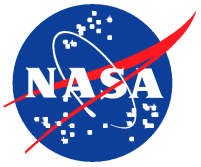
National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001



Reply to
Attn of: SMD/DAAR

March 11, 2019

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

Dear Dr. Harrison:

I would like to express my appreciation for the September 2018 delivery of the pre-publication "Exoplanet Science Strategy" report. I thank you and the members of the Exoplanet Science Strategy 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 seven concrete actions that NASA (and the NSF) should undertake. The analysis and guidance provided in the Report represents valuable input to the planning and implementation of NASA's Exoplanet Exploration Program. The National Academies has started work on assembling the Committee and panels for the 2020 Decadal Survey of Astronomy and Astrophysics (hereafter Astro2020) and I expect that the Report will provide valuable input to its deliberations. Please express my appreciation to the Co-chairs, Drs. David Charbonneau and B. Scott Gaudi, the Study Director, Mr. Nathan Boll, 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
Associate Administrator

NASA's Response to "An Exoplanet Science Strategy"

The National Aeronautics and Space Administration (NASA) Authorization Act of 2017 (Section 508) required NASA to engage the National Academies of Sciences, Engineering, and Medicine (NASEM) to develop a science strategy for the study and exploration of extrasolar planets. That strategy is to be used to inform roadmaps, strategic plans, and other activities of the Administration as they relate to extrasolar planet research and exploration, and to provide a foundation for future activities and initiatives related to extrasolar planet research and exploration. The NASEM study was conducted over a period of 9 months during which the study panel engaged with the broad exoplanet science community to evaluate the current status of the field, to define goals for the field, and to develop pathways to meet those goals. The results of the study are summarized in a report titled, "Exoplanet Science Strategy" that was delivered to NASA in September 2018 (hereafter, "The Report").

The Report identifies two overarching goals for exoplanet science. Those goals are as follows:

- **Goal 1** is to understand the formation and evolution of planetary systems as products of the process of star formation, and characterize and explain the diversity of planetary system architectures, planetary compositions, and planetary environments produced by these processes.
- **Goal 2** is to learn enough about the properties of exoplanets to identify potentially habitable environments and their frequency, and connect these environments to the planetary systems in which they reside. Furthermore, scientists need to distinguish between the signatures of life and those of nonbiological processes, and search for signatures of life on worlds orbiting other stars.

To achieve these goals, the Report recommends a series of seven concrete actions that NASA (and the NSF) should undertake. The analysis and guidance provided in the Report represents valuable input to the planning and implementation of NASA's Exoplanet Exploration Program. The National Academies has started work on assembling the Committee and panels for the 2020 Decadal Survey of Astronomy and Astrophysics (hereafter Astro2020. We also expect that the Report will provide valuable input to its deliberations. Pending the release of Astro2020, NASA will defer efforts to implement any specific mission recommendations.

In the following, we present NASA's initial responses to the recommendations found in the Report.

Recommendation 1: NASA should lead a large strategic direct imaging mission capable of measuring the reflected-light spectra of temperate terrestrial planets orbiting Sun-like stars. (Chapter 4)

NASA concurs with this recommendation. NASA has funded concept studies of four candidate large strategic missions for consideration by Astro2020, two of which have direct detection and characterization of potentially habitable, rocky planets as a primary science goal. Should Astro2020 make such a mission its top priority for the coming decade, NASA will be prepared to move forward on that mission upon successful completion and launch of the Webb and WFIRST missions.

This recommendation is consistent with the 2010 Decadal Survey of Astronomy and Astrophysics, *New Worlds, New Horizons in Astronomy and Astrophysics*, (hereafter Astro2010) which identified searching for nearby habitable planets one of its three overarching science objectives, and recommended a program to advance precursor science and technology development leading to such a mission as its top medium-class recommendation for NASA. In the years since its release, NASA has responded to Astro2010 by investing aggressively in the development of starlight suppression technologies (both coronagraphs and starshades) as well as other key technologies that will enable a future exoplanet direct imaging mission, including adding a coronagraph technology demonstration instrument to the WFIRST mission. In addition, NASA funded the completion of the Large Binocular Telescope Interferometer (LBTI) and its use to characterize exozodiacal dust levels around a sample of nearby bright, main sequence stars, and partnered with the NSF to provide the exoplanet community with access to a new, cutting-edge precision radial velocity spectrometer on the WIYN Telescope at Kitt Peak National Observatory. Concurrently, NASA's Kepler mission revolutionized our understanding of the occurrence rates of small planets. We recognize the Report's finding that advancements in key technologies and our knowledge of the occurrence rate of small planets over the last decade has significantly reduced the risk associated with implementing an exoplanet direct detection mission as indicating the effectiveness of NASA's activities over the past decade.

Recommendation 2: The National Science Foundation (NSF) should invest in both the GMT and TMT and their exoplanet instrumentation to provide all-sky access to the U.S. community. (Chapter 4)

This recommendation is not directed at NASA.

Recommendation 3: NASA should launch WFIRST to conduct its microlensing survey of distant planets and to demonstrate the technique of coronagraphic spectroscopy on exoplanet targets. (Chapter 4)

NASA concurs with this recommendation. The recommendation that NASA implement WFIRST reiterates recommendations from Astro2010 and from the NASEM report *Evaluation of the Implementation of WFIRST/AFTA in the Context of New Worlds, New Horizons in Astronomy and Astrophysics* (2014). NASA is continuing to make progress on WFIRST, subject to FY19 appropriations. WFIRST is currently in the preliminary design phase (Phase B), and its science and technology requirements include a microlensing survey of distant planets and demonstration of the technique of coronagraphic spectroscopy.

Recommendation 4: NASA and NSF should establish a strategic initiative in extremely precise radial velocities (EPRVs) to develop methods and facilities for measuring the masses of temperate terrestrial planets orbiting Sun-like stars. (Chapter 4)

This recommendation echoes the recommendation of Astro2010 that NASA and NSF should support, "an aggressive program of ground-based high-precision radial velocity surveys of nearby stars to identify potential candidates [for a future direct detection mission]." It is clear that precision radial velocity observations not only play a crucial role in validating planet candidates discovered by NASA's Kepler and TESS missions and prioritizing planets for potential follow-up observations by JWST and WFIRST, they are also crucial to the design of future exoplanet direct detection missions. In response to the Astro2010 recommendation,

NASA and the NSF established the NASA-NSF EXoPLanet Observational REsearch (NN-EXPLORE) partnership to provide open access to a state-of-the-art precision radial velocity instrument through the NOAO share of the 3.5-m WIYN telescope at Kitt Peak National Observatory. That instrument is scheduled to be installed and commissioned during 2019 and should be available for NN-EXPLORE guest observers beginning with the Fall 2019 observing semester.

The current state-of-the-art in precision radial velocity measurements (~1 m/s) is not sufficient to detect potentially-habitable, Earth-sized planets around FGK stars, which requires measurement precisions of less than 10 cm/s. NASA, working in collaboration with the NSF, is working on a community-informed process to develop a strategic initiative in extreme precision Doppler spectroscopy. That plan will be considered as part of the Agency's annual budget planning process and implemented as funding allows and in a manner consistent with the priorities of Astro2020.

Recommendation 5: NASA should create a mechanism for community-driven legacy surveys of exoplanet atmospheres early in the JWST mission. (Chapter 4)

NASA partially concurs with this recommendation. Full exploitation of JWST's capabilities will require thorough characterization of its on-orbit performance. Only with that information in hand will it be possible to identify the most promising targets and push JWST to the limits of its capabilities. However, it is unlikely that legacy science programs will be a component of the early stages of the JWST prime mission. If and when legacy observing programs are introduced, the Space Telescope Science Institute (STScI) will use the recommendations of scientific peer review committees, which are best qualified to evaluate and prioritize the highest value programs.

Recommendation 6: Building on the NExSS model, NASA should support a cross-divisional exoplanet research coordination network (RCN) that includes additional membership opportunities via dedicated proposal calls for interdisciplinary research. (Chapter 4)

NASA concurs with this recommendation. The search for life is an inherently interdisciplinary effort, and it was that recognition that led to the establishment of the NExSS RCN as a collaboration between NASA's Astrobiology Program and the Exoplanet Exploration Program. NASA has announced that the Astrobiology Program will include funding opportunities for membership in its RCNs, including NExSS.

Recommendation 7: NASA should support a robust individual investigator program that includes grants for theoretical, laboratory, and ground-based telescopic investigations; otherwise, the full scientific yield of exoplanet missions will not be realized. (Chapter 4)

NASA's Astrophysics Division currently supports individual investigator-led exoplanet research under its Astrophysics Data Analysis (ADAP), Astrophysics Research and Analysis (APRA) program, Astrophysics Theory Program (ATP), and the cross-divisional Exoplanet Research Program (XRP). The Astrophysics Division's total investment in individual investigator programs in exoplanet science has grown along with the field over the current decade and now stands at more than $7M annually. If one includes related exoplanet science that is funded under

the auspices of NASA's Planetary Science Division, this total investment rises to over $11M annually.