

National Aeronautics and  
Space Administration  
Headquarters  
Washington, DC 20546-0001



Reply to Attn. of: SMD/DAA/R

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

Dear Dr. Kivelson:

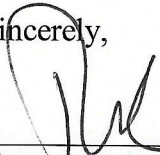
I would like to express my appreciation for the pre-publication copy of *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023 – 2032* delivered this past April. This comprehensive and insightful review of the state of planetary science and NASA's portfolio is both carefully considered and inspiring in its recommendations. The Strategy's approach to focusing at the largest-scale science questions along with detailed prioritization of missions is especially useful to NASA. Please express my deep gratitude to the co-chairs—Drs. Robin M. Canup and Philip R. Christensen—and all of the volunteers and staff—especially Dr. David Smith—who worked to bring this complex and comprehensive project to such a successful conclusion.

The leadership teams of PSD, ESSIO, and other mission directorates have been analyzing the Strategy's recommendations in detail since the pre-publication release. Appended to this letter, we provide initial acknowledgement as well as preliminary assessments and responses to the Strategy's recommendations. Overall, it is apparent that our existing programs and plans are well aligned with the recommendations. We are supportive of almost all of the guidance and proposed activities, and we are already discussing ways to begin the study phase for the recommended strategic mission to Uranus. While the current PSD budget is less than the proposed *Level* budget through 2028, we will fully consider the recommended portfolio along with the stated *Budgetary Decision Rules* in our future planning.

We note, however, that new mission-size activities and recommended cadences for competed mission programs require discussions at the highest levels of NASA and with our external stakeholders. While the responses herein address many of the actions that we will take in response to the Strategy, it will take us at least two budget cycles to develop more complete strategic approaches. We expect to be reporting on these developments regularly to CAPS as they emerge, and for updates about this process or any other questions related to our response, please do not hesitate to contact the Director of our Planetary Science Division, Dr. Lori Glaze, at [Lori.S.Glaze@nasa.gov](mailto:Lori.S.Glaze@nasa.gov) or (202) 358-1588.

In closing, I thank you again for such an excellent and useful report.

Sincerely,



Thomas H. Zurbuchen, Ph.D.  
Associate Administrator  
Science Mission Directorate

Date

8/11/22

cc:

SMD/M. New

SMD/L. Glaze

NASEM/C. Hartman

# **Appendix: NASA’s initial responses to the recommendations in *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023–2032***

**Notes:** The recommendations in the decadal survey were limited to Chapters 16 to 22. Our responses are grouped by chapter, using a numbering system of Chapter#-Rec#. For example, “22-7” denotes the seventh recommendation in Chapter 22.

## **Chapter 16: State of the Profession**

**16-1: NASA PSD and NSF with its wide experience with programs such as the Louis Stokes Alliances for Minority Participation (LSAMP) and Organizational change for Gender Equity in STEM Academic Professions (ADVANCE), should make it a priority to obtain currently lacking evidence about fundamental aspects of the state of planetary science and astrobiology communities. NASA PSD and NSF should engage with experts to undertake data collection on 3-to-5-year cycles with a focus on obtaining accurate data on:**

- **The size and identity of PS&AB, given their deeply interdisciplinary nature**
- **The demographic composition of PS&AB along all relevant dimensions, and**
- **The workplace climate at NASA PSD and affiliated institutions, as well as the social issues that facilitate or impede scientific progress in PS&AB.**

**Response:** NASA PSD concurs with the need for robust quantitative measures of fundamental aspects of the state of the PS&AB communities, especially for tracking the impact of any implemented strategies over time. Pursuant to Section 9 of the 2021 Executive Order on *Advancing Racial Equity and Support for Underserved Communities Through the Federal Government*, the U.S. government has created an Interagency Working Group (IWG) on Equitable Data to consider what information can be collected and how it should be used across the federal government. The Science Mission Directorate (SMD) may adjust its processes based on the outcome of the IWG’s efforts. Regardless, NASA PSD will continue to work with the Deputy Associate Administrator for Research, and the Office of the Chief Scientist, on data collection and analysis efforts, and appreciates these guidelines and specific considerations.

**16-2: NASA PSD should adopt the view that bias can be both unintentional and pervasive. To address potential bias issues, NASA should:**

- **Seek the expertise of behavioral scientists to develop methods for analyzing its decision-making practices and procedures (e.g., advertising, recruiting, selection, hiring, onboarding, promotion, compensation, managing teams, fieldwork, and mission planning).**
- **Determine where bias does, and does not, play a role and work with the evidence to reduce and eliminate bias from its procedures wherever it is found to exist.**
- **Proactively engage with the PS&AB community in the development of creative initiatives to uncover and mitigate bias in existing processes.**

- **Consider evidence-based bias education for itself and associated institutions. Honest discussions of policies and practices that no longer serve the functioning of modern scientific enterprises should be sought with enthusiasm that mirrors the enthusiasm NASA PSD brings to its scientific innovation.**
- **Follow education at a foundational level with discussions among individuals within NASA PSD with authority to effect change.**
- **Include regular focus on different aspects of the issues, e.g., opportunities for tenure of NASA-funded PS&AB members in academia, advancement to senior civil service positions at NASA centers, peer-reviewed research funding opportunities, addressing climate issues, participation in space mission teams, keynote presentation opportunities at scientific conferences, and awards by professional societies.**
- **Publicize the procedures and policies that have been reviewed and transformed each year.**

**Response:** NASA PSD acknowledges that bias can be both unintentional and pervasive. We note that, in coordination with SMD, various strategies to this effect have already been implemented. NASA PSD—and SMD, where appropriate—will consider each of these specific actions, as well as others, and will work to determine the best way to effectively mitigate biases across the division over the coming decade.

**16-3: NASA PSD should revisit the centralization policy on public engagement and consider mechanisms to support direct engagement of planetary scientists with members of society, particularly students in STEM fields.**

**Response:** NASA PSD acknowledges this recommendation, and our implementation will conform to NASA-wide policy and applicable laws. Since the OIG report *NASA's Education Program* (<https://oig.nasa.gov/docs/IG-16-001.pdf#page=3>), Congressional appropriations repeatedly have codified NASA's STEM reorganization (i.e., centralization). Furthermore, the Foundations for Evidence-Based Policymaking Act of 2019, also known as the Evidence Act, requires federal agencies to develop evidence and learning agendas to support policymaking. As PSD is an organization within NASA, it must abide with the current Federal STEM Strategic Plan. In March 2022, NASA released a new [Strategic Plan](https://www.nasa.gov/sites/default/files/atoms/files/fy_22_strategic_plan.pdf) ([https://www.nasa.gov/sites/default/files/atoms/files/fy\\_22\\_strategic\\_plan.pdf](https://www.nasa.gov/sites/default/files/atoms/files/fy_22_strategic_plan.pdf)), including the Agency's first Learning Agenda. PSD's future activities will employ mechanisms most likely to contribute to *NASA's Strategic Objective 4.3 Build the next generation of explorers. Engage students to build a diverse future STEM workforce.* NASA's agency-wide STEM engagement seeks to attract, engage, and educate students, and to support educators, educational institutions, and professional and student organizations; part of this is implemented by SMD's Science Activation program ([https://smd-prod.s3.amazonaws.com/science-pink/s3fs-public/atoms/files/2020\\_SciAct\\_Primer\\_TAGGED.pdf](https://smd-prod.s3.amazonaws.com/science-pink/s3fs-public/atoms/files/2020_SciAct_Primer_TAGGED.pdf)). This program funds microgrants to Subject Matter Experts (SMEs) who engage with science education experts closest to communities, networks, and institutions recognized for their learner expertise (e.g., through Arizona State University's SCoPE award, <https://science.nasa.gov/science-activation-team/smd-community-of-practice-for-education>). Additionally, the SMD/Exploration Systems Development Mission Directorate's (ESDMD's) forthcoming joint Solar System Exploration Research Virtual Institute (SSERVI) Cooperative Agreement Notice connects to Science Activation, Citizen Science, and Public Engagement. NASA PSD and SMD will continue to explore potential ways to implement this recommendation over the next decade.

**16-4: PSD should regularly evaluate programs that enhance participation of students and faculty from URCs; fellowship programs that facilitate engagement of NASA funded planetary scientists and astrobiologists with faculty at URC institutions; and mechanisms for supporting education and outreach as an integral part of research via, e.g., the inclusion of outreach activities as optional add-ons to R&A grants, or as a requirement for missions or cooperative agreements.**

**Response:** NASA acknowledges and supports this recommendation. As stated in NASA's recently released Equity Action Plan (<https://www.nasa.gov/press-release/nasa-releases-equity-action-plan-to-make-space-more-accessible-to-all>), the Agency is reviewing its grant and cooperative agreements process to: (1) identify Historically Black Colleges and Universities and Minority-Serving Institutions and small/minority-owned businesses that are eligible to compete for awards but are not submitting proposals; and (2) analyze barriers for those that did not apply or applied but did not receive awards. The study, scheduled for completion by the end of 2024, will allow the Agency to identify and address recurring barriers. SMD has also established the SMD IDEA Working Group which is composed of six (6) sub-groups (i.e., Programming; Outreach and Engagement; Inclusion and Culture; Leadership Development and Growth; Missions, Projects, and Program; Recruitment, Hiring, Promotions and Retention; Research and Analysis). This working group is in the process of implementing various activities that will also directly address aspects of this recommendation.

**16-5: PSD should strengthen and expand programs aimed at educating the community about the mission proposal process (e.g., PI Launchpad) and actual mission operations (e.g., participating scientist programs), particularly to reach out to URCs. Providing access to personnel or tools that can help guide investigators through the process should be considered, including participation as contributing members of the mission teams.**

**Response:** NASA concurs with and supports this recommendation. PSD intends to leverage existing NASA activities to strengthen and expand programs aimed at educating the community about the mission proposal process and mission operations, particularly to reach out to URCs. For example, the recent release of NASA's Equity Action Plan stated NASA's intentions to: (1) provide free, multilingual training on how to use NASA data, to address priority needs in underserved communities, and (2) launch the Science Mission Directorate Bridge Program, to foster collaboration and partnerships between NASA centers and Historically Black Colleges and Universities, Minority-Serving Institutions, Primarily Undergraduate Institutions, and very high research universities. SMD has also established the SMD IDEA Working Group (with multiple sub-groups including R&A, Missions, Projects, & Programs, etc; as noted in the response to 16-4) and is in the process of implementing various activities that will directly address aspects of this recommendation. Additionally, PSD has recently offered multiple opportunities to early-career researchers, for example: (1) the opportunity to observe a mission science team meeting; (2) the launch of the pilot "Here to Observe (H2O)" program that pairs missions with MSI institutions, in an effort to spark and maintain an interest in planetary science for URC students; and (3) support for the Lucy Student Pathway Accelerator and Competency Enabler (L'SPACE) program and the Capstone Projects and Innovation Toolkit Online Courses developed through the Psyche mission. In addition, NASA plans to continue the PI Launchpad Program and make the slides and participant workbooks publicly available for increased accessibility. NASA intends to continue to find new, innovative ways to provide access to personnel or tools that can help guide investigators through the process of mission development, implementation, and other learning opportunities over the next decade.

**16-6: NASA and PSD should reinstate the Harriett G. Jenkins and similar predoctoral fellowship projects as part of an effort to retain members of URC in the fields of PS&AB prior to them reaching existing pinch points at which substantial decline in URC representation is seen in both fields.**

**Response:** The Harriet G. Jenkins predoctoral fellowship was recently replaced by the National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM) fellowship, which aims to support American Indian/Native, African American/Black, and Hispanic American/Latino students pursuing an MS or Ph.D. in STEM. PSD will continue to find ways to partner with GEM, various Minority University Research and Education Project (MUREP) opportunities, and similar predoctoral fellowship projects, in an effort to retain members of URCs in the fields of PS&AB. NASA PSD will look for ways to work closely with these entities and other NASA centers to determine the best role for the Agency to fill (e.g., provide mentors, facilitate) over the coming decade.

**16-7: PSD should implement Codes of Conduct (CoC) for funded field campaigns, conferences, and missions, and should expect acknowledgement of receipt and understanding. The CoC should be codified, reviewed, and updated at regular intervals. An effective CoC should outline expected behavior, explain unacceptable behavior, explain how policies will be enforced, provide clear instructions on how to report incidents, and explain consequences of violations. The process should demonstrate sensitivity to the difficulty of bringing forward accusations and to the rights of the accused.**

**Response:** NASA concurs with and supports this recommendation, but also acknowledges the difficulty in implementation and the legal limitations associated with interorganizational Codes of Conduct (CoC). There are numerous efforts currently underway to support and implement this recommendation. For example, PSD panelists are provided with a CoC when serving on a ROSES panel; various solicitations including the Topical Workshops, Symposia, and Conferences (TWSC) and Solar System Exploration Research Virtual Institute (SSERVI) require a CoC; C.1 of Research Opportunities in Space and Earth Sciences (ROSES) requires a CoC, or similar effort, for proposers conducting fieldwork (section 3.15); and PSD has a CoC for field work

([https://ssed.gsfc.nasa.gov/MajorRandAThemes/GIFT/docs/RISE2\\_GIFT\\_GEODES\\_JointCodeOfConductTEMPLATE.pdf](https://ssed.gsfc.nasa.gov/MajorRandAThemes/GIFT/docs/RISE2_GIFT_GEODES_JointCodeOfConductTEMPLATE.pdf)) that was developed by the Goddard Instrument Field Team (GIFT) and which is available for use by the community. Although some missions currently have “Rules of the Road” and CoCs that team members are expected to follow, we are currently working to implement these across all mission teams and ensure consistency among the various CoCs. Furthermore, the Missions, Projects, and Programs subgroup of the SMD IDEA Working Group has developed a CoC template for mission teams and flight projects (currently undergoing the required approvals), with the ultimate goal of making this a standard requirement for all missions moving forward. These CoCs are intended to be updated at regular intervals to reflect community best practices. NASA will continue to work with its legal team to ensure that any enforcements are supported by the law.

**16-8: NASA PSD and affiliated institutions should clearly identify a Point of Contact or ombudsperson as part of the CoC to provide access to individuals who experience violations to the CoC. The egregious nature of the sexual harassment reported in field work requires immediate attention by NASA.**

Response: NASA concurs with and supports this recommendation. NASA, as an employer and a federal agency, is committed to creating and maintaining a workplace environment that encourages and empowers each individual employee to perform at their best. Harassment, therefore, has no place at NASA. It is NASA's longstanding policy that harassment in the workplace is prohibited and will not be tolerated. This prohibition applies to harassment by anyone, including supervisors, coworkers, and contractor personnel, in the workplace at any NASA facility. NASA's anti-harassment program is available to NASA employees, contractors, interns, participants in NASA-conducted programs, and other personnel working onsite at NASA facilities. In addition, NASA imposed a Term and Condition requirement in 2020, which requires award recipients to notify NASA when the PI or Co-I on a NASA-funded project is found to have engaged in harassment, or is placed on leave in connection with a harassment investigation. Upon receipt of such notification, NASA will promptly convene a working group to consider the safety and security of personnel supported by the NASA award, among other factors. Furthermore, through its Equity Action Plan, NASA has pledged to increase awareness of legal protections afforded under civil rights laws to beneficiaries of NASA-funded opportunities, which will educate those in the planetary science disciplines of the avenues available to them to report unlawful harassment. Moreover, SMD has established the SMD IDEA Working Group (with multiple sub-groups including R&A, Missions, Projects & Programs, etc) and conversations with the Deputy Associate Administrator of Research's office are underway to determine the appropriate approach to designate a point of contact or ombudsperson as part of the CoC template development. Since NASA only has the authority to discipline NASA employees, it is recognized that to be impactful, this will require a larger community effort and participation from institutions that support PS&AB research.

## Chapter 17: Research and Analysis

**17-1: NASA's PSD should adopt a consistent definition of what is included in the Division's R&A portfolio, including, in particular, an easy-to-distinguish category for the openly competed programs as defined in Table 17.1. This definition should be communicated to the science community and utilized in publicly reported metrics, tracking, etc., which should be made readily available on an annual basis. As programs are added and removed these changes should be advertised clearly.**

**Response:** NASA concurs with this recommendation. Over the past two years, PSD has been working to clearly define two terms:

- The Planetary R&A Portfolio includes all activities funded under the Research & Analysis budget line.
- The Planetary Research Program (PRP) includes all activities funded within the R&A Portfolio and those funded under mission lines.

These definitions will be publicly presented at CAPS and PAC meetings, and will be updated each year to account for any programmatic changes. PSD defines "openly-competed" programs as those where the solicitation is publicly announced and available. An openly competed program may have restrictions on eligibility for proposers (e.g., the Early Career Award program). These definitions will be the foundation for all future reporting.

**17-2: ISFM funds should only be used to pay NASA civil servant salaries. Funding for other individuals should be pursued through standard R&A proposal processes.**

**Response:** NASA does not concur with this recommendation. NASA’s Internal Scientist Funding Model (ISFM) was created as a result of a 2015 internal NASA study, which was broadly communicated. A conclusion of this study was that it is in the national interest that many of the activities performed by Civil Servant (CS) scientists be conducted and supported in a way that optimizes the NASA workforce’s productivity and realizes its leadership potential as part of the broader community. The concept for the ISFM program was developed under the direction of NASA’s Chief Scientist and was implemented within SMD; in both planning and implementation, a key principle was “ISFM work may also involve contractors and external collaborators”. A summary of the history and implementation of ISFMs can be found in a presentation given to the PAC by Dr. Michael New, Deputy Associate Administrator for Research, on November 30, 2020. This presentation can be found at [https://science.nasa.gov/science-pink/s3fs-public/atoms/files/06\\_ISFMOverview1\\_New\\_PACNov2020\\_TAGGED.pdf](https://science.nasa.gov/science-pink/s3fs-public/atoms/files/06_ISFMOverview1_New_PACNov2020_TAGGED.pdf).

**17-3: For greater transparency, NASA should document and communicate to its civil servants and the broader community how the ISFM is managed, and the processes by which proposals are solicited and evaluated to ensure the most meritorious civil servant science is supported.**

**Response:** The ISFM implementation plan has been presented both within NASA and made public (<https://science.nasa.gov/science-pink/s3fs-public/atoms/files/ISFM-implementation-v14.pdf>). Previously, we have reported on the establishment and management of ISFMs (c.f., Stephen Rinehart’s presentation to the PAC on November 15, 2021, [https://science.nasa.gov/science-pink/s3fs-public/atoms/files/04-R\\_A Update - S. Rinehart.pdf](https://science.nasa.gov/science-pink/s3fs-public/atoms/files/04-R_A Update - S. Rinehart.pdf)). To ensure that the ISFMs are providing high-quality science, PSD has implemented a higher degree of review than for any other research program: this includes multiple levels of internal review, as well as external review. These reviews focus not only on the scientific merit of the work, but on other success metrics for ISFM, including community service.

**17-4: SSERVI represents a valuable and potentially powerful means to foster important interactions between PSD and ESDMD. As a primarily PSD-funded program, SSERVI should emphasize decadal-level science that can be enabled by human exploration activities, in addition to science needed to support exploration goals. Team selections and program activities (including redirection of existing nodes) should reflect a balance between science and exploration that is consistent with the relative PSD and ESDMD contributions to SSERVI program funding. This balance should be evaluated by an appropriately constituted group mid-decade.**

**Response:** NASA concurs that SSERVI provides an important path for coordination between PSD and ESDMD, and SMD interacts routinely with counterparts in ESDMD to discuss scientific objectives for human exploration activities, both in the context of SSERVI and overall Artemis science. NASA also agrees that the objectives pursued by SSERVI should be reviewed on a regular basis so that they appropriately reflect the science and exploration priorities of SMD and ESDMD. For long-term planning for SSERVI, however, it must be recognized that the priorities of, and constraints on, ESDMD may limit their participation and funding contributions.



**17-5: Given the scale and strategic importance of ICAR to NASA’s astrobiology efforts, immediate evaluation by an appropriate external body to ensure that it is optimally designed to maximize desired return to NASA and to PSD is warranted. Particular issues that should be addressed include, but are not limited to, the best mechanisms for generating RCNs, whether and how proposals should be topically constrained, and how the program structure should evolve in response to scientific advances and community input.**

**Response:** NASA agrees that the timely evaluation and review of all major programs is critical for ensuring that programs are fulfilling expectations. NASA, however, does not concur with the need for an immediate review of the Interdisciplinary Consortia for Astrobiology Research (ICAR). ICAR is a relatively new program and has completed only a single proposal round. NASA partially concurs with the recommendation to regularly review the RCNs. The RCNs are not funded research programs, but are voluntary, strategic coordination structures that receive modest support from PSD for thematic activities that enhance research collaboration. Currently, PSD plans to assess each RCN every five years as part of the intrinsic management plan (the first such assessment, for the Nexus for Exoplanet System Science, is planned for the latter half of 2022). Given the nature of the RCNs, such assessments are not focused on performance metrics but instead focus on how the individual RCNs meet NASA’s strategic needs as the RCNs evolve and adapt to scientific advances and changing priorities.

**17-6: NASA should regularly (i.e., every few years) assess the PSD R&A portfolio to establish if the component programs are optimized for meeting PSD’s science objectives. That assessment should consider (1) how the record of research products produced by each program compares with its funding level and strategic importance, (2) whether the existing mix of programs encourages cross-cutting science, and (3) the balance of team versus individual investigator programs. Changes in program structure should be announced with significant lead time to allow ongoing research programs to adjust.**

**Response:** NASA acknowledges the importance of regularly assessing the Planetary Research Program (and the R&A portfolio) to ensure continued alignment with its science objectives. Through the yearly ROSES cycle, PSD looks at programmatic needs across the Program and makes adjustments as necessary. More in-depth reviews are potentially valuable for assessment of program health; for instance, the 2009 National Research Council report “An Enabling Foundation for NASA’s Earth and Space Science Missions” highlighted the importance of R&A programs. This, in combination with Visions and Voyages, resulted in an effort from 2011–2014 that culminated in the restructuring of the PSD R&A Program. The NRC further reviewed the restructured program in 2017, producing the report “Review of the Restructured Research and Analysis Programs of NASA’s Planetary Science Division.” These studies are valuable because of the significant time and effort provided by the community, and as such, they cannot be carried out at the cadence suggested here.

NASA concurs that changes to programs and to program structures should be announced in a timely way.

**17-7: To improve the proposal review process, NASA should establish a mechanism to permit PIs to respond to major weaknesses from previous submission rounds.**

**Response:** Within the current framework, a PI may already respond to weaknesses from previous submission rounds within the Science/Technical/Management page limit for proposals. This recommendation seems to suggest that such responses be allowed outside of the normal page limit, but this would be a fundamental philosophical shift in NASA’s proposal review system. As described in the ROSES-22 Solicitation, Section 1(f): “Proposers are welcome to resubmit proposals.... Will be peer reviewed and considered with neither advantage nor disadvantage along with new proposals.” The provision of extra pages for resubmissions would be an advantage and contrary to the “even playing field” philosophy of NASA peer review.

**17-8: NASA should undertake a process to continuously evaluate and improve its R&A proposal review and selection procedures such as, e.g., review efficiency; optimizing information collected through NSPIRES; review panel formulation, implementation, and oversight; reviewer incentivization; factors that influence proposal selection; and ensuring an appropriate balance between high and low risk proposals.**

**Response:** NASA concurs with this recommendation. SMD regularly monitors several characteristics of the R&A solicitation, evaluation, and selection processes, including success rates, the time taken to announce selections, submission and selection rates of high-risk/high-impact science, and the number of new PIs selected for every R&A solicitation. SMD has also implemented a specific fund to increase the likelihood of selection for proposed research designated as high-risk/high-impact. Additionally, SMD annually analyzes demographic trends in proposals and selections, and will soon add analyses of reviewer demographics. SMD is planning on releasing an annual “Research Programs Yearbook” starting with ROSES-2021 that will report many of these statistics to the community. SMD also encourages and sponsors trials of process innovations such as the “just in time” budget approach of the ROSES 2021 Discovery Data Analysis Program, the removal of due dates from PSD major programs, dual-anonymous peer review, and the Astrophysics Division’s test of requiring Diversity and Inclusion Plans in proposals to some programs. Such experiments generally last three years and are evaluated against their initially stated goals at the end of that time.

**17-9: An appropriately constituted independent group should evaluate the impact of DAPR and NoDD on R&A program outcomes, including proposal pressure, proposer and grantee demographics, proposal review ease and fairness, and overall R&A program functionality, before these policy changes are implemented across the full R&A program.**

**Response:** NASA partially concurs with this recommendation. Dual-anonymous peer review (DAPR) was piloted by the Science Mission Directorate (SMD); the DAPR success metrics were developed with external consultants who continue to be involved in the evaluation process. This process is ongoing and may be used to refine the DAPR implementation. DAPR has been strongly endorsed by multiple advisory bodies.

No Due Date (NoDD) is currently at the beginning of the second year of its planned three-year trial. Updates on NoDD will be forthcoming at future PAC meetings. An internal assessment of the program is planned for the third year of NoDD and will explore the topics mentioned in this recommendation. This assessment will be shared with CAPS and the PAC, and the advice from PAC and CAPS on further evaluation will be sought.

**17-10: NASA should collect comprehensive (as legally permitted) information on proposers and submitted proposals as needed to support internal and external assessments of the health of its R&A program, addressing issues that include, e.g., proposing team demographics and employment trends, and factors affecting proposal pressure and budgets.**

**Response:** NASA concurs with this recommendation. Pursuant to Section 9 of the Executive Order on *Advancing Racial Equity and Support for Underserved Communities Through the Federal Government*, the U.S. government has created an Interagency Working Group on Equitable Data to consider what information can be collected and how it should be used across the federal government; SMD will likely adjust its processes based on the outcome of the IWG's efforts. Within this context, PSD is working within SMD to determine both what data can be collected and how it can be collected without imposing significant burden on either the community or Program Officers.

**17-11 and 22-14: NASA PSD should increase its investment in R&A activities (defined in Box 17.2) to achieve a minimum annual funding level of 10 percent of the PSD total annual budget by mid-decade. This increase should be achieved through a progressive ramp-up in funding allocated to the openly competed R&A programs (Table 17.1). Mid-decade, NASA should work with an appropriately constituted independent group to assess progress in achieving this recommended funding level.**

**Response:** PSD partially concurs with this recommendation. PSD has been, and will continue, working through the annual budget cycle to augment the budget for the entire Planetary Research Program (PRP). The PRP includes all activities funded within the R&A Portfolio and those funded under mission lines, and is not limited solely to openly competed R&A programs as defined by this decadal survey.

**17-12: NASA and NSF would realize greater return on their R&A investments by working together to streamline the mechanisms by which researchers can propose and conduct science that is of benefit to both agencies.**

**Response:** NASA concurs with this recommendation. The NASA Astrobiology Program is already engaged with relevant directorates at NSF (e.g., Biological Sciences, Geosciences, Mathematical and Physical Sciences). Using the framework established by the existing NASA/NSF Interagency Act Agreement and keeping within the boundaries set by law, PSD will work with NSF to explore additional possible avenues for collaboration and improved mechanisms by which they could be implemented. Scientific areas of particular interest include Oceanography, Astronomical Sciences, and Polar Science.

## Chapter 18: Planetary Defense

**18-1: NASA’s PDCO should be robustly supported and sustained as the critical organization to advance U.S. planetary defense capabilities and initiatives in the next decade and beyond.**

**Response:** NASA concurs that PDCO is a critical organization. NASA will continue to assess the support and sustainment needs for PDCO, balanced within PSD’s overall portfolio and resources, so that it can continue its lead role in advancing U.S. and international planetary defense capabilities and initiatives into the next decade.

**18-2 and 22-18: NASA should fully support the development, timely launch, and subsequent operation of NEO Surveyor to achieve the highest priority planetary defense NEO survey goals.**

**Response:** NASA partially concurs with this recommendation. NASA will continue to assess the support for the NEO Surveyor, balanced within PSD’s overall portfolio and resources. The NEO Surveyor mission entered Phase B in June 2021 and is on track to complete Preliminary Design Review in the Fall of 2022. NASA is pursuing the earliest launch date possible within the available appropriated funding.

**18-3: NASA should support planning, monitoring, and coordination among the global planetary defense, NEO observing, meteor/bolide, and meteoritics communities to take advantage of the opportunistic events provided by atmospheric entry of NEO materials, and to collect any associated meteorites in order to advance planetary defense objectives.**

**Response:** NASA concurs with this recommendation. Through the Near-Earth Object Observations (NEOO) Program, the PDCO continues to support efforts to derive physical characteristics from observations of natural objects entering the Earth’s atmosphere, as well as the collection of meteorites that fall to Earth’s surface. The PDCO will continue these projects and enhance their reaction times and effectiveness as opportunities and funding become available.

**18-4 and 22-31: NASA and NSF should support studies to develop a plan for ground-based planetary radar capabilities comparable to or exceeding those of the Arecibo Observatory necessary for achieving planetary defense objectives.**

**Response:** NASA believes that Arecibo is useful but not necessary for achieving its planetary defense objectives. NSF is leading a study that NASA is participating in—along with the U.S. Space Force and possibly supported by other entities—to establish the context of the broad national needs for a next-generation planetary radar capability and possible technology concepts for addressing those needs. This NSF-led study is expected to begin in late summer 2022.

**18-5. As the steward of ground-based observatories with NEO observing capabilities, NSF should support and prioritize critical planetary defense observations of NEOs at its ground-based facilities.**

**Response:** NASA has communicated this recommendation to NSF.

**18-6: NASA should study all relevant observing opportunities surrounding the unique Apophis encounter, using both ground and space-based assets. To maximize the scientific and planetary defense return, NASA should develop plans for making the best use of these identified assets during the Apophis encounter and support international cooperation in carrying out these valuable observations.**

**Response:** NASA concurs with this recommendation. NASA has chartered a Specific Action Team (SAT) within the Small Bodies Assessment Group (SBAG) to identify, assess, and prioritize the unique science opportunities presented by this event. The SAT will deliver its report to PSD in August 2022. In addition:

- The OSIRIS-REx extended mission (OSIRIS-APEX) to rendezvous with Apophis shortly after closest approach in 2029 was approved;
- The 2020–21 global observing campaign, coordinated by PDCO through the International Asteroid Warning Network (IAWN), increased international cooperation and ruled out an Earth impact for more than 100 years;
- Plans are in progress, in tandem with those for the International Year of Planetary Defense in 2029, to further increase international awareness and observing activity; and
- PSD and PDCO are maintaining an awareness of mission concepts in development, both in the United States and internationally.

**18-7: NASA should increase levels of support for multiphysics modeling and laboratory experiments necessary to meet the Goal 2 objectives described in the National Near-Earth Object Preparedness Strategy and Action Plan.**

**Response:** NASA acknowledges this recommendation. NASA will continue to examine the programmatic balance of such mitigation research with the primary astronomical aspect of the Near-Earth Object Observations portfolio, to ensure that the level of support continues progress toward meeting the objectives under Goal 2 of the National NEO Preparedness Strategy and Action Plan. NASA's Near-Earth Object Observations Program increased funding for such studies from <5% to >10% as the overall program budget was increased over the past decade, resulting in over a seven-fold increase in funding since 2012.

**18-8: To achieve the modeling, prediction, and information integration objectives listed under Goal 2, NASA should allocate resources for the establishment of a planetary defense modeling pipeline, including support for collaboration between modeling teams and software developers to establish initial requirements.**

**Response:** NASA concurs with this recommendation. NASA will continue to budget for integrated modeling and collaborative technical interchange, to meet the objectives under Goal 2 of the National NEO Preparedness Strategy and Action Plan. NASA plans to build on the capability begun in 2015 with

the establishment of the Asteroid Threat Assessment Project (ATAP) at NASA Ames Research Center, which has developed a Probabilistic Asteroid Impact Risk (PAIR) model that incorporates asteroid sizes and properties to analyze impact scenarios. This involves collaboration with other NASA Centers, U.S. National Laboratories, and other institutions, and ATAP continues to expand participation through the Modeling Working Group and associated technical interchange meetings.

**18-9 and 22-19: The highest priority planetary defense demonstration mission to follow DART and NEO Surveyor should be a rapid-response, flyby reconnaissance mission targeted to a challenging NEO, representative of the population (~50-to-100 m in diameter) of objects posing the highest probability of a destructive Earth impact. Such a mission should assess the capabilities and limitations of flyby characterization methods to better prepare for a short-warning-time NEO threat.**

**Response:** NASA concurs with this recommendation and recognizes that the ability to determine the key characteristics of an imminently dangerous NEO quickly and accurately may be critical to the success of any future mitigation efforts. Moreover, developing a rapid-response capability may significantly enhance Planetary Science opportunities for the study of long-period comets and interstellar objects, which are unpredictable targets of opportunity.

**18-10: Following a rapid-response, flyby reconnaissance mission demonstration, the next highest priority planetary defense mission would be a characterization and/or mitigation mission.**

**Response:** NASA concurs with this recommendation. PDCO will continue to sponsor studies of potential methods to mitigate an NEO impact hazard while in space and ways to more-rapidly characterize an impact-threat object, in collaboration with the international Space Mission Planning and Advisory Group (SMPAG). PDCO will also continue to identify future opportunities for characterization and mitigation mission demonstrations that show sufficient potential for effectiveness and implementation.

**18-11: NASA's Planetary Defense Coordination Office should be funded at adequate levels to conduct a robust program of necessary planetary defense-related activities, technologies, and demonstration missions launching on a regular cadence.**

**Response:** See 18-1.

## **Chapter 19 Human Exploration**

**19-1: Conducting decadal-level science should be a central requirement of the overall human exploration program.**

**Response:** NASA SMD concurs with the intent of this recommendation, but notes that the goals of the human exploration program are often set by the Administration and U.S. Congress and not only by any group internal to NASA. However, the opportunity afforded by human exploration to conduct scientific investigations on the surface of another body should enable us to address Decadal-level science questions. NASA established the Exploration Science Strategy and Integration Office (ESSIO) within SMD as SMD's primary interface with ESDMD. ESSIO, in coordination with PSD, has been guided by the science priorities outlined in community documents, including the previous Decadal, to identify high-priority science objectives to achieve with crew. With the release of this new Decadal report, NASA will look to the science priorities outlined as ESSIO and PSD jointly develop an overarching exploration science strategy (see Responses to Recommendations 19-3 and 19-5). ESSIO is working closely with our ESDMD colleagues to advocate for SMD science objectives and to ensure that the capabilities of Artemis align with SMD needs.

**19-2: NASA should engage with the science community to 1) define scientific goals for its human exploration programs at the early stages of program planning; and 2) ensure scientific expertise in field geology, planetary science, and astrobiology in its astronaut teams.**

**Response:** NASA SMD concurs with this recommendation. SMD, led by ESSIO, has engaged, and will continue to engage, with the science community at every opportunity to define scientific goals for human exploration.

For example, SMD, led by ESSIO and in coordination with ESDMD, has been engaging directly with the science community on a regular basis, through the Lunar Surface Science Workshop (LSSW) series, to receive timely input on critical topics that span all science disciplines. ESSIO, in coordination with Mars Exploration Program (MEP) and ESDMD, has also initiated discussions with the science community to define science objectives for human exploration of Mars, to provide science inputs for early mission planning. SMD works closely with Lunar Exploration Analysis Group (LEAG) and Mars Exploration Program Analysis Group (MEPAG) and have requested input on several critical activities through Special Action Team (SAT) reports (e.g., [Lunar Critical Data Products](#), [Analog Objectives for Artemis](#)). ESSIO and PSD intend to release a call through ROSES22 for a competed Artemis III Geology Team, as well as a call for deployed instruments for the first two crewed missions to the lunar surface.

SMD does not have control over astronaut selection, but supports the inclusion of geoscientists in the astronaut corps and notes that several scientists/geoscientists have been selected in recent years and are among the Artemis Team of astronauts. ESSIO and PSD have also been working closely with the astronaut office for many years to incorporate science, particularly geology, into the astronaut training curriculum and are now developing plans to expand the scientific training for Artemis missions, which will be led by members of the Artemis Internal Science Team.

**19-3: PSD should develop a strategic lunar program that includes human exploration as an additional option to robotic missions to achieve decadal-level science goals at the Moon.**

**Response:** NASA SMD concurs with the intent of this recommendation to develop a lunar strategy that includes human exploration and robotic missions. ESSIO and PSD have initiated discussions to update NASA's lunar science strategy for the Lunar Discovery and Exploration Program (LDEP), to include all mission options at our disposal, including human exploration as well as directed Solar System

Exploration missions and competed New Frontiers, Discovery, Commercial Lunar Payload Services (CLPS), and Small, Innovative Missions for PLanetary Exploration (SIMPLEx) mission classes, to ensure lunar missions address decadal-level science goals.

**19-4: NASA should adopt an organizational approach in which SMD has the responsibility and authority for the development of Artemis lunar science requirements that are integrated with human exploration capabilities. NASA should consider establishing a joint program office at the Associate Administrator level for the purpose of developing Artemis program-level requirements across SMD, ESDMD, SpaceOps, and other Directorates as appropriate.**

**Response:** NASA SMD acknowledges that lunar science requirements must be integrated with human exploration capabilities, with the caveat that SMD and PSD do not have the authority to tell NASA where to place authority and responsibility for major programs that are not in SMD or PSD. As of 2021, the HEO-006 Artemis Utilization Plan assigns to SMD the authority to define science objectives for the Artemis Moon to Mars campaign. NASA has developed an organizational framework that enables SMD to define science objectives for human exploration and to work closely with ESDMD at the program and project levels, to translate those objectives into requirements for specific missions and for specific exploration elements. Key requirements documents and decisions are brought to decisional boards, at both project and program levels, where SMD has voting representation at the DAA and AA levels. As the Artemis campaign evolves, the organizational structure will evolve as well, but the foundation has been set for each directorate to have a voice in key decisions. ESSIO will continue to support the integration of science objectives into mission requirements to ensure human exploration achieves decadal-level science.

**19-5: PSD should have the authority and responsibility for integrating science priorities into the human exploration plans for Mars.**

**Response:** NASA SMD acknowledges this recommendation, with the caveat that SMD and PSD do not have the authority to tell NASA where to place authority and responsibility for major programs. Our efforts at the Moon will provide a foundation for developing a strategy for Mars exploration. NASA has developed an organizational framework that enables SMD to define science objectives for human exploration and to work closely with ESDMD at the program and project levels to translate those objectives into requirements for specific missions and for specific exploration elements. SMD concurrence is required to make any changes to mission science objectives or to requirements that impact science. ESSIO will continue to work closely with MEP/PSD, to ensure high-priority, decadal-level science is addressed and appropriately incorporated into requirements in the Artemis Moon to Mars architecture.

**19-6: NASA should develop a strategy to utilize opportunities to fly science payloads on commercial test flights and crewed missions to the Moon and Mars as such opportunities arise.**

**Response:** NASA PSD concurs with this recommendation. ESSIO and PSD have initiated discussions to update NASA's lunar science strategy for LDEP to include all mission options at our disposal, including human exploration as well as directed Solar System Exploration missions and competed New Frontiers, Discovery, CLPS, and SIMPLEx mission classes. In the coming decade, ESSIO and MEP will further



initial discussions specific to developing a Mars science strategy for missions of opportunity to Mars. NASA will assess approaches to preparing for missions of opportunity within the programmatic and budgetary guidance provided in the Decadal Survey.

## Chapter 20: Infrastructure

**20-1: NASA should expand uplink and downlink capacities as necessary to meet the navigation and communication requirements of the missions recommended by this decadal survey, with adequate margins, while also balancing the demands from other projects, including JWST, Roman Space Telescope, Artemis, and others.**

**Response:** NASA concurs with this recommendation. NASA especially acknowledges this concern and recognizes the growing challenges to supporting current and future human and robotic missions with its Deep Space Network (DSN). Further, without adequate uplink and downlink capacity this Decadal Survey cannot be effectively implemented. The NASA Space Communications and Navigation (SCaN) organization is initiating an ~18-month-long study of the DSN, starting in FY23, to determine the required investments in areas such as infrastructure, automation, and new technology. The study will be coordinated at NASA HQ to ensure that all NASA organizations are represented, while the technical details of the study will be executed by JPL/DSN. Once complete, the study will be delivered to the Space Studies Board (SSB) of NASEM for review.

**20-2 and 22-26: NASA, in partnership with ESA and community stakeholders, should develop the plan for the end-to-end processing of samples returned from Mars. This plan should include the definition, design, and construction of the Mars Sample Receiving Facility to ensure that it is ready to receive the samples by 2031. The plan should also outline the approach for expeditiously distributing the samples to the scientific community for analysis and to a long-term curation facility.**

**Response:** NASA concurs with this recommendation and recognizes the importance of early planning and execution in order for facilities to be ready when samples arrive. Much of the recommended framework for managing the samples has been generated through the Mars Sample Return Science Planning Group and was recently published (Meyer et al. 2022, <http://doi.org/10.1089/ast.2021.0121>). There has also been significant progress recently in preparing for sample arrival. The Science Memorandum of Understanding between NASA and ESA, concerning managing the science of the samples, was submitted to the U.S. State Department and will soon be sent to ESA for formal negotiation. The contracts have been initiated for trade studies examining different sample facility modalities and associated costs. Furthermore, the Mars Sample Return Campaign Science Group (MCSG) members, recently selected through open competition, will help ensure the realization of the science potential of the samples. Our next near-term activities include establishment of the NASA-ESA Joint Sample Management Plan, governing the management of the samples, and the Sample Receiving Project plan governing the facility to be constructed. Development of the sample management plan will follow the five guiding principles of accessibility, transparency, science maximization, return on investment, and one collection, as per the details in Meyer et al. (2022).

**20-3 and 22-27: NASA should evaluate plutonium-238 production capacity against the mission portfolio recommended in this report and other NASA and national needs, and increase it, as necessary, to ensure a sufficient supply to enable a robust exploration program at the recommended launch cadence.**

**Response:** NASA concurs with this recommendation. PSD will continue to update its assessment of the need for plutonium in support of future missions, consistent with this Decadal Survey. The RPS Program Office will continue to work closely with DOE to communicate changes in RPS mission needs and perform timely assessments of both the sufficiency of Pu-238 production and Fast Critical Assembly processing, to meet any increased need. If NASA deems additional plutonium production is needed, NASA will request that DOE communicate the requirements for additional funding through the annual budget formulation process (PPBE).

**20-4 and 22-28: NASA should continue to invest in maturing higher efficiency radioisotope power system technology to best manage its supply of plutonium-238 fuel.**

**Response:** NASA acknowledges this recommendation. PSD will continue to assess the need for higher-efficiency systems and identify options for an appropriate development schedule as the budget allows.

**20-5 and 22-29: NASA should develop a strategy to focus and accelerate development of high energy launch capability, or its equivalent, and in-space propulsion to enable robust exploration of all parts of the solar system. Any new systems that are developed should also build the pedigree to permit the launch of nuclear materials.**

**Response:** NASA acknowledges this recommendation, but a high-energy launch capability is outside of the authorities and responsibilities of SMD/PSD. Although PSD has interest in in-space propulsion, this recommendation will be referred to the Space Technology Mission Directorate (STMD), which has responsibility for developing transformative mission enabling technology. PSD/SMD will work with STMD, as well as the Exploration Systems Development Mission Directorate, in their planning to develop deep-space power and propulsion technologies, to ensure missions are effectively and efficiently supported within the current development roadmaps.

**20-6 and 22-30: NSF-supported, ground-based telescopic observations provide critical data to address important planetary science questions. The NSF should continue (and if possible, expand) funding to support existing and future observatories (e.g., NOIRLab, ALMA, TMT, GMT, ngVLA) and related PI-led and guest observer programs. Planetary astronomers should be included in future observatory plans and development in order to maximize the science return from solar system observations.**

**Response:** NASA has communicated this priority to NSF's Division of Astronomical Sciences.

20-7: See 18-4

## Chapter 21 Technology

**21-1 and 22-34: NASA PSD should strive to consistently fund technology advancement at an average of 6 to 8 percent of the PSD budget.**

**Response:** NASA acknowledges this recommendation. PSD has been, and will continue, working through the annual budget cycle to support technology advancement as best it can as a priority within its available budget. To inform future budget discussions of the technology matters raised in this decadal survey, PSD will develop a new technology plan as described in 21-2.

**21-2: The PSD technology program should create a PSD Technology Program Plan that provides the details on what the program goals are, how the program operates, who is involved, and how the science community and supporting organizations can play a role. This plan should include how plans, funding levels, solicitation approaches, including selection rates, and results are communicated to the community at large. This plan should be prominent on the PSD PESTO website and updated annually. Based on PESTO's charter, this office should be cognizant of all technology efforts related to planetary science, astrobiology and Planetary Defense and could serve as the single organization responsible for all technology development or as a minimum for integrating all technology development.**

**Response:** NASA concurs with this recommendation. Technology is not a program within PSD as defined by NASA Procedural Requirements 7120.5F, but PSD does have a technology plan that was published in 2015 and communicated to all the relevant Advisory Groups ([https://science.nasa.gov/science-pink/s3fs-public/atoms/files/PSD\\_Technology\\_Plan\\_submitted\\_Dec\\_2015\\_2.pdf](https://science.nasa.gov/science-pink/s3fs-public/atoms/files/PSD_Technology_Plan_submitted_Dec_2015_2.pdf)). PSD will develop a revised technology plan within the next two years that considers the priorities and recommendations of this decadal survey, mechanisms to inform the community, the available technology plans from the PSD Analysis and Assessment Groups, and input from the planetary science community as solicited. This plan will have a focus on how best to keep the community at large informed.

**21-3: PSD should establish a standard mechanism for the science community and other relevant organizations to provide input into PSD on technology needs, including new and creative approaches to technology, similar to how the science community provides input through the various science assessment groups (AG). Two possible examples could be a PSD Technology AG, similar to the science AGs, or a collaboration among existing AG technology leads. A mechanism of this sort would be an effective way to increase transparency in the technology program.**

**Response:** Such engagement processes already exist. For example, PSD regularly engages with technology leads in each Analysis and Assessment Group (AG) to receive input and looks to the Decadal Survey every 10 years, and at the mid-term, to provide input on technology needs. If the community believes additional coordination of technology input is required, it is suggested that the community convene an annual meeting with the technology leads from each existing AG, which PSD would attend.

**21-4: PSD should develop a set of return-on-investment metrics that guide the investment and encourage incorporation of technologies. These metrics should be transparent to the planetary science and astrobiology community.**

**Response:** NASA PSD acknowledges this recommendation and will study models for technology return on investment (ROI) metrics as part of the PSD technology plan.

**21-5: This second obstacle (technology at TRL-6 deemed too risky) should be addressed by PSD, and a solution implemented that considers the long-term return on investment of all technologies under development.**

**Response:** NASA acknowledges this recommendation and will assess whether many PSD technologies are truly trapped at TRL-6. If so, PSD will consider remedies in the new technology plan that will be developed (see response to recommendation 21-2). In general, PSD disagrees that TRL-6 technologies are currently deemed too risky. Our Announcements of Opportunity that solicit new missions state the following:

Proposals may contain less mature technologies and/or advanced engineering developments necessary to achieve the Baseline and Threshold Science Missions. These are permitted as long as proposals contain plans for maturing associated systems to TRL 6 (see NASA/SP-2016-6105 Rev 2, *NASA Systems Engineering Handbook*) by no later than PDR, as well as backup plans that will provide adequate mitigation in the event that the systems cannot be matured as planned.

In addition, some of NASA's recent mission selections reflect a willingness to accept these risks when they achieve exciting science. PSD, however, cannot sustain or develop all technologies until there is a return on investment because such an approach would drain resources, especially those resources necessary to develop the new technologies that reflect emerging science priorities.

**21-6: STMD should ensure that its level of investment in SMD mission technologies is balanced at approximately 30 percent of its overall budget with the PSD portion at no less than 10 percent.**

**Response:** SMD and PSD are important customers for STMD. STMD, however, serves not only all NASA Directorates, but also the United States commercial space industry. In addition, many of the technologies STMD works on are cross-cutting and serve multiple customers. STMD does not plan to commit to spending fixed amounts of its funding on particular customers. PSD coordinates with the SMD Chief Technologist to determine which STMD investments are relevant to PSD and will continue to provide STMD a prioritized list of technologies for investment considerations.

**21-7: NASA should initiate or continue activities that pursue the technologies identified in this decadal survey, with particular emphasis on those technologies that enable the recommended science (missions and strategic research), those enhancing technologies that will improve the overall science return on investment, and those dormant technologies that have achieved TRL 6 but are not yet deemed sufficiently mature for inclusion in flight missions.**

**Response:** NASA concurs with this recommendation. As part of the revised technology plan, PSD will review the technologies identified in this decadal survey, prioritizing them based on mission needs.

**21-8: NASA should maintain cognizance of emerging new technologies and encourage the science and engineering communities to explore new ways that these technologies can enable greater science while reducing development and operations costs.**

**Response:** NASA PSD concurs with the recommendation. PESTO will continue to monitor new technology developments through participation in technology conferences and workshops. PSD will continue to engage with the private sector's technology efforts through NASA's SBIR/STTR programs, the Entrepreneurs Challenge, and Technology Showcase (scheduled for January 2023). Additionally, PSD will strengthen ties with other relevant U.S. government agencies (NSF, DARPA, USAF, USSF, etc.), as well as international space agencies (ESA, JAXA, etc.), through sponsorship and participation in appropriate technical interchange meetings, to enhance awareness of its investments and interest in new technologies. PSD will continue to engage with the technology user community on new technologies, through participation in AG meetings and science conferences/workshops. PSD will continue supporting technology infusion programs and incentivize the use of new technologies in AOs.

## **Chapter 22: Recommended Program**

**22-1: NASA's suite of planetary missions should continue to consist of a balanced mix of small, medium, and large missions, enabling both a steady stream of new discoveries and the capability to make major scientific and technical advances, as well as the needed training of future generations of planetary scientists.**

**Response:** NASA concurs with this recommendation and notes that it is in line with our priorities, programs, and plans.

**22-2: NASA should continue the development of the Europa Clipper mission and closely monitor the mission's cost.**

**Response:** NASA concurs with this recommendation, is proud of the progress made by the Europa Clipper team, and is enthusiastic about the mission and its science. Monitoring and containing cost have been, and will continue to be, a priority throughout this mission's development.

**22-3: The highest scientific priority of NASA's robotic exploration efforts this decade should be completion of Mars Sample Return as soon as is practicably possible with no increase or decrease in its current scope.**

**Response:** NASA concurs with the recommendation to return the scientifically selected samples collected by Perseverance for study using advanced instruments available on Earth, as early as practical. There are no current plans to reduce or increase scope.

**22-4: Mars Sample Return is of fundamental strategic importance to NASA, US leadership in planetary science, and international cooperation and should be completed as rapidly as possible. However, its cost should not be allowed to undermine the long-term programmatic balance of the planetary portfolio. If the cost of MSR increases substantially ( $\geq 20$  percent) beyond the \$5.3 billion level adopted here or goes above  $\sim 35$  percent of the PSD budget in any given year, NASA should work with the Administration and Congress to secure a budget augmentation to ensure the success of this strategic mission.**

**Response:** NASA acknowledges the importance of balancing the NASA investment in Mars Sample Return with other priorities in the Planetary Science Division portfolio. The program is currently in Phase A and is working to develop mature cost and schedule estimates prior to agency confirmation at Key Decision Point C. NASA will continue to ensure the most cost-effective approach to program implementation and will continue to assess programmatic balance, and use independent cost estimates and schedule reviews, to inform decision making. In particular, NASA will critically assess any cost increases that exceed the suggested threshold of 35% of the PSD budget in any given year. Based on past experience, a budget augmentation is unlikely in the event of a large cost overrun; rather cuts will probably need to be made to other missions.

**22-5: NASA should develop scientific exploration strategies, as it has for Mars, in areas of broad scientific importance, e.g., Venus and ocean worlds, that have an increasing number of U.S. missions and international collaboration opportunities.**

**Response:** NASA does not concur with this recommendation and asserts that specific scientific exploration strategies should be community-generated by bodies such as the Analysis Groups, advisory committees, and NASEM's standing boards and commissioned studies. Moreover, apart from the notable exceptions of Mars and the Moon, NASA does not balance its portfolio based on specific targets; rather the portfolio is balanced on a broad and evolving range of priorities. Included among these priorities are those identified in this decadal survey, as well as by NASA's competitive processes, administration priorities, emerging synergies with international missions, and other planning that occurs within NASA's broadly applicable programs, such as technology.

**22-6: NASA should maintain the Mars Exploration Program, managed within the PSD, that is focused on the scientific exploration of Mars. The program should develop and execute a comprehensive architecture of missions, partnerships, and technology development to enable continued scientific discovery at Mars.**

**Response:** NASA concurs with this recommendation. The Mars Exploration Program will develop a comprehensive architecture by the end of CY 2022 that can be implemented in parallel with MSR. The architecture will consider science priorities, mission implementation approaches, infrastructure, competed-versus-directed missions, technology, international/commercial partnerships, MSR Sample Receiving Project, and preparing for humans at Mars. To this end, NASA will engage a broad community to help inform the architecture; examples to further this objective include:

- Leveraging previous studies, including the Mars Architecture Strategy Working Group (MASWG) Report.
- The MEP program conducted a community workshop in March 2022 for Low-Cost Science Mission Concepts for Mars Exploration.
- The Mars Exploration Program Analysis Group (MEPAG) has chartered the Mars Concurrent Exploration Science Analysis Group (MCE-SAG) to identify and prioritize scientific objectives and/or investigations that could be executed within the next ten years, in parallel with the Mars Sample Return effort, and in conjunction with Decadal Survey guidance for the Mars Exploration Program (MEP).
- MEP will host an "Industry Day" in fall 2022 to explore potential public/private partnerships. MEP will engage with the international community, through the International Mars Exploration Working Group (IMEWG), to discuss potential collaborations.

Once a draft architecture is developed, MEP will present it publicly (forum TBD) to obtain community feedback.

**22-7: Subsequent to the peak-spending phase of MSR, the next priority medium-class mission for MEP should be Mars Life Explorer.**

**Response:** NASA acknowledges this recommendation and will consider a life-detection mission as part of the MEP architecture plan and conduct concept studies. These studies will include representation from the broader astrobiology community.

**22-8: The development of the goals and measurement requirements for missions addressing both science and human exploration interests should be developed to meet the objectives of both communities.**

**Response:** NASA concurs with this recommendation. SMD is, and will continue, working closely with our ESDMD colleagues, to ensure that science goals and measurement needs are understood and documented, and that the human exploration architecture is designed to meet those needs. SMD will continue to work with ESDMD as the Artemis campaign progresses to generate mission-specific and asset-specific requirements that ensure Artemis missions can address decadal-level science and exploration goals, as defined by community documents.

**22-9: NASA should consider an implementation of I-MIM that prepares for ISRU by humans and addresses the priority climate science questions at Mars related to near-surface ice.**

**Response:** NASA acknowledges this recommendation. I-MIM (International-Mars Ice Mapper) was not funded in the FY23 President's Budget Request. However, the remaining partners (CSA, JAXA, Italian Space Agency (ASI), and Netherlands Space Office (NSO)) are continuing to explore implementation of I-MIM. NASA will remain open to the possibility of a modest contribution to I-MIM, pending results from the Measurement Definition Team, if there is interest from the international partners and it can be accommodated within the MEP program architecture.

**22-10: NASA should continue to support commercial innovation in lunar exploration. Following demonstrated success in reaching the lunar surface, NASA should develop a plan to maximize science return from CLPS by, for example, allowing investigators to propose instrument suites coupled to specific landing sites. NASA should evaluate the future prospects for commercial delivery systems within other mission programs and consider extending approaches and lessons learned from CLPS to other destinations, e.g., Mars and asteroids.**

**Response:** NASA concurs with this recommendation and notes that we are also looking forward to successful CLPS demonstrations. ESSIO's current CLPS strategy is to maximize the science that can be achieved with each delivery, while leveraging the evolving capabilities of the CLPS vendor landers. ESSIO's CLPS science strategy has increasingly focused on high-priority science objectives, with the current PRISM payloads that are small, but complete, packages designed by the community to address important science questions, as outlined in community documents. ESSIO is evaluating how to allow investigators to propose instrument suites coupled to landing sites of their choosing in future PRISM calls. ESSIO is in regular conversation with the CLPS providers to understand their current capabilities and encourage them to grow their capabilities to meet the science community's needs. ESSIO's and PSD's overarching strategy for lunar science (see recommendation 22-11) will include a strategy for using CLPS for lunar science. To better communicate that strategy to the science community, ESSIO is also developing a website to outline the role that ESSIO has within SMD, as well as to provide information about CLPS, including the science payloads scheduled for delivery to the lunar surface.

**22-11: PSD should execute a strategic program to accomplish planetary science objectives for the Moon, with an organizational structure that aligns responsibility, authority, and accountability.**

**Response:** NASA partially concurs with this recommendation. NASA concurs that an integrated lunar science strategy is needed, and that strategy is under development as addressed in the responses to the recommendations in Chapter 19. SMD has an organizational structure with lines of responsibility, authority, and accountability that are clearly defined and continues to explore ways to ensure it is effective. ESSIO is charged with developing and executing the SMD-level strategic program for science and exploration at the Moon. It is important to note that these responsibilities extend beyond PSD to consider the needs of the Heliophysics, Astrophysics, and Biological and Physical Sciences Divisions. With regards to PSD programs, the need for an overarching strategy that includes CLPS and Artemis is understood, as well as the need for directed Solar System Exploration missions and competed New Frontiers, Discovery, CLPS, SIMPLEX mission classes, and lunar R&A. The lunar leadership in PSD



works directly with ESSIO to ensure that LDEP's strategy fully embraces PSD goals. SMD also acknowledges the importance of communicating its organizational structure externally and will continue to be transparent about these relationships in future reporting.

**22-12: The advancement of high priority lunar science objectives, as defined by PSD based on inputs from this report and groups representing the scientific community, should be a key requirement of the Artemis human exploration program. Design and implementation of an integrated plan responsive to both NASA's human exploration and science directorates, with separately appropriated funding lines, presents management challenges; however, overcoming these is strongly justified by the value of human-scientific and human-robotic partnerships to the agency and the nation.**

**Response:** See 19-1.

**22-13: Endurance-A should be implemented as a strategic medium-class mission as the highest priority of the Lunar Discovery and Exploration Program. Endurance-A would utilize CLPS to deliver the rover to the Moon, a long-range traverse to collect a substantial mass of high-value samples, and astronauts to return them to Earth.**

**Response:** NASA acknowledges this recommendation. NASA is assessing the feasibility of Endurance-A and considering different implementation approaches to achieving Endurance-A's science objectives within the scope of programmatic and budgetary guidance provided by this decadal survey. NASA is considering all solutions, including alternative solutions that emerge as the capabilities of the CLPS vendors and the Artemis campaign evolve.

**22-14: See 17-11**

**22-15: See 17-12**

**22-16: NASA and other relevant agencies should catalyze research focused on emerging systems-level thinking about dynamic habitability and the coevolution 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 biosignature—a measurement result interpreted as indicative of the presence of past or present life) and continues to initiate strategies that promote cross-discipline collaboration.

Since receiving this recommendation in the *2019 NASEM Astrobiology Strategy for the Search for Life in the Universe*, the NASA Astrobiology Program has established three new Research Coordination Networks (RCNs) that are interdisciplinary, cross-divisional and facilitate systems-level thinking about dynamic habitability and the coevolution of planets and life, with a focus on problems and not disciplines. The three new RCNs are the Network for Ocean Worlds, Pre-biotic Chemistry in Early Earth Environments, and Early Cells to Multicellularity.

In the coming decade, the NASA Astrobiology Program will work with the research community via the RCNs and relevant AGs for ideas and connections to other agency activities designed to enhance systems-level approaches to answering the fundamental questions in Astrobiology. We will also use the framework established by the existing NASA/NSF Interagency Act Agreement, and continue to engage with relevant directorates at NSF (e.g., Biological Sciences (BIO), Geosciences (GEO), and Mathematical and Physical sciences (CHE Division)), to develop new partnerships to advance system science through co-sponsored workshops and coordinated research announcements of opportunity. Partnerships with other federal agencies, academic institutes, and non-profits (e.g., Simons Foundations, Kavli Foundation, Templeton Foundation) will be explored.

**22-17: 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 in applicable astrobiology research and exploration on subsurface habitability.

Since receiving this recommendation in the *2019 NASEM Astrobiology Strategy for the Search for Life in the Universe*, the NASA Astrobiology Program has shifted its funding focus to prioritized support for investigations involving targets (e.g., subglacial/sub-ice environments, caves, aquifers, deep sea), technologies (e.g., drilling and AUV), and research-enabling subsurface exploration.

In the coming decade, the NASA Astrobiology Program will continue to prioritize subsurface research and technology. In addition, program leadership will take advantage of advisory board service (e.g., Sanford Underground Research Facility (SURF), International Ocean Drilling Program, Ocean Exploration Advisory Board) to expand opportunities for NASA researchers to engage in subsurface exploration.

**22-18: 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 Planetary Sciences Division’s PICASSO and MatISSE instrument development programs, targeted technology development programs for Ocean Worlds, and the Planetary Science and Technology through Analog Research (PSTAR) program.

Since receiving this recommendation in the *2019 NASEM Astrobiology Strategy for the Search for Life in the Universe*, the NASA Astrobiology Program has worked with the Planetary Exploration Science and Technology Office (PESTO) and Space Technology Mission Directorate (STMD) to develop solicitations for instruments and sample handling technology related to life detection. Additionally, the program and PESTO co-sponsored a two-week Future of the Search for Life (FoSL) workshop, run by the Network for Life Detection (NfoLD) RCN, bringing together scientists and engineers to develop specific life-detection technology requirements necessary to strengthen our solicitations.

In the coming decade, the NASA Astrobiology Program will directly engage with PESTO and STMD to look for additional opportunities to accelerate the development of technologies necessary for future life-detection missions. NASA may, for example, consider incentivizing life-detection technologies in AOs.

**22-19: See 18-2**

**22-20: See 18-9**

**22-21: The Discovery program has made important and fundamental contributions to planetary exploration and should continue to be supported in the coming decade.**

**Response:** NASA concurs with this recommendation and notes that the Discovery Program is a continuing part of PSD programs and plans for the coming decade.

**22-22: NASA should provide a ~50 percent increase in the SIMPLEx cost cap for future calls to expand the range of possible destinations and increase the scientific return from this program.**

**Response:** NASA appreciates the effort undertaken by the Decadal Survey Committee to evaluate cost caps, which mirrors a debate that NASA has been having internally for quite some time. Because cost cap policies are a major driver in our competitive mission process, NASA plans to continue its analysis and will carefully consider this input.

**22-23: The Discovery Phase A through F cost cap should be \$800 million in FY25 dollars, exclusive of the launch vehicle, and periodically adjusted throughout the decade to account for inflation. This cap will enable the Discovery Program to continue to support missions that address high-priority science objectives, including those that can reach the outer solar system.**

**Response:** NASA concurs with the intent of this recommendation. Beyond that, NASA offers the same response as to 22-22, with the amendment that further analysis is needed to ensure that missions to the outer solar system are feasible under the suggested approach.

**22-24: Mission themes for the NF-6 and NF-7 calls should continue to be specified by the decadal survey. Additional concepts that may arise mid-decade due to new discoveries should be evaluated by an appropriately constituted group representing the scientific community and considered for addition to NF-7.**

**Response:** NASA concurs with this recommendation. NASA also appreciates the science prioritization inherent in the list of mission themes mission provided by this decadal survey for New Frontiers opportunities. NASA believes that science community involvement when setting parameters for announcements of opportunity, including the mission themes for New Frontiers, is extremely valuable and intends to continue this practice.

**22-25: New Frontiers should have a single cost cap that includes both Phase A-D and the primary mission Phase E-F costs, with a separate, additional cost cap allocation for a mission's quiet cruise phase. This approach will enable the NF Program to optimize mission science, independent of cruise duration.**

**Response:** NASA concurs with the intent of this recommendation. Beyond that, NASA offers the same response as to 22-22, with the amendment that further analysis is needed to ensure that missions to the outer solar system are feasible under the suggested approach.

**22-26: The NF Phase A-F cost cap, exclusive of quiet cruise phase and launch vehicle costs, should be increased to \$1.65 billion in FY25 dollars. A quiet cruise allocation of \$30 million per year should be added to this cap, with quiet cruise to include normal cruise instrument checkout and simple flyby measurements, outbound and inbound trajectories for sample return missions, and long transit times between objects for multiple-target missions.**

**Response:** NASA concurs with the intent of this recommendation. Beyond that, NASA offers the same response as to 22-22, with the amendment that further analysis is needed to ensure that missions to the outer solar system are feasible under the suggested approach.

**22-27: See 20-2**

**22-28: See 20-3**

**22-29: See 20-4**

22-30: See 20-5

22-31: See 20-6

22-32: See 18-4 (20-7 is also a duplicate of this recommendation)

22-33: See 19-1

22-34: See 19-4

22-35: See 21-1

## Other recommendations in Chapter 22 that are not called out individually

**Representative Flight Programs, page 22–36:** NASA acknowledges the representative *Program Portfolios* offered for both *Recommended* and *Level* programs. NASA notes that the current PSD budget is less than the *Level* budget through 2028 and will consider these recommended portfolios along with the *Budgetary Decision Rules* in future planning.

**Flagship Missions, page 22–37:** NASA acknowledges the recommended flagship missions of Uranus Orbiter and Probe (UOP) and Enceladus Orbilander (EO). NASA plans to initiate studies of the UOP no later than FY2024 that will explore the range of options and costs for consideration. NASA notes that the current PSD budget through 2028 is less than the *Level* budget and that it will be challenging to support the start of a new flagship in that period. Further, it is anticipated that studies of the EO concept will be initiated no earlier than FY26.

**Budgetary Decision Rules, page 22–40:** NASA welcomes the clearly stated list of priorities to be considered if the budget is reduced below the proposed *Level* program, and appreciates both the challenge and effort inherent in creating this list. NASA will carefully consider this input in future planning and budgeting processes, but acknowledges that other factors—including, but not limited to, NASA and administration priorities, national needs, and emerging programmatic matters—will also play a role in priority setting.