work and diligence in preparing such a clear and comprehensive strategy under the time pressure of a Congressionally-directed timeline.

The Report recommends a series of ten actions that NASA should undertake. The analysis and guidance provided in the Report represents valuable input to the planning and implementation of NASA's Astrobiology Program. I have reviewed the findings and recommendations of the report and I am pleased to convey our responses to them. In general, our existing efforts appears, by and large, well-aligned with the report's recommendations within the constraints of available and anticipated funding. Please express my appreciation to the Chair, Dr. Barbara Sherwood Lollar, the Study Director, Mr. David Smith, and to all of the volunteers and staff who worked to bring this complex and comprehensive project to such a successful conclusion.

In the attachment to this letter, I provide initial acknowledgement and preliminary assessments and responses to the Survey's NASA-focused recommendations. Please do not hesitate to contact Dr. Michael New, who can be reached at (202) 358-1766 or at michael.h.new@nasa.gov, with any questions.

Sincerely,

Thomas H. Zurbuchen, PhD
Associate Administrator,
Science Mission Directorate

NASA's Response to "An Astrobiology Strategy for the Search for Life in the Universe"

Recommendation: NASA and other relevant agencies should catalyze research focused on emerging systems-level thinking about dynamic habitability and the co-evolution of planets and life, with a focus on problems and not disciplines — that is, using and expanding successful programmatic mechanisms that foster interdisciplinary and cross-divisional collaboration.

Response: NASA concurs with this recommendation and shares the committee's acknowledgment of the importance of systems-level thinking about many topics in Astrobiology (*e.g.,* dynamic habitability and understanding biosignatures — a measurement result interpreted as indicative of the presence of past or present life) and continues to initiate strategies that promote cross-discipline collaboration. As the committee notes in its report, in the three short years since NASA released its updated Astrobiology Strategy in 2015, "significant scientific, technological, and programmatic advances in the quest for life beyond Earth have taken place. Scientific advances have revolutionized fields of astrobiological study, ranging from results from missions focused on exoplanets, such as Kepler, to continuing discoveries from existing planetary missions."

The NASA Astrobiology Program has long supported initiatives to promote interdisciplinary research and to keep up with new discoveries and the changing landscape of origin of life and life detection research. NASA established the NASA Astrobiology Institute in 1998 as a virtual research institute, an innovative development at the time, intended to bring together researchers from across disciplines such as astronomy, biology, geology, and planetary science regardless of their geographic location.

In recent years, the NASA Astrobiology Program has explored other ways of promoting interdisciplinary research. In 2010, NASA partnered with the National Science Foundation (NSF) to co-fund the Center for Chemical Evolution (CCE), which continues to support researchers across the country today. The CCE is primarily funded by the NSF's Division of Chemistry as part of its Centers for Chemical Innovation (CCI) program, a network of nine centers each focused on a major research challenge in chemistry. The CCE is co-funded by the NASA Astrobiology Program to further research into prebiotic chemistry as it relates to understanding the origin of life on Earth and the potential for life elsewhere in the Universe.

The NASA Astrobiology Program is also collaborating with NSF to sponsor Ideas Labs, intensive workshops focused on finding innovative solutions to grand-challenge problems. In 2015, the NASA Astrobiology Program and NSF's Directorates for Biological Sciences (BIO) and Geosciences (GEO) held its initial Ideas Lab focused on fostering the development of a theoretical framework that encompasses the "metabolism first" and "RNA first" theories for the origin of life by stimulating creative thinking and new research on the earliest events leading to life on early Earth. This workshop resulted in the selection of five highly innovative research proposals that are just beginning to produce some transformative results. Based on the success of this first Ideas Lab, the NASA Astrobiology Program is looking to co-sponsor another with NSF or a broader consortium of public and private funders interested in the origins of life. Most recently, on November 1, 2018, NASA announced a new programmatic infrastructure for the Astrobiology Program in response to advances in the field and a growing need for systems-science approaches to complex problems. By the end of 2019, the Astrobiology Program will establish several virtual collaboration structures called research coordination networks (RCNs) that will replace the coordination role of the NASA Astrobiology Institute (NAI). NASA established its first RCN, the Nexus for Exoplanet Systems Science (NExSS), in 2015, recognizing the need for a systems science approach to the study of planetary habitability. NExSS is accelerating the discovery and characterization of other potentially life-bearing worlds in the galaxy, using a systems science approach. The three productive years of NExSS collaborations and its overwhelming success has paved the way for additional astrobiology RCNs to be established. These new RCNs will facilitate systems-level thinking about dynamic habitability and the coevolution of planets and life, with a focus on problems and not disciplines. Researchers funded by any of the Science Mission Directorate's four divisions may participate in these RCNs. Researchers not funded by NASA can apply to be an affiliate and participate in the RCNs.

The Astrobiology Program's new RCN infrastructure is consistent with the findings of the National Academies' *ad hoc* committees on Exoplanet Science Strategy and Astrobiology Strategy for the Search for Life in the Universe. The new infrastructure of self-managed, interdisciplinary networks will be better suited to the current astrobiology community, which has grown and matured significantly in the past 20 years, than the NAI.

Recommendation: NASA's programs and missions should reflect a dedicated focus on research and exploration of subsurface habitability in light of recent advances demonstrating the breadth and diversity of life in Earth's subsurface, the history and nature of subsurface fluids on Mars, and potential habitats for life on ocean worlds.

Response: NASA concurs with this recommendation and acknowledges the importance of expanding its efforts on research and exploration of subsurface habitability. In the past, NASA funded the Atacama Rover Astrobiology Drilling Studies (ARADS) project intended to iteratively develop a simulated Mars rover mission, and which successfully conducted its first field test in Chile's Atacama Desert in 2016. Multiple systems to support future missions have been designed, developed or modified to be tested in ARADS field experiments including, the fifth generation of a series of space-prototype, one- to two-meter-class, rotary-percussive drills by Honeybee Robotics; a sample-transfer robotic arm from MDA Aerospace (the developer of robotic arms for NASA's Phoenix and InSight missions to Mars); and a new autonomous mid-sized rover concept (K- REX2) developed by NASA Ames.

NASA also funded the Mars Analog Rio Tinto Experiment (MARTE), aimed at developing drilling, core- and sample-handling, and instrument technologies relevant to searching for life in the Martian subsurface and demonstrating them in a Mars-analog site on Earth, Spain's Rio Tinto region. The MARTE drilling system was developed for future use on Mars by Honeybee Robotics which has developed drilling and sample-handling systems for NASA's last three Mars landers, including the first drill to look inside a rock on Mars.
In addition, NASA is collaborating with international partners on sharing data from future missions with subsurface exploration. For example, NASA's Mars 2020 rover will feature a drill that can collect core samples of the most scientifically promising rocks and soils and cache them on the surface of Mars for future retrieval and return to Earth. Meanwhile, the European Space Agency's (ESA's) ExoMars 2020 rover will collect samples with a drill down to a depth of two meters and analyze them with next-generation instruments in an onboard laboratory. NASA and ESA are closely coordinating work on these two missions and will be sharing data from science operations.

Moreover, NASA Astrobiology will be co-hosting a conference titled "Mars Extant Life: What's Next?" in the fall of 2019, at the National Cave and Karst Research Institute. The conference will focus on understanding and discussing strategies for exploring candidate target environments on Mars that may host evidence of extant life including surface, shallow subsurface, and deep subsurface niches.

Astrobiology is also well represented on NASA's Europa Clipper mission team, which will conduct a detailed reconnaissance of Jupiter's moon Europa to see whether the postulated sub-ice ocean might be habitable. Furthermore, the science definition team for the Europa Lander mission concept study included several astrobiologists and identified three science goals for the mission that are relevant to future astrobiology studies: (1) detect and characterize biosignatures and signs of life, (2) analyze in-situ habitability, and (3) prepare for future exploration. The mission concept team identified a model payload for this mission that includes, among other instruments, a microscope for life detection and an organic compositional analyzer.

However, the technological challenges of exploring subsurface environments on icy worlds are formidable. On Earth, researchers have only reached a depth of 3.5 kilometers beneath ice covering Lake Vostok, Antarctica. Europa's ice shell could be as much as 15 kilometers deep. Consequently, the NASA Astrobiology Program has supported a number of technology development and demonstration projects for in-situ exploration of subsurface environments on other planetary bodies. For example, the program has supported the development of four Stone Aerospace autonomous underwater vehicles (AUVs) that are prototypes for subsurface exploration of Europa: DEPTHX (Deep Phreatic Thermal Explorer), ENDURANCE (Environmentally Non-Disturbing Under-ice Robotic ANtarctiC Explorer), VALKYRIE (an ice-penetrating robot), and ARTEMIS (Autonomous Rovers/airborne-radar Transects of the Environment beneath the McMurdo Ice Shelf).

Further, NASA's Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO), MATuration of Instruments for Solar System Exploration (MatISSE), and Planetary Science and Technology through Analog Research (PSTAR) programs have funded a number of projects aimed at aiding the exploration of subsurface planetary environments. Examples include but are not limited to a rover-mounted dielectric spectrometer for in-situ subsurface planetary exploration, which could measure subsurface material composition at radio frequencies (PICASSO); development and testing of a prototype digital beamforming polarimetric synthetic aperture radar for subsurface imaging, which could detect and map buried ice deposits and measure the depths of such deposits (MATISSE); and the SUBSEA project, which is exploring the habitability of a seamount off the coast of the Big Island of Hawaii as an analog for icy moons using two submarine-type remotely operated vehicles (PSTAR).

Finally, just last year, NASA's Astrobiology Program awarded a $7 million grant to a Georgia Tech-led Oceans Across Space and Time alliance to intensify the search for life in our solar system's present and past oceans. This alliance is a member of the Network for Life Detection (N-FoLD), an astrobiology RCN focusing on life detection strategies and methods. Sometime within the next year, proposals will be solicited that describe an interdisciplinary approach to a single, compelling question in astrobiology, and may address a single 2015 Astrobiology Strategy goal or several Science Strategy goals, for projects larger than the scope of the individual research programs, but within the scope of the Research Coordination Networks. The NASA Astrobiology Program will fund these types of awards through a new solicitation tentatively called Interdisciplinary Consortia for Astrobiology Research (ICAR).

Recommendation: NASA should implement high-contrast starlight suppression technologies in near-term space- and ground-based direct imaging missions.

Response: NASA concurs with this recommendation. NASA has made substantial investments in high-contrast starlight suppression technologies, including investments in both coronagraphs and starshades, as prioritized by the 2010 Decadal Survey in Astronomy and Astrophysics. NASA has added a coronagraph technology demonstration instrument to the baseline design of WFIRST, a near-term direct imaging mission. NASA conducted a mission concept study for a starshade that could work with the WFIRST mission. NASA also studied two future direct imaging missions with high contrast starlight suppression: the Habitable Exoplanet Observatory (HabEx) and the Large UV/Optical/IR Surveyor (LUVOIR). All three mission concepts will be presented to the 2020 Decadal Survey in Astronomy and Astrophysics for prioritization.

Recommendation: The search for life beyond Earth requires more sophisticated frameworks for considering the potential for non-terran life; therefore, NASA should support research on novel and/or agnostic biosignatures.

Response: NASA concurs with this recommendation and recognizes the importance of applying more sophisticated frameworks and rigor to biosignatures that represent terran life and have taken steps to additionally address the possibility of "life as we don't know it". To this end, NASA has sponsored studies by the NASEM as well as community workshops.
As early as 2004, NASA contracted with the Space Studies Board (SSB) to conduct a study of the "Limits of Organic Life in Planetary Systems" (often called the "weird life" report). The SSB's 2007 "weird life" report noted that "if life originated independently, even within our own solar system, it might have non-terran characteristics and, thus, not be detectable by NASA's in-situ or remote-sensing missions designed explicitly to detect terran biomolecules or their products."
For the past several years, the NASA Astrobiology Program has supported efforts to conceptualize and identify novel or agnostic biosignatures. In September 2016, NASA Astrobiology convened a workshop to rethink biosignatures titled "Agnostic Biosignatures: Recognizing Life as We Don't Know It." The workshop focused on three questions: 1) Can a framework be developed for defining biosignatures based not on a small number of preselected features of an object but on measures (distributions) over sets of features of the object? 2) How valuable would such a framework be? 3) How can such a framework be implemented and tested? Participants of this workshop concluded that there are a number of possible approaches to defining biosignatures that are independent of our understanding of how terran life works. Key to these approaches is a set of null hypotheses, proposing what we might expect to see in the absence of life. Workshop participants came up with several possible approaches to developing agnostic biosignatures that were developed into proposals for NASA Astrobiology funding. Several were selected. This area of research remains an important thrust for the Astrobiology Program.
More recently, in July 2016, NASA Astrobiology supported an "Exoplanet Biosignatures Workshop Without Walls," with attendees participating in person and online. This workshop brought together astrobiologists, astrophysicists, and members of the science and technology definition teams for exoplanet observation mission concepts to focus on three questions: 1) What are the known remotely observable biosignatures, the processes that produce them, and their known non-biological sources? 2) How can we develop a more comprehensive framework for identifying additional biosignatures and their possible abiotic mimics? 3) What standards can we

agree to use for assessing biosignature observations, both known biosignatures and those we have yet to identify? The workshop produced five coordinated peer-reviewed papers published in the Astrobiology Journal in 2018.

Currently Astrobiology is supporting the Laboratory for Agnostic Biosignatures, an N-FoLD project that is focusing on laying the groundwork for characterizing potential biosignatures that do not presuppose any particular molecular framework and developing new life detection tools and strategies for interpreting their results.
For all the work that has been done on biosignatures, much more work needs to be done. NASA Astrobiology will remain focused on supporting biosignatures research.

Recommendation: NASA should direct the community's focus to address important gaps in understanding the breadth, probability, and distinguishing environmental contexts of abiotic phenomena that mimic biosignatures. (Chapter 4)

Response: NASA concurs with this recommendation and agrees that the evaluation of biosignatures has not adequately and, in some cases, completely ignored environmental context. As a result, the NASA Astrobiology team developed a "ladder of life detection"[1] tool intended to guide the design of investigations to detect microbial life within the practical constraints of robotic space missions. This tool builds on lessons learned from previous attempts at detecting life, derives criteria for a measurement (or suite of measurements) to constitute convincing evidence for indigenous life, summarizes features of life as we know it, how specific they are to life, and how they can be measured, and sort these features in a general sense based on their likelihood of indicating life. The tool proposes a small but expandable set of decision rules determining whether the abiotic hypothesis is disproved. The ladder of life detection is not intended to endorse specific biosignatures or instruments for life-detection measurements, and is by no means a definitive, final product. It is intended as a starting point to stimulate discussion, debate, and further research on the characteristics of life, what constitutes a biosignature, and the means to measure them. NASA is soliciting community input to the ladder of life detection, which will be refined over the next several years. The ladder of life detection is one step in what will be an ongoing process to understand the breadth, probability, and distinguishing environmental contexts of agnostic and false-positive biosignatures. Biosignature detection in the context of the environment in which they are found will be one of the foci for the Network For Life Detection (N-FoLD), one of NASA Astrobiology's new RCNs established in recognition of the importance of focusing and coordinating NASA's research investments and the research community towards a primary goal of SMD, to search for life beyond Earth. NASA is committed to ensuring that the result of these efforts will feed into the interpretation of results from current missions and the planning and instrument selection for future missions.

Recommendation: NASA should support expanding biosignature research to addressing gaps in understanding biosignature preservation and the breadth of possible false positives and false negative signatures. (Chapter 4)

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[1] Neveu et al, The ladder of life detection, Astrobiology 18 (11), 2018, https://doi.org/10.1089/ast.2017.1773. Also see: https://astrobiology.nasa.gov/research/life-detection/ladder/

Response: NASA concurs with this recommendation. In May 2016, NASA Astrobiology co-hosted a conference on biosignature preservation and detection in Mars analog environments. This conference addressed strategies to detect a range of possible biosignatures on Mars in different categories of geologic settings by assessing the attributes and preservation potential of various biosignatures in different Mars-analog habitable environments on Earth. The aim of the conference was to develop a better understanding of biosignature preservation in three classes of ancient martian environments: lacustrine and deltaic sediments, near-surface chemical sediments, and deep crustal rocks.

In July, 2016, the NExSS and the Astrobiology Program hosted Exoplanet Biosignatures Workshop that brought together the astrobiology, exoplanet, and mission concept communities to review, discuss, debate, and advance the science of biosignatures. Three papers published in the Astrobiology Journal as an outcome of this meeting addressed how to approach interpretation of biosgnatures to increase their reliability, specifically considering false positives, false negatives and the preservation of atmospheric biosignatures in the presence of competing or destructive photochemistry.
Biosignature preservation and reliability in the context of the environment in which they are detected will be two of the foci for the Network For Life Detection (N-FoLD), one of NASA Astrobiology's new RCNs established in recognition of the importance of focusing and coordinating NASA's research investments and the research community towards a primary goal of SMD, to search for life beyond Earth.

NASA Astrobiology will continue to support biosignature research to address gaps in understanding biosignature preservation and the breadth of possible false positives and false negative signatures.

Recommendation: NASA should support the community in developing a comprehensive framework for assessment—including the potential for abiosignatures, false positives, and false negatives—to guide testing and evaluation of in-situ and remote biosignatures.

Response: NASA concurs with this recommemdation and acknowledges the difficulty in assessing in-situ and remote biosignatures and has grappled with false positives ever since claims of positive results from the labeled-release experiment on the Viking mission to Mars. The National Academies' 1977 report, "Post-Viking Biological Investigations of Mars," established a consensus that these results were false-positive.

In 1996, NASA responded to a claim of possible fossil evidence of nanobacteria in the Martian meteorite ALH 84001 by providing funding for further analysis of the meteorite and by 1998, establishing an Astrobiology Program, which included and expanded upon its long-standing Exobiology Program. Another outgrowth of the claim of fossil nanobacteria in ALH 84001 was that NASA asked the National Academies to hold a workshop on the size limits of very small organisms. A report on this workshop was published in 1999. This report noted that "part of the legacy of the ALH84001 meteorite is a significant increase in the vigor of NASA's programs in astrobiology, the exploration of the context and possible evidence for life elsewhere."
As noted previously, the NASA Astrobiology team developed a "ladder of life detection. This tool proposes a small but expandable set of decision rules determining whether the abiotic hypothesis is disproved. The ladder of life detection is a first step toward developing a

comprehensive framework for assessing in-situ and remote biosignatures, including potential abiosignatures, false positives, and false negatives.

With colleagues, NASA Astrobiology Principal Investigator Victoria Meadows, director of the University of Washington's Virtual Planetary Laboratory, has been focusing on the challenge of false-positive atmospheric biosignatures. She is a co-author of a paper published in the journal *Astrobiology*, "Exoplanet biosignatures: a review of remotely detectable signs of life" (E.W. Schwieterman et al, 1 June 2018, https://doi.org/10.1089/ast.2017.1729) that addresses false positives for biotic oxygen and possible spectral discriminators.

Recommendation: To advance the search for life in the universe, NASA should accelerate the development and validation, in relevant environments, of mission-ready, life detection technologies. In addition, it should integrate astrobiological expertise in all mission stages—from inception and conceptualization to planning, development, and operations.

Response: NASA concurs with this recommendation and is committed to, and actively supports, the acceleration, development, and validation of life-detection technologies through the Science Mission Directorate's PICASSO and MatISSE instrument development programs. In 2016 and 2018, these programs had two targeted solicitations. "Concepts for Ocean worlds Life Detection Technology (COLDTech)" sought to a) develop and advance the maturity of science instruments, especially those focused on the detection of evidence of life, especially extant life, in the ocean worlds of the outer Solar System (e.g., Enceladus, Europa, and Titan); b) sample acquisition, delivery and analysis systems for such missions, and c) spacecraft technologies required to access the oceans. The Instrument Concepts for Europa Exploration (ICEE) 2 program is supporting the development of instruments and sample transfer mechanism(s) for Europa surface exploration and had a focus on life- detection technology.

A number of Astrobiology-supported PIs have been, or now are, members of planetary missions. As NASA is increasing its focus on the search for evidence of habitability and life in the Solar System and beyond, NASA Astrobiology is increasing its efforts to bring more people into the astrobiology community who have the expertise to contribute to relevant missions such as the Europa Lander SDT mentioned above. For example, NASA-supported astrobiologists are well represented on the science and technology definition team for the Large UV/Optical/IR Surveyor (LUVOIR) exoplanet mission concept development team. NASA-supported astrobiologists are also represented on the science and technology team for the Habitable Exoplanet Observatory (HabEx) – a mission concept for a space-based observatory designed to directly image Earth-like exoplanets and characterize their atmospheric contents – potentially the first mission to provide this capability.

NASA recently held a workshop on reducing barriers to participating in missions. To continue its efforts to eliminate disciplinary and other barriers to participation in missions, NASA is considering taking the following steps:

- Increasing the frequency of proposal writing workshops at national science meetings;
- Creating a "missions 101 workshop" to explain how NASA evaluates, selects, and manages PI-led missions;
- Establishing a "PI incubator" program to provide mid-career scientists with the knowledge and skills to pitch a mission proposal to mission management centers and aerospace companies. This program will include horizontal and vertical networking opportunities; and,

- Creating a "NASA new researchers community of practice" through either a web-based effort or a program like NSF's Dissertations Symposium in Chemical Oceanography (DISCO) (http://www.discosymposium.org/).

NASA also is working on training programs to increase diversity, inclusion, exposure, and experience on missions. This year, NASA's Science Mission Directorate released an inaugural Future Investigators in NASA Earth and Space Science and Technology (FINESST) solicitation for grants to universities for graduate student research, another means of promoting diversity and inclusion as well as increasing exposure and experience.
There is still much work to do, and NASA will continue to look for ways to incorporate astrobiologists on mission teams as early as possible in the process.

Recommendation: 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.

Response: NASA concurs with this recommendation and notes that while the NASA Astrobiology Program has a good record of collaborations with national and international entities on scientific research, technology development, and mission design, the potential for such collaborations is not yet fully realized. To promote scientific leadership and collaboration in the astrobiology community, the NASA Astrobiology Program is committed to working with international partners, increasing and diversifying public-private partnerships, and exploring additional opportunities for collaboration.

Partnerships between NASA and other national space agencies contribute to the goals and objectives of the NASA Astrobiology program. Current collaborations include international partnerships for research and data sharing with foreign agencies, and NASA provides direct funding for individual scientists to collaborate on mission science through Participating Scientist Programs. NASA-supported astrobiologists have contributed instruments to ESA's ExoMars rover mission, and non-U.S. astrobiologists have contributed instruments to NASA's Mars Science Laboratory and Mars2020 missions. NASA-supported astrobiologists have collaborated on field expeditions with researchers in several countries including Australia, Norway, Oman, and Spain.
The NASA Astrobiology Program is interested in expanding opportunities to partner with private for-profit and non-profit entities when NASA and partner goals overlap. One of NASA's most recent successful partnerships was with the Frontier Development Lab (FDL), an applied artificial intelligence (AI) research accelerator established to maximize new AI technologies emerging in academia and the private sector and apply them to challenges in the space sciences. The SETI Institute hosts the FDL while private-sector partners included Nvidia, Intel, IBM, Lockheed Martin, Google Cloud, Space Resources LU, XPrize, and Kx. In 2018, NASA Astrobiology supported two FDL challenges: "Understanding what is universally possible for life," and "From biohints to confirmed evidence of life: possible metabolisms within extraterrestrial environmental substrates."
NASA is among several Federal agencies that have established programs that allow for promising research proposals to be matched with external philanthropic foundations, thereby allowing the private-sector to provide funds to support research and projects of interest to NASA. Additionally, a number of independent foundations are advancing their own goals of

supporting astrobiology research and engaging in education and public outreach efforts that are in line with those of the NASA Astrobiology Program. For example, the John Templeton Foundation and the Gordon and Betty Moore Foundation are funding astrobiology research, and both organizations have asked the NASA Astrobiology Program to participate in reviewing research proposals. In September 2018, NASA signed two Space Act Agreements with the Breakthrough Foundation, a private philanthropic organization, to collaborate on concept development for a life-detection mission to Enceladus. The NASA Astrobiology Program will continue to explore possibilities for partnerships with commercial and other private-sector partners as appropriate opportunities arise.