National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

Reply to Attn of: Science Mission Directorate

APR 16 2019

Dr. Fiona Harrison
Chair, 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 sincere appreciation for the Committee's report, Visions into Voyages for Planetary Sciences in the Decade 2013-2022: A Midterm Review. NASA appreciates the Committee's comprehensive review which will ultimately help inform NASA science during the remainder of this decadal period. I would also like to express our gratitude and congratulations to Dr. Louise Prockter and Mr. Joseph Rothenberg, the Committee's co-chairs; the volunteer members; and the National Academies staff for their diligent support of this effort.

I have reviewed the findings and recommendations of the report, and I am pleased to convey NASA's responses to them. In general, our existing planning appears, by and large, well-aligned with the report's recommendations. Please do not hesitate to contact Dr. Michael New with any questions about NASA's response. He can be reached at (202) 358-1766 or michael.h.new@nasa.gov.

Sincerely,

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

CC: Space Studies Board/C. Hartman
- D. Smith
- D. Day

Science Mission Directorate/M. New
- L. Glaze

NASA Response to Visions Into Voyages for Planetary Science in the Decade 2013-2022
A Midterm Review

On Research and Analysis Investment

Recommendation: NASA is largely following or exceeding the *Vision and Voyages*-recommended levels of research and analysis and technology spending. It should continue to make these critical investments.

Response: NASA recognizes the importance of the research and analysis (R&A) program and strongly concurs with this recommendation. PSD plans to continue the steady increase in spending on R&A and technology as prescribed in *Vision and Voyages*, providing future Planetary Science Division (PSD) budgets support such plans.

Recommendation: The next decadal survey committee should work with NASA to better understand the categorization and tracking of the budget for each of the research and analysis program elements, specifically providing insight into the budget for (1) principal investigator (PI)-led, competed, basic research and data analysis; (2) ground-based observations; (3) infrastructure and management; and (4) institutional or field center support. Also, the next decadal survey should be unambiguous when stipulating programs and recommended levels of spending.

Response: NASA concurs with this recommendation. NASA is committed to working with the next decadal survey committee to provide transparency in PSD's R&A programs and will provide information on existing program structures in a way that is consistent with current Congressional and OMB direction but can more easily guide future recommendations. PSD strives to maximize the fraction of R&A dollars spent on competed, PI-led basic research and analysis.

The implementation of Key Words in all funded R&A activities allows NASA to categorize and track our investments by type of investigation, target body in the solar system, and science discipline. Analysis of the Key Words over the past several years has shown consistent, steadily increasing investments in almost all areas while maintaining broad programmatic balance. Some areas (*e.g.*, exoplanet research) have grown faster than others — which stands to reason following the discovery of thousands of candidate exoplanets by the Kepler mission — while some areas have fluctuated due to external factors (*e.g.,* number of program elements available).

Ground-based observations of planetary objects is covered by the Solar System Observations program which contains both the NEOO (Near-Earth Object Observations) and PAST (Planetary Astronomy) programs. A portion of the NEOO budget managed by NASA's Planetary Defense Coordination Office is competed and the budget for the PAST program has remained steady at approximately $5 million per year for several years.

Finally, PSD supports several legacy facilities including AVGR, PAL, and the RPIF that have been reviewed extensively and reported on, informing PSD's plan for soliciting and funding future facilities.

On Programmatic Balance (Among Mission Classes)

Recommendation: NASA should issue Discovery announcements of opportunity (AOs) at the *Vision and Voyages* recommended cadence of ≤24 months, recognizing that an AO that selects two missions would count as two AOs for the purpose of meeting the *Vision and Voyages* recommendation. To approach meeting the *Vision and Voyages* recommendation, NASA should select three missions from AOs issued in 2019 and 2021.

Response: NASA concurs and is committed to increasing the cadence of Discovery mission launches. PSD is planning the release of the next Discovery AO in March 2019, which is planned to select up to two missions for flight in two launch opportunity windows. As long as budgets are sustained at current or better levels, the expectation is to release Discovery AOs every 4 – 5 years, with two selections per opportunity.

Recommendation: NASA should issue the New Frontiers 5 announcement of opportunity as soon as possible, but at a minimum release the announcement of opportunity no later than five years after the issuance of the New Frontiers 4 announcement of opportunity (*i.e.,* December 2021).

Response: NASA concurs and is committed to conducting two New Frontiers competitions per decade. The current expectation is that the New Frontiers 5 AO will be released in 2021 or 2022.

Recommendation: If scientific discoveries or external factors compel NASA to reassess decadal survey priorities, such as the list of New Frontiers missions, NASA should vet these changes via the Committee on Astrobiology and Planetary Science and allow for input from the community via assessment and analysis groups as time permits.

Response: NASA concurs that the Committee on Astrobiology and Planetary Science (CAPS) is the appropriate mechanism for assessing planetary science decadal survey priorities between decadal surveys. Since the time of the last New Frontiers solicitation, CAPS has gained the ability to provide formal advice to NASA, including the ability to weigh in on possible changes to priorities such as the list of New Frontiers targets.

Recommendation: NASA should continue to closely monitor the cost and schedule associated with the Europa Clipper to ensure that it remains executable within the approved life cycle cost (LCC) range approved at Key Decision Point-B (KDP-B) without impacting other missions and priorities as defined by the decision rules in *Vision and Voyages*. If the LCC exceeds this range, NASA should de-scope the mission in order to remain consistent with the *Vision and Voyages* decision rules.

Response: NASA concurs with this recommendation. Independent programmatic analysis of Europa Clipper LCC and schedule estimates will be updated in 2019 prior to confirmation. While the KDP-B range does not constrain the decision made at confirmation, the budget range identified for Europa Clipper was consistent with expectations for a cost-effective mission. NASA is committed to following the *Vision and Voyages* decision rules and to exploring options for descope, if required, to develop a fully achievable Europa Clipper confirmation agreement. For example, the ICEMAG (Interior Characterization of Europa using MAGnetometry) instrument was recently terminated as a result of continued, significant cost growth and

remaining cost risk. However, recognizing the important science objectives to be gained, NASA is investigating options for including a simpler, less complex magnetometer and all ICEMAG Co-Investigators will be invited to remain on the Europa Clipper science team to support the mission.

Recommendation: As a prospective large strategic (flagship) mission, the results of the NASA Europa lander studies should be evaluated and prioritized within the overall PSD program balance in the next decadal survey.

Response: NASA concurs with this recommendation. NASA is committed to implementing a strong program of planetary science and exploration that is consistent with the recommendations of the *Vision and Voyages* Decadal Survey. The work that has been done to date to study a Europa Lander concept will be available for the next decadal survey committee to include in their assessment of priorities for the next decade.

Recommendation: NASA should perform a new mission study based on the original ice giants science objectives identified in *Vision and Voyages* to determine if a more broad-based set of science objectives can be met within a $2 billion cost cap.

Response: NASA agrees that a study of ice giant mission concepts is prudent and has taken steps to address the basis of this recommendation. The Decadal Survey strongly recommended that NASA begin implementation, within the decade, of the ice giant flagship mission described in the report. It became apparent in the latter half of the decade that it was not possible to initiate another planetary science flagship mission in that time frame. Instead, NASA elected to study a broader range of ice giant mission concepts with varying levels of cost, complexity, and science return. This study explicitly built upon, and was not limited to, the flagship mission described in the Decadal Survey. It was hoped that the results might enable NASA to accelerate implementation of the mission in a mission category other than flagship.

NASA expects the next decadal survey to consider an ice giants mission as part of its deliberations for flagship missions in the 2023-2032 decade and is currently formulating its plan to execute mission studies in advance of the next decadal survey. In addition, NASA is working with the European Space Agency (ESA) to explore a collaborative, NASA-led mission to continue ice giants exploration. Specific plans for additional studies of ice giant missions will be made in light of those activities.

Recommendation: NASA's Planetary Science Division should implement an Independent Cost and Risk Review Process at Mission Definition/System Definition Review (Key Decision Point-B, or KDP-B) specifically for large planetary large strategic (flagship) missions to ensure that potential mission costs and cost risks are understood.

Response: NASA's PSD concurs with the recommendation. Indeed, this function is implemented through our standing review boards which independently assesses a project's readiness to proceed at each lifecycle milestone. We are assessing how to improve this process for planetary science flagship missions based upon our most recent experiences with Mars 2020 and Europa Clipper. While KDP-B estimates do not constrain the confirmation decision, they are key to setting expectations on the size of the commitment that is intended.

Further, NASA is in the process of implementing a new strategy that will require flight projects with a life cycle cost of at least $1 billion to conduct a Joint Cost and Schedule Confidence Level (JCL) corresponding with the System Requirements Review leading up to KDP-B. NASA will also add a requirement for the respective flight projects to conduct/update a JCL at the Critical Design Review. Finally, flight projects that are not performing to plan will have a requirement to conduct/update a JCL at the System Integration Review leading up to KDP-D. These changes will not affect the existing JCL requirement for the Preliminary Design Review leading up to KDP-C.

On PSD Infrastructure

Recommendation: NASA should conduct an assessment of the role and value of space-based astronomy, including newly emerging facilities, for planetary science. This assessment should be finished before the next decadal survey is significantly under way.

Response: NASA agrees that it is important to continue to explore the role that space-based astronomy plays in planetary science and will seek community input for an assessment through a mechanism such as a community workshop or study, the planning for which will begin in 2019. Further, NASA recognizes that space-based astronomy has already proven its value for planetary science such as observing the Comet F2 D/1993 Shoemaker-Levy 9 impacts with Jupiter using the Hubble Space Telescope (HST); discovering approximately fifty of the potentially hazardous asteroids with NEOWISE and characterizing many more with NEOWISE and Spitzer; discovering the New Horizons follow-on target 2014 MU69 in the Kuiper Belt with HST; and assessing the potential hazard to the Mars orbiters posed by Comet C/2013 A1 (Siding Spring) using HST, NEOWISE, Spitzer and Swift.

It is also important to note that NASA maintains a fleet of space-based assets for astronomy with publicly-competed time allocation for the non-survey assets and with public data archiving for all. Astronomers in the planetary science community have access to these NASA data archives and space telescope assets with capabilities across the spectrum such as HST, Chandra, Spitzer, Kepler, Swift and NEOWISE. In recent years, many of NASA's space telescope projects have held workshops at the AAS/Division for Planetary Sciences Meeting in order to encourage more usage of these available assets by the planetary science community. The planetary science community has also been participating on working groups to examine the capabilities of future space-based telescopes, including JWST and WFIRST in development, so that planetary science capabilities will be a consideration on NASA astronomy assets.

Recommendation: The committee endorses the *Vision and Voyages* recommendation that all three Deep Space Network complexes should maintain high-power uplink capability in the X- and Ka-band, and downlink capability in the S-, X-, and Ka-bands.

Response: NASA agrees that this uplink capability remain a part of the Deep Space Network capability for the foreseeable future. PSD has emphasized this to NASA's Space Communication and Navigation office (SCaN), and SCaN will continue to support RF capability while introducing optical communication capability as well.

Recommendation: NASA should consider the budget for curation by sample-return missions, as developed in the announcement of opportunity-required Curation Planning documents, a phase E

cost, regardless of the phase in which the costs are actually incurred. This would ensure that sample return missions are on equal footing with other mission proposals and discourage unrealistically low budgets for sample curation.

Response: NASA recognizes that missions with short cruise times (*e.g.,* lunar sample returns) might need to incur costs during Phases B-D, such as new laboratory construction and outfitting, that may put them at a disadvantage over long-cruise missions, which may defer the costs until later. NASA will consider the recommendation to move curation costs for sample-return missions to Phase E when calculating the cost cap.

Recommendation: NASA should ensure that all constituencies relating to sample return missions, both competed and directed, be coordinated through the Curation and Analysis Planning Team for Extraterrestrial Materials (CAPTEM) to optimize communication, avoid duplication of effort, and maximize existing expertise.

Response: NASA agrees that all constituencies related to sample return missions should be coordinated and the intent is that coordinating organizations will be established. NASA is currently planning how this should be done for a complex campaign such as Mars sample return, with broad international participation, which is unlike previous sample return missions. NASA intends to bring all of its available expertise together in planning the best strategy, including from within the Mars Exploration Program, the Astromaterials Acquisition and Curation Office at JSC, CAPTEM, international partners, and the science community at large. This will be done in a way that is consistent with a new NASA policy on Curation of Astromaterials, which is expected to be approved in 2019.

<u>On Education and Outreach</u>

Recommendation: In order to enable the excitement of space exploration to be fully communicated to the broader public, the STEM Activation program should work with all NASA planetary missions to define science content and program implementation. NASA's Planetary Science Division should link education and outreach activities directly to the missions that are providing the science content for them, interfacing through the PIs for competed missions, and through the project scientists for directed missions. Education experts within the STEM Activation program should work directly with the mission scientists and engineers (subject matter experts, or SMEs) to ensure a strong connection to NASA's mission results. NASA had previously provided funds equal to 1 percent of the overall project budget to support these activities. New funding at this level would provide robust support for project engagement in these education and outreach activities.

Response:. NASA agrees that linking education and outreach activities to the missions that are providing the science content is important to maximize impact and SMD seeks to leverage resources in a way that connects most effectively with the intended audience. However, implementing a 1 percent funding level without an overarching strategy and metrics to connect the return on investment ultimately proved to be an ineffective approach. Any future funding increases must connect to the current SMD Science Plan, derive from results from new content/discoveries (e.g. how the Solar System was formed from Juno mission results) and link to how Earth and space science is taught/received with analytics used to inform future decisions.

For science education, SMD's Science Activation Program connects learners with science content and experts based on evidence-based needs of the audience, rather than a pre-assigned percentage of each of SMD's 100+ missions. NASA Science experts, authentic experiences, and content are the most unique value we provide to the Nation's educational ecosystem. In 2016, SMD adapted to advances in science education methodologies, in particular adoption of the Next Generation Science Standards, and digital learning advances to optimize our inspirational, exciting science directly from the people that make new discoveries. Connecting experts with volunteer and community networks has been of particular focus. Recent online tools have been released to strengthen this connection: A "Hotline" service for anyone wanting more information on the Science Activation Program and a "Subject Matter Expert" map service, based on the successful tool used during the 2017 Total Solar Eclipse. Both services are located at https://science.nasa.gov/learners and will be promoted extensively in the future. To date, the majority of the SMEs posted are planetary science experts due to the 2015 commitment NASA's Planetary Science Division made for extended mission SMEs. That commitment allowed up to 1 FTE per year for missions passing Senior Review and provided over 60 planetary science SMEs access to funding for such activities.

In addition, a new metric on connecting with SMEs has been added to the 2020 GPRAMA for the Science Activation Program in order to track progress; and in 2019, the National Academies will perform an assessment of the overall Science Activation Program with specific attention to increasing SME connections and effectiveness with learners.

On Planetary Science Technology

Recommendation: NASA should continue investment in development of the mission-enabling technologies at the 6 to 8 percent level.

Response: NASA concurs with this recommendation. NASA recognizes the value of developing technologies to enable new science capabilities. The PICASSO and MatISSE instrument development solicitations are expected to continue on their current cadence of once per year for PICASSO and every other year for MatISSE, and the RPS Program is expected to continue to develop new energy conversion technologies for radioisotope power sources as noted in the following response. In addition, NASA will respond to opportunities as they arise for targeted technology investments as identified by Congress, such as instrumentation and technologies for lunar science and the exploration of icy worlds. These investments are expected to continue the practice of constituting 6 to 8 percent of the total PSD budget.

Recommendation: NASA should continue to work closely with the Department of Energy to ensure that the schedules for Pu-238 and clad production and the development of the Multi-Mission Radioisotope Thermoelectric Generator are maintained. It is also important that NASA continue the longer term developments of advanced energy conversion techniques.

Response: NASA concurs with this recommendation. NASA and the Department of Energy (DOE) signed a new Memorandum of Understanding on October 31, 2016, renewing our commitment to working together to ensure Radioisotope Power Systems (RPS) are available to support NASA's space exploration goals. Since that time, DOE has developed a new strategy to produce heat-source Plutonium-238 and process it into Fuel Clad Assemblies on a regular

cadence to reduce uncertainty in availability to NASA missions, and provide stability to the production infrastructure. NASA and DOE continue to produce MMRTG hardware to support Mars 2020 and potentially the Dragonfly New Frontiers mission (if selected) as well as the next round of Discovery missions. Furthermore, NASA's RPS Program maintains investments in advanced power conversion technologies. Under those investments, NASA is developing thermoelectrics with reduced degradation to potentially enhance the long-term performance of the MMRTG. NASA is also continuing to develop reliable dynamic power conversion to provide future radioisotope power systems with 25 percent or more efficiency to reduce the waste heat for missions that are sensitive to it, as well as reduce the plutonium need for high power missions. Finally, NASA is preparing to develop a modular Next Generation RTG based on highly reliable, improved power conversion technologies to serve a range of missions in the next decade and beyond.

On Mars Exploration Architecture

Recommendation: NASA should continue planning and begin implementation of its proposed "focused and rapid" architecture to return samples from the Mars 2020 mission to achieve the highest priority decadal survey large strategic (flagship)-class science for consideration for the next decadal survey.

Response: NASA agrees with the Committee's recommendation and is continuing with the planning of a focused architecture for Mars Sample Return (MSR) at the earliest feasible opportunity, working jointly with ESA with the intent of having a mature approach defined by the end of 2019. The Fiscal Year 2019 President's Budget Request proposed that NASA receive $50 million for this effort.

Recommendation: NASA should ensure the longevity of the telecommunications infrastructure at Mars to support the science return from current and planned landed assets (*e.g.,* Mars Science Laboratory, InSight, ExoMars, Mars 2020), to mitigate the risks associated with the existing aging assets. This should not be accomplished by sacrificing the science being conducted by existing orbiters.

Response: NASA agrees that ensuring the longevity of the telecommunications at Mars is critical to support current and planned missions. NASA's PSD has been working aggressively to extend the life expectancy of the orbital fleet at Mars, improving fault responses and battery charging, preparing stellar-only pointing modes, and minimizing fuel consumption. Now that MAVEN has completed its prime mission and a mission extension, its periapsis will be lowered to approximately 4500 kilometers in order to improve its telecommunications relay capability for Mars 2020, while continuing with approximately 80 percent of the science capability – an adjustment that was planned for in the beginning of the mission. PSD will continue to work to sustain science operations on all missions.

In addition, NASA has an agreement in place to utilize ESA's Trace Gas Orbiter (TGO) telecommunications relay services and has begun testing those services with the Curiosity rover now that the TGO spacecraft is in its operational science orbit.

Recommendation: NASA should immediately work to reinvigorate international cooperation to

help implement Mars exploration more effectively and affordably. This could involve international contributions of instruments, other hardware, or whole missions that complement what the United States is providing or leading, as suggested in *Vision and Voyages* and as proposed in the "focused and rapid" concept for Mars sample return.

Response: NASA has been working with ESA for the past two years to reinvigorate international cooperation for Mars exploration. On April 26, 2018 NASA signed a Statement of Intent with ESA to work jointly to plan Mars Sample Return. In this statement, ESA expressed interest in potentially contributing the orbiter mission and substantial payload hardware for the lander mission. PSD's Mars Exploration Program has established working groups to develop the details of the coordination. NASA is extremely pleased with the cooperation between the two space agencies and hopes to bring other international partners into the MSR discussions in the future.

As mentioned in the previous reponse, NASA also has an agreement in place to utilize ESA's Trace Gas Orbiter (TGO) telecommunications relay services for continuity at Mars to support the science return. NASA has begun testing those services with the Curiosity rover now that the TGO spacecraft is in its operational science orbit.

Recommendation: NASA should develop a comprehensive Mars Exploration Program (MEP) architecture, strategic plan, management structure, partnerships (including commercial partnerships), and budget that address the science goals for Mars exploration outlined in *Vision and Voyages*. The architecture and strategic plan should maximize synergy among existing and future domestic and international missions, ensure a healthy and comprehensive technology pipeline at the architectural (versus individual mission) level, and ensure sustenance of foundational infrastructure (telecommunications, imaging for site certification, etc.). This approach of managing the MEP as a program, rather than just as a series of missions, enables science optimization at the architectural level. This activity should include assurance that appropriate NASA/MEP management structure and international partnerships are in place to enable Mars sample return.

Response: NASA agrees with the Committee's recommendation and is working to re-establish the MEP as a program with a stable budget and is committed to developing a long-term strategic plan by 2020. As part of the activities coming into the next decadal survey, it is MEP's intention to develop this strategic plan by working with the community through the Mars Exploration Program Analysis Group (MEPAG).

<u>On Preparing for the Next Decadal Survey</u>

Recommendation: NASA should sponsor 8 to 10 mission concept studies based on the list produced by the Committee on Astrobiology and Planetary Sciences, prioritized with input from the assessment and analysis groups, prior to the next decadal survey. Mission concept studies for large strategic (flagship)-class missions should include options as described in the 2017 report *Powering Science: NASA's Large Strategic Science Missions* (NASEM, 2017b).

Response: NASA concurs with this recommendation and is currently in the process of preparing a ROSES call to fund multiple mission concept studies specifically in preparation for the next decadal survey.

Recommendation: In preparation for the next decadal survey, NASA should consider priorities and pathways for advancing the state of the art of CubeSat and SmallSat technology, and how science-driven planetary small mission concepts that leverage emerging capabilities are identified and possibly implemented for flight.

Response: NASA concurs with this recommendation. Included in the suite of critical technologies that NASA is developing are those needed for SmallSat missions, including CubeSats. PSD is working closely with NASA's Space Technology Mission Directorate to ensure that SmallSat technologies being developed are applicable to future planetary science missions. NASA has also released the SIMPLEx solicitation and expects to frequently fly SmallSats as secondary payloads on future flights.

Recommendation: A formal assessment by NASA of how well the program structure and funding of the virtual institutes are aligned with the Planetary Science Division's science goals should be conducted on a regular basis, appropriately phased to the cycle of decadal surveys and midterm reviews.

Response: NASA concurs with the recommendation to periodically review strategic activities such as SSERVI on a regular cadence appropriately phased to the cycle of decadal surveys and midterm reviews. In addition, the newly established Research Coordination Networks (RCNs) within the Astrobiology Program that will succeed the NASA Astrobiology Institute include such periodic review and assessments as part of their basic charters.

Recommendation: The next decadal survey committee should assess NASA's ability to respond to new needs for data archiving and interoperability from spacecraft, laboratories, and publications.

Response: NASA's SMD has established a Strategic Data Management Working Group to address these needs across the Directorate. Science community input has been requested over the past year, and a second public workshop was conducted on October 30-31, 2018. A new, SMD-wide Strategic Data Strategy is in the early stages of preparation.