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

JUL 29 2011

Reply to Attn of: SMD/Planetary Science Division

Dr. Charles F. Kennel
Chair, Space Studies Board
National Research Council
500 5th Street, NW
Washington, DC 20001

Dear Dr. Kennel:

In March 2011, the National Research Council (NRC) delivered the new planetary science decadal survey entitled "Vision and Voyages for Planetary Science in the Decade 2013-2022." I would like to thank you for this comprehensive review of NASA's programs in this field and its carefully considered recommendations for the future. Indeed, its innovative decision tree provisions for future flagship missions have already made a central contribution to decision-making in our Mars Exploration Program. Please express my appreciation to the Chair, Dr. Steven Squyres, and to all of the volunteers and staff who worked to bring this unusually complex project to such a successful conclusion.

We have reviewed the findings and recommendations of the report and I am pleased to convey to you our responses to them. In the enclosure, you will find these recommendations and our responses clustered by topic for readers' convenience. In general, our existing planning appears, by and large, well-aligned with the report's recommendations within constraints of available and anticipated budgets. Please do not hesitate to contact Dr. Jim Green, who can be reached at (202) 358-1588 or at james.green@nasa.gov, with any questions.

Sincerely,

Edward J. Weiler
Associate Administrator for
Science Mission Directorate

Enclosure

Planetary Science Division Response to the Planetary Science Decadal Survey

Based on the recommendation of the Chair of the Committee on the Planetary Science Decadal Survey Steering Group, the recommendations of the Decadal Survey and our responses to them follow the general order of Chapters 9, 10, and 11 of the Decadal Survey. The recommendations directed to the NSF are not discussed here, and in many cases, recommendations are grouped by topic into one response.

1. (9-4) **Cost analysis**

"In order to maintain a balanced and orderly program, their (the missions studied) **final costs must not be allowed to grow significantly beyond those estimated here"** (CATE Analysis).

Response

NASA concurs with this recommendation. The independent Cost and Technical Evaluations (CATE) performed for the Decadal Survey were NRC-directed and NASA supported. These evaluations as well as several other tools will be used as guides for validating cost estimates as future missions are considered. Should the expected cost of a mission grow significantly, NASA will reconsider the science benefit relative to the increased cost in order to make a determination to descope, delay, cancel, or move forward with the mission. For missions with higher technical risk, pre-mission investment in relevant technology and/or an extended Phase A or B mission phase may be implemented to help prevent cost overruns later in the mission. NASA will continue to keep the Planetary Science Subcommittee and the NASA Advisory Council informed of mission costs and areas of cost growth on a periodic basis, seeking their recommendations as problems arise.

2. (9-6) **Portfolio Funding Strategy**

"NASA's suite of planetary missions for the decade 2013-2022 should consist of a balanced mix of Discovery, New Frontiers, and Flagship missions, enabling both a steady stream of new discoveries and the capability to address larger challenges like sample return missions and outer planet exploration."

Response

NASA concurs with this recommendation. The guidance provided in the Planetary Decadal Survey is a well thought-out decision tree that will be used to guide planning under the current and near-term budget environment and as the Agency prepares its Fiscal Year (FY) 2013 and subsequent budget requests. In addition, NASA will use the NASA Advisory Council structure to engage the planetary science community as the portfolio of missions to be conducted in the next decade is considered and determined.

3. (9-7 & 9-8) **Discovery Program**

"The Discovery Program has made important and fundamental contributions to planetary exploration, and can continue to do so in the coming decade." "The committee recommends that NASA continue to allow Discovery missions to be proposed to all planetary bodies, including Mars". "The committee recommends continuation of the Discovery program at its current level, adjusted for inflation, with a cost cap per mission that is also adjusted for inflation from the current value (i.e., to about $500 million FY2015)." "The committee recommends a regular, predictable, and preferably short (≤24 month) cadence for Discovery Announcement of Opportunity (AO) releases and mission selections." "The committee recommends that future Discovery AOs allow space-based telescopes to be proposed, and that planetary science from space-based telescopes be listed as one of the goals of the Discovery program."

Response

NASA agrees with the tremendous value provided to planetary science of the Discovery-class projects and that they should be our most frequently solicited planetary missions. NASA will continue to solicit for science proposals on all solar system bodies, excluding Earth and Sun, via the Discovery Program. We plan to maintain the cost cap at the current value ($425M FY2010 $), adjusted for inflation and excluding launch vehicle costs that will be covered under other Discovery Program funding. We will strive, budget allowing, to achieve a 24-month period between Discovery Announcements of Opportunity (AOs), although it will take a few years of budget adjustment before this becomes routine again. Specifically, the next AO may not be released until at least 36 months after the Discovery 2010 AO (June 7, 2010) because of budget constraints. However, our goal would be to then achieve the 24-month cadence. Remote observation of solar system bodies by a space-based telescope will continue to be allowed as a Discovery project, but a specific planetary science objective must still be a focus of the mission proposal, and it must be demonstrated to be affordable under Discovery Program cost caps. Extrasolar planet-focused missions would not qualify for the Discovery Program and should be proposed to the Explorer Program sponsored by NASA's Astrophysics Division. In addition, we plan to continue to offer government-furnished technologies—*e.g.*, the Advanced Stirling Radioisotope Generator (ASRG)—to Discovery Program proposers to utilize NASA-developed technologies.

4. (9-9) **Extended Missions**

"The committee recommends that early planning be done to provide adequate funding of mission extensions, particularly for Flagship missions and missions with international partners."

Response

The PSD recognizes the importance of extended missions for maximizing science value and return on the original investments in these missions. Due to ongoing budget

constraints, the Planetary Science Division (PSD) is currently planning to hold senior reviews for all its planetary missions jointly. This is in line with SMD policy and how the other SMD Divisions perform their reviews. The next such senior review will be in early calendar year 2012. Efforts will be made to minimize the impact of preparing senior review proposals at the time of mission-critical operations. Having all missions compete for limited extended mission funds together will be accomplished as early as possible and in time to notify our international partners with the results for their planning purposes.

5. (9-10) **SALMON**

"The committee welcomes the introduction of this highly flexible SALMON approach, and recommends that it be used wherever possible to facilitate Mission of Opportunity collaborations."

Response

The Stand Alone Mission of Opportunity Notification (SALMON) was developed to provide a rapid and easy opportunity for the science community to participate in opportunity announcements that lead to NASA-funded investigations on non-NASA missions. It is envisioned that this mechanism will continue well into the future.

6. (9-10) **Mars Trace Gas Orbiter**

"The committee supports flight of the Mars Trace Gas Orbiter in 2016 as long as this division of responsibilities with ESA is preserved." "Holding to the 2016 launch schedule is important, as failure to do so could significantly affect other missions, particularly to Mars, that are recommended below". As discussed in greater detail below, the Mars Trace Gas Orbiter is intended to be part of a long term NASA-ESA collaboration on the exploration of Mars".

Response

NASA agrees. The joint NASA/ESA 2016 Mars mission, the ExoMars/Trace Gas Orbiter (EMTGO), has advanced on both sides. The NASA portion of the 2016 mission completed a successful Key Decision Point (KDP)-A review on March 30, 2011, and formally entered Phase A. A Formulation Authorization Document (FAD) was signed shortly thereafter, transitioning the NASA portion of EMTGO into a project. The ESA portion of the mission passed a Systems Preliminary Design Review (PDR) in December 2010 and received approval from the review board to move to Phase C/D. ESA is now negotiating the Phase C/D contract with industry.

The original division of responsibility between NASA and ESA for the 2016 mission has remained stable since the July 2009 bilateral meeting between ESA and NASA: The 2016 mission is led by ESA and will be launched by a NASA-supplied launch vehicle; ESA will provide the EMTGO spacecraft and a technology demonstration Entry, Descent and Landing Demonstrator Module (EDM). The orbiter will conduct a survey of trace gases in the Mars atmosphere to understand the gases' lifetimes and the location and nature of subsurface sources that produce gases such as methane, as originally planned, and the

science payload consists of four U.S. instruments and one European instrument, which were selected jointly. Programmatically, the 2016 orbiter will also serve as a telecommunications relay for future landers and rovers using a U.S.-provided Electra radio. NASA will also be responsible for the Science Operations and a Science Operations Center located at NASA/JPL. With the approval of KDP-A, the schedule for the 2016 orbiter has been established and is being followed.

7. (9-10) **Scientific priorities**

"The appropriate balance across the solar system must be found by selecting the set of missions that best addresses the highest priorities among the overarching questions in Chapter 3. The recommendations below are made in accordance with this principle."

Response

Priorities for Flagship missions are very clearly defined in the Decadal Survey (and discussed elsewhere in this response), as are the New Frontiers-4 and -5 targets, which were defined by the Decadal panels with the science questions in Chapter 3 in mind. As budgets allow, we will address priorities based on the key science questions delineated in Chapter 3, which provide an excellent basis for potential future Discovery missions to propose. The New Frontiers missions are already well balanced from a discipline perspective, because once a mission type is selected, it will be dropped from the competitive list in the next competition. Within Discovery and New Frontiers competitions, NASA will also use technical readiness in the evaluation and selection process in order to maintain a higher likelihood of cost control. Balance is a programmatic concern. NASA does reserve the right to consider programmatic issues as part of the selection process.

8. (9-11 & 9-12) **New Frontiers**

"The committee recommends changing the New Frontiers cost cap to $1.0 billion FY2015, *excluding* launch vehicle costs". "In order to achieve an appropriate balance among small, medium, and large missions, NASA should select two New Frontiers missions in the decade 2013-2022".

Response

NASA concurs and intends to make selections of both New Frontiers-4 and New Frontiers-5 within the decade 2013–2022 in response to AOs with this cost cap.

9. (9-12 & 9-13) **New Frontiers Candidates**

"New Frontiers Mission 4 should be selected from among the following five candidates": Comet Surface Sample Return, Lunar South-pole Aiken Basin Sample Return, Saturn Probe, Trojan Tour and Rendezvous, and Venus In Situ Explorer. **"If either SAGE or Moon Rise is selected by NASA in 2011 as the third New Frontiers mission, the corresponding mission candidate should be removed from the above list**

of five, reducing the number of candidates from which NASA should make the New Frontiers Mission 4 selection to four. For the New Frontiers Mission 5 selection, the IO Observer and the Lunar Geophysical Network should be added to the list of remaining candidate missions."

Response

NASA concurs with the committee's recommendation and is planning to make selections of both New Frontiers-4 and New Frontiers-5 within the decade 2013–2022. The Decadal Survey will be the basis for the science and targets that investigators may propose to accomplish. Given NASA's recent selection of OSIRIS-REx as the New Frontiers-3 mission, the New Frontiers-4 candidate list is currently intended to be the five potential mission candidates as listed in the Decadal Survey report; however, NASA will finalize the candidate mission list for NF-4 after careful deliberation and study coupled with discussion with the advisory structure and updates from the midterm review.

10. (9-14 & 9-16) **Mars Flagship Mission**

"The highest priority Flagship mission for the decade 2013–2022 is MAX-C" the Mars surface science and sample caching mission **"which will begin the NASA-ESA Mars Sample Return campaign".** The mission concept studied for the Decadal Survey, the Mars Astrobiology Explorer-Cacher (MAX-C), envisioned two separate rovers—a NASA sample-caching rover and the ESA ExoMars rover—landed on a pallet by the "sky crane" entry, descent, and landing (EDL) system that is derived from the Mars Science Laboratory (MSL) EDL system. **"However,"** the Decadal Survey considered the $3.5 billion estimated cost of this concept to be a "disproportionate share of the NASA's planetary budget" and **"the cost of MAX-C must be constrained in order to maintain programmatic balance." "The committee recommends that NASA should fly the MAX-C mission in the decade 2013–2022 only if it can be conducted for a cost to NASA of no more than approximately $2.5 billion (FY2015 dollars)."** The Decadal Survey noted that this "high cost results in large part from the goal to deliver two large and capable rovers" to the Martian surface. The Decadal Survey's cost and technical assessment projected that "accommodation of two such large rovers would require major redesign of the MSL EDL system, with substantial associated cost growth". Therefore, the Decadal Survey stated that, "It is likely that a significant reduction in mission scope will be needed to keep the cost of MAX-C below $2.5 billion." **"In order to be of benefit to NASA, this partnership must also involve ESA participation in other missions of the three-mission Mars Sample Return campaign."** The best way to maintain the partnership will be an equitable reduction in scope of both the NASA and ESA objectives for the joint MAX-C/ExoMars mission, so that both parties still benefit from it." Joint NASA-ESA engineering studies that had been underway for over a year were simultaneously coming to a similar conclusion, and by December 2010 NASA had determined the dual-rover mission carried unacceptably high cost and technical risk and would have to be descoped, and had begun those discussions with ESA in February 2011. **"The guiding principle for any descope process should be to preserve the highest priority science objectives of the total Mars program for both agencies while reducing costs to acceptable levels."**

Response

NASA agrees. The NASA/ESA Joint Mars Exploration Program is currently studying a rescoped joint Mars 2018 mission concept to achieve the science and technology objectives of both NASA and ESA. Consistent with the Decadal Survey's recommendation, a significant cost reduction is being pursued by accomplishing those objectives with a single rover design that eliminates the landed pallet and avoids a major redesign of the MSL-derived EDL system, while maintaining the NASA-ESA partnership for the Mars Sample Return (MSR) campaign and science objectives. It is envisioned to have landing site accessibility and rover traverse ranges that are comparable to MSL. One benefit of the joint rover concept is that the analytical capability provided by the Pasteur payload on ExoMars may be utilized in the selection of sample suites for the cache. The envisioned combination of robust *in situ* analytical capability with accessibility to scientifically compelling landing sites results in a Mars astrobiological surface/subsurface exploration mission that promises "Decadal-class" scientific return as well as a sample cache for Earth return.

Scientifically, this recommendation is consistent with MEPAG goals and with previous NRC studies, including the 2003 Decadal Survey and the 2007 *An Astrobiology Strategy for the Exploration of Mars*. The Mars Exploration Program and Mars community have been planning for this challenging opportunity for quite a number of years. The Mars community has recognized the challenges of defining the criteria for selecting samples for caching and returning to Earth. Over the past several years, three Science Analysis Groups (SAGs) have been commissioned to consider the site characteristics, the sampling regime, measurements required for selecting samples, the number and mass of the samples to be cached, and the requirements for containing the cached samples, all of which are factors to be considered to maximize the science return on the sample acquired on Mars. Studies have included the Next Decade SAG, focused on the nature and number of the samples, the Mid-Rover SAG, focused on medium-sized rover capabilities and sample selection, and an ongoing End-to-End international SAG to develop the overall goals of MSR, from which the goals of the Mars 2018 mission and the follow-on architecture required to complete the MSR campaign will be derived. The deliberations include how certain landing sites fulfill different sets of multiple science objectives and what instrument capabilities should be added to the joint rover to effectively select samples for caching. Currently, the joint NASA/ESA rover under study is expected to retain elements of the ExoMars Pasteur scientific payload and the subsurface drill, as well as a NASA sample handling and caching system and the scientific instruments needed to select an outstanding sample. It is also clear that the range of accessible samples is extremely site-dependent and a process for determining future landing sites is in progress. A Joint Science Working Group is currently being formed to fill the role of a traditional science definition team, and will set the science requirements for the 2018 mission.

11. (9-16 & 9-17). **Jupiter Europa Orbiter Flagship**

"The second highest priority Flagship mission for the decade 2013 - 2022 is JEO (Jupiter Europa Orbiter). **However, its cost as currently designed is so high that both**

a decrease in mission scope and an increase in NASA's Planetary Budget are necessary to make it affordable. "It should fly in the decade 2013-2022 only if changes to both the mission and the NASA planetary budget make it affordable without eliminating any other recommended missions". "NASA should immediately undertake an effort to find major cost reductions for JEO, with the goal of minimizing the size of the budget increase necessary to enable the mission". The committee also recommends that JEO switch to Advance Stirling Radioisotope Generators (ASRGs) for power production, rather than Multi-Mission Radioisotope Thermoelectric Generators (MMRTGs), reducing the amount of plutonium-238 necessary to carry out the mission."

Response

NASA agrees with the constraints recommended for a Europa Flagship mission and has initiated a new study to examine descoped, lower-cost missions focused only on Europa science objectives. This set of focused missions will be presented to OPAG and the PSS in October 2011, with the expectation that one or two of these focused mission concepts will be studied in greater detail in 2012. The results of the 2012 study will undergo independent science and technical review. Assuming a successful outcome of this study, NASA will consider implementing the mission as funding allows. These mission concepts have been directed to utilize ASRGs or solar power instead of MMRTGs.

12. (9-17) **Potential Flagship Missions**

The committee provides a prioritized list of five Flagship missions (MAX-C, JEO, Uranus Orbiter and Probe, Enceladus Orbiter, Venus Climate Mission) and states, **"The third highest priority Flagship mission is the Uranus Orbiter and Probe mission."** The committee recommends **"the Uranus Orbiter and Probe mission should be initiated in the decade 2013 - 2022 even if both MAX-C and JEO take place". "The fourth and fifth highest priority Flagships missions are, in alphabetical order,"** (not prioritized) **"the Enceladus Orbiter and the Venus Climate Mission". "These missions should be considered for the decade 2013-2022 only if higher-priority Flagship missions cannot be flown for unanticipated reasons, or if additional funding makes them possible as noted below".** However, **"The scope of each of the recommended Flagship missions cannot be permitted to increase significantly beyond what was assumed during the committee's cost estimation process."**

Response

NASA agrees with the prioritized list of Flagship missions and the constraints recommended for their flight schedule. NASA also supports the Survey's view that continued study and technology development both enable missions and reduce their cost and risk. To that end, NASA anticipates continued study of these Flagship missions and the deferred missions. One or two of these studies will be conducted each year. The scientific community will be involved via Science Definition Teams and the appropriate Assessment Group(s), and each study will conclude with an independent technical and scientific evaluation. As the studies are completed, NASA will evaluate inserting the identified technology needs for each mission into its technology development portfolio.

NASA will use the Decadal Survey's recommendations to limit the scope of each of the recommended Flagship missions.

Under the current budget environment, NASA faces immense fiscal challenges initiating the highest priority Flagship missions (MAX-C and JEO), and it is unlikely that NASA can execute the Survey's recommendation to initiate the Uranus Orbiter with Probe mission along with MAX-C or JEO in this decade. The Uranus Orbiter with Probe mission will be studied as part of the process described above, as will the Enceladus Orbiter and the Venus Climate Mission if funds become available.

13. (9-21) **Priorities under increased budgets**
"If this (increased funding for planetary exploration) **happened, the committee's recommended additions to the plans presented above would be, in priority order: 1) an increase in funding for the Discovery Program, 2) Another New Frontiers Mission, and 3) Either the Enceladus Orbiter or the Venus Climate Mission."**

Response
If NASA obtains additional funding, the Decadal Survey's decision-making rules and recommendations will be used to affect its distribution. International collaborations will be pursued when possible to reduce the cost to NASA and enable scientific achievement sooner than if the mission was funded solely by NASA.

14. (9-17) **Deferred Flagship Missions**
The committee further recommends those **"candidate Flagship missions from the list above that cannot be initiated in 2013–2022 should receive thorough technical studies and technology investments, so that they will be ready in time for consideration in the next decade."**

Response
NASA intends to continue and expand its program of regular future mission studies with the goal of identifying as early as possible the technology requirements and common needs for likely future missions, as well as the highest priority technologies for maturation, demonstration, and infusion. When appropriate, these studies should be community-driven and peer-reviewed. The results of these studies should be captured and documented using a common template for study reports. The goal is to target NASA's technology program on the planetary missions that NASA intends to fly, and NASA's technology activities will be competed wherever possible.

15. (9-21) **Priorities under reduced budgets**
"If cuts to the program are necessary, the committee recommends that the first approach should be descoping or delaying Flagship missions. Changes to the New Frontiers or Discovery programs should be considered only if adjustments to Flagship missions cannot solve the problem. And high priority should be placed on

preserving funding for Research and Analysis programs and for technology development.

Response
The President's FY12 budget delivered to Congress in February 2011 shows a reduced budget. NASA will use the decision-making rules delineated in the Decadal Survey to develop a program that is as balanced as possible.

16. (9-22) **Titan Saturn System Mission**
"Because the Titan Saturn System Mission is a particularly strong candidate for the future, continued thorough study of it is recommended".

Response
Given the importance attached to the Titan Saturn System Mission, the low probability of the full mission flying within the next two decades, and the mission's ability to be split into smaller missions, NASA anticipates future studies to devolve this large Flagship mission into separate flight opportunities of varying sizes. In the meantime, Cassini is still operating, with at least 44 more flybys of Titan planned (budget permitting). A Discovery-12 candidate mission is under Phase-A study to land and float on a large methane-ethane sea on the Saturnian moon, in the first direct inspection of an ocean environment beyond Earth. The mission proposes to study the composition and behavior of the sea and its interaction with Titan's weather and climate and look for the complex organic chemistry believed to exist on the moon, and which may be similar to that which led to the development of life on Earth.

17. (9-22) **Future Flagship technology development**
"it is important to make significant technology investments in the Mars Sample Return Lander, Mars Sample Return Orbiter, Titan Saturn System Mission, and Neptune System Orbiter and Probe"

Response
NASA supports the Survey's view that continued study and technology development for operations in extreme environments both enable future missions and reduce their cost and risk. To that end, NASA anticipates continued study of these Flagship missions and the deferred missions. One or two of these studies will be conducted each year. The scientific community will be involved via Science Definition Teams and the appropriate Assessment Group(s), and each study will conclude with an independent technical and scientific evaluation. As the studies are completed NASA will evaluate inserting the identified technology needs for each mission into its technology development portfolio.

Recommendation regarding JEO's use of ASRGs (9-26) is included in #11 above.

18. (9-26) **Plutonium-238 Restart**

"The committee is alarmed at the status of plutonium-238 availability for planetary exploration. Without a restart of plutonium-238 production, it will be impossible for the United States, or any other country, to conduct certain important types of planetary missions after this decade."

Response

NASA believes that the domestic production of Pu-238 is central to continued leadership in deep space exploration. Without Pu-238 or a suitable alternative, it is only a matter of time before much of the outer solar system and certain types of lunar missions are closed to NASA.

NASA continues to work aggressively with the Department of Energy (DOE) to establish funding for a project to restart Pu-238 production in the United States. NASA has provided a report to Congress as requested in the NASA Authorization Act of 2010, on NASA's requirements for Pu-238, and the planned implementation of a Pu-238 production project with DOE. Under the terms negotiated between NASA and DOE, the cost of the Pu-238 production project will be shared between NASA and DOE. NASA has been authorized to fund this effort in the NASA Authorization Act of 2010. Under the terms of the full year continuing resolution for FY2011, NASA will begin funding the Department of Energy to provide an analysis of alternatives on how the Pu-238 production project may be accomplished, and establish a range for possible project cost and schedule in order to achieve the DOE milestone "Approve Alternative Selection and Cost Range." NASA will hold the project at this milestone pending resolution of the project co-funding issue. NASA awaits Congressional action on appropriations for FY2012, and is prepared to fund the effort to restart Pu-238 production capabilities with the commitment of NASA and/or DOE resources by Congressional appropriators.

19. (10-3) **R&A funding**

"The committee strongly encourages NASA to find ways (e.g., by merging related research programs and lengthening award periods) to increase average grant sizes and reduce the number of proposals that must be written, submitted, and reviewed by the community." "The committee recommends that NASA increase the research and analysis budget for planetary science by 5 percent above the total finally approved FY2011 expenditures in the first year of the coming decade, and increase the budget by 1.5 percent above the inflation level for each successive year of the decade."

Response

The recommendation to increase grant size and reduce the number of proposals written and reviewed may be implemented after we determine the effects of such changes, including their potential impact on the community. Without a significant increase in the R&A budget, increasing grant size and length of awards will decrease selection rates (especially changing annual grant sizes). This may result in less work for selected proposal teams, but can actually increase the grant-writing burden for others, in particular

early-career scientists trying to break into programs. Careful consideration needs to be given to the impact of changes to the R&A programs' structure, opportunities, and additional requirements of the calls and review process. Certain proposed "fixes" for the community work load may have negative results such as a loss of community members (particularly early-career) or a reduction in the quality of proposals submitted and/or funded, etc.

We strive to minimize the proposal/review burden across the whole community (including especially young investigators) while still maintaining the highest scientific standards. This will be addressed in detail with the Planetary Science Subcommittee of the NASA Advisory Council, and must be in line with their current pending program review.

The Decadal recommendation for increased R&A funding is unrealizable given the declining PSD budget profile in the President's FY12 budget. Rather, PSD will maintain the R&A budget at approximately $200M per year, even as the overall PSD budget declines from FY13 onward. If budgets rise in the future, PSD will seek to implement the Survey's recommendation. The technology elements of the R&A program (PIDDP, ASTID, MIDP, Mars Sample Return Tech, and Outer Planets Technology) will be pulled out of the R&A budget and placed in the PSD Technology Program, providing competitive opportunity for "pure" science content in the R&A program and for flight hardware development in the Planetary Technology Program.

20. (10-6) **Planetary Data System**

The committee provided a number of recommendations to maintain and improve both the extent of data available in the PDS and the overall user experience during interactions with the system. They recommend that **"it is crucial that the capabilities of the Planetary Data System be maintained by NASA, both to provide a permanent archive of planetary data and to provide a means of distributing those data to the world at large".**

Response

The PSD is committed to the continued evolution and improvement of the PDS. Recent, and all future, mission AOs detail the NASA policy to require delivery of datasets to the PDS within a specified time after ground receipt of the data. Subsequent funding for analysis of mission data that is not available in the PDS is not permitted, as Data Analysis Programs require that archival-quality data be available in either the PDS or another publicly available, recognized archive. In addition to contractual obligations on the part of data providers, past performance of Principal Investigators and instrument team members will be evaluated by NASA during the selection process. The generation and submission of higher-level data products will be documented in the Project Data Management Plans (PDMP) for future missions, and approved before confirmation (KDP-C). PSD will continue to provide funding to develop high-level data products for currently operating missions that were confirmed prior to this contractual requirement, in order to ensure their archiving into PDS.

As the PDS has evolved over the past 25 years, the transition from a simple data depository / archive facility to an online resource has required both major and incremental changes. The rollout of the next major revision to the PDS, PDS4, will begin in the next fiscal year. Standards and accepted data formats have been revisited and revised, with a focus on improved search capability and user experience. Results of a recent survey of the PDS are being worked and incorporated into the PDS4 product. The entire user community is encouraged to respond to future surveys and provide feedback to PDS management as we continue to improve this system.

As a founding member of the International Planetary Data Alliance (IPDA), NASA also significantly supports the PDS, encourages interoperability of the PDS with other international repositories of planetary data, and will continue to do so over the next decade. The IPDA builds on the strong cooperative effort between NASA's PDS and the European Space Agency's Planetary Science Archive (PSA). Numerous international space agencies have joined the IPDA, which a PDS member currently chairs on a rotating basis.

21. (10-6) **Funding for derived data products**
The committee recommends that **"For future missions, Announcements of Opportunity (AOs) should mandate that instrument teams propose and be funded to generate derived products before missions have completed Phase E."**

Response
NASA agrees that some critical higher-level data products of archival quality should be funded (consistent with cost caps) by PSD, generated by flight project instrument teams, and delivered to the PDS during Phase E. These data products will be documented in the PDMPs that are developed and approved prior to entering into Phase-C/D at KDP-C.

22. (10-8) **Education and Outreach Funding**
"The committee strongly endorses NASA's informal guideline that a minimum of 1 percent of the cost of each mission be set aside from the project budget for education and public outreach activities."

Response
NASA agrees with this recommendation so strongly that the matter is now covered by a formal policy. The Science Mission Directorate (SMD) Policy Document SPD-18, *Policy and Requirements for the Education and Public Outreach Programs of SMD Missions,* was signed by the SMD Associate Administrator (AA) in January 2010. The funding requirement in this policy states that SMD missions must have an E/PO program that is funded with at least 1% of the total prime mission cost excluding launch vehicle, and that exceptions require approval of the SMD AA. Additional requirements are included in the areas of E/PO management and reporting, review, and approval.

23. (10-12) **Ground based observations**

"Ground-based facilities that receive NASA support, including the Infrared Telescope Facility (IRTF), the Keck Observatory, Goldstone, Arecibo, and the Very Long Baseline Array, all make important and in some cases unique contributions to planetary science. NASA should continue to provide support for the planetary observations that take place at these facilities.

Response

PSD supports ground-based observations through existing R&A program elements (*e.g.*, PAST, PMDAP, NEOO) and will continue to do so. The level of funding will be determined within the context of the capped R&A program. Per Congressional direction, NASA provides $2 million per year for the operation of the Arecibo radar. This directed funding began in FY11. Goldstone is part of NASA's Deep Space Network and is well supported and maintained and an upgrade to Goldstone's radar system is currently in progress. The NASA portion of the funding for the Keck Observatories is funded through NASA's Astrophysics Division.

24. (10-12) **Suborbital platforms**

"A funding line to promote further use of suborbital observing platforms for planetary observations would complement and reduce the load on the already over-subscribed planetary astronomy program.

Response

The Planetary Astronomy (PAST) program does provide for sub-orbital balloon and rocket-borne telescopes as possible assets for observations in its ROSES call. Two separate Decadal Survey white papers expounded upon this topic. It is important to note that proposals that are accepted in this area for suborbital flight must be exceptional due to the limited R&A and technology funds available. Past experience shows that planetary science has very limited use for suborbital platforms, as compared to Heliophysics and Astrophysics. However, suborbital platforms are expected to improve over this next decade (*e.g.*, stability, pointing, duration, etc.), and PSD will continue to monitor their utility to the planetary science community.

25. (10-15) **Deep Space Network**

The committee recommends that all three DSN complexes should maintain high power uplink capability in X and Ka-band, and downlink capability in S, Ka, and X-bands. NASA should expand DSN capacities to meet the navigation and communication requirements of missions recommended by this decadal survey, with adequate margins.

Response

NASA's Space Communication and Navigation (SCaN) program in the Space Operations Mission Directorate has the responsibility to supply the necessary communication and some navigation services to meet the needs of NASA's constantly evolving fleet,

including the Deep Space Network (DSN). Planetary Science, as a principal stakeholder in the DSN, regularly works with SCaN to assure that the necessary services will be available for future missions and especially those identified in the Decadal Survey. As each mission continues to be refined through study within the Planetary Science Division, SCaN will continue to update the necessary requirements with appropriate margins.

Planetary Science recognizes that the DSN also plays a key role as part of mission radio science investigations such as Cassini Radio Science and JUNO Gravity Science. As a result, PSD will continue to work with SCaN to maintain necessary capabilities to achieve identified science goals of these mission investigations.

26. (10-16) **Advisory group for returned samples**
"NASA should establish a single advisory group to provide input on all aspects of collection, containment, characterization and hazard assessment, and allocation of such samples" from Restricted Earth Return missions. **"This advisory group must have an international component."**

Response
NASA concurs that there should be a single source for advice on restricted Earth return missions and that it should have an international component. For unrestricted sample returns, CAPTEM, whose chair is a member of the Planetary Science Subcommittee (PSS) of the NASA Advisory Council (NAC), provides advice on all aspects of sample curation and distribution, and serves as the forum for discussing plans for future sample returns. Restricted sample returns present many more challenges than do unrestricted ones, and will require broader advice than can be supplied by CAPTEM alone. NASA will work toward forming a joint working group that includes CAPTEM and other representation from the PSS, the Planetary Protection Subcommittee of the NAC, as well as other interested organizations, as recommended in previous reports on this subject (e.g., the several SSB reports on MSR, and the NASA Draft Test Protocol). NASA will explore ways of implementing international involvement in this working group within the context of existing procedural and legal requirements.

27. (10-17) **Inclusion of sample curation costs**
"Every sample return mission flown by NASA should explicitly include in the estimate of its cost to the agency the full costs required for appropriate initial sample curation."

Response
Currently, both Discovery and New Frontiers AOs have requirements for budgeting and developing curation plans. The curation plans must cover periods up to two years after the sample has been returned. These costs will be determined for Mars samples, as the Mars Sample Return Campaign matures and details of the Sample Receiving Facility and curation are determined.

28. (10-17) **Technology development for characterization and analysis of future returned samples**

"Well before planetary missions return samples, NASA should establish a well-coordinated and integrated program for development of the next generation of laboratory instruments to be used in sample characterization and analysis."

Response

NASA fully agrees with this recommendation. Note that PSD currently has a program for this purpose, Laboratory Analysis of Returned Samples (LARS), which seeks to develop new analytical instrumentation leading to significant improvements in the precision, resolution, or sensitivity of measurements compared to the existing state of the art instrumentation. This program has already been used to fund technology development for samples returned by the Discovery missions Genesis and Stardust, and accepts proposals to develop analytical capabilities for future sample-return missions, especially selected missions (*e.g.*, OSIRIS-REx).

The potential return of samples from Mars in the next decade will present a unique set of challenges in this area, as specialized instrumentation may need to be developed for use in a future Mars Sample Receiving Facility (SRF). The Mars Exploration Program in consultation with the PSS, PPS, and CAPTEM will develop a proposal for an NRC study to provide recommendations on the technology needed for sample characterization and analysis within an SRF for the purpose of the evaluation of potential risks, release of samples to a curation facility, and distribution to selected laboratories.

29. (11-2) **Substantial Technology Development Program**

The committee unequivocally recommends that a substantial program of planetary exploration technology development should be reconstituted and carefully protected against all incursions that would deplete its resources. This program should be consistently funded at approximately 6-8% of the total NASA Planetary Science Division budget.

Response

NASA agrees that the investment in technology should be increased and will use the 6–8% range of PSD's total budget as a target. NASA also concurs with the principles stated in the recommendation "to protect the technology budget against all incursions that would deplete its resources." NASA will create, and annually adjust, a balanced Planetary Science portfolio that includes technology critical to the science agenda set by the Decadal Survey report. Maintaining a solid technology portfolio will also enable Planetary Science to leverage other technology investments around the agency.

30. (11-13) **Develop through TRL 6**

"The committee recommends that the Planetary Science Division's technology program should accept the responsibility, and assign the required funds, to continue the development of the most important technology items through TRL 6."

Response

NASA agrees with the Committee's recommendation for the PSD technology program to accept responsibility and intends to assign the required funds to continue the development of the most important technology items through TRL 6.

31. (11-4) **Incentivize Technology**

"The committee recommends that NASA should continue to provide incentives for these technologies (i.e., NEXT, AMBR, Aerocapture, ASRG) **until they are demonstrated in flight. Moreover, this incentive paradigm should be expanded to include advanced solar power (especially lightweight solar arrays) and optical communications, both of which would be of major benefit for planetary exploration."**

Response

NASA concurs with this recommendation and is pleased that the Decadal Survey noted the attempts to incentivize the use of NASA-developed emerging technology in our competitive AOs. As more technologies are infused into flight systems, newer, lower-TRL technologies can be matured that will benefit Planetary Science.

32. (11-4) **Technology Program**

"It is therefore essential that the Planetary Science Division develop its own balanced technology program."

Response

NASA concurs with this recommendation. NASA's PSD will develop and maintain its own balanced technology program that responds to the Committee's recommendations. In addition, a solid, sustained Planetary Science-specific technology program will enable leverage of other investments across the Agency. NASA's Office of Chief Technologist (OCT) has already begun soliciting proposals for investment in maturing and demonstrating mission-enabling technologies.

33. (11-5) **Advanced Stirling Radioisotope Generator (ASRG)**

"Since more efficient use of the limited plutonium supply will help to ensure a robust and ongoing planetary program, **the committee's highest priority for near-term multi-mission technology investment is for the completion and validation of the Advanced Stirling Radioisotope Generator."**

Response
NASA concurs with this recommendation and continues to partner with the Department of Energy to ensure it delivers a system capable of meeting our power needs in anticipation of a possible launch in the 2016-2018 timeframe. The qualification of the ASRG will provide Planetary Science with a highly efficient power source adequate to meet the diverse needs of planetary exploration for many years to come.

34. (11-5) **Fundamental Technology**
"It is imperative that NASA expand its investment program in these fundamental technology areas (i.e., the "Core Multi-Mission Technologies" on page 11-4) with the twin goals of both reducing the cost of planetary missions and improving their scientific capability and reliability."

Response
NASA agrees with this recommendation and will invest appropriate resources in "Core Multi-Mission Technologies" as an element of our Technology Development program, expected to be approximately 6–8% of PSD's annual budget. We will seek to establish a balance between technology investments reducing the cost of planetary missions vs. improving their scientific capability and reliability.

35. (11-5) **Systems investments**
"The committee recommends that NASA consider making equivalent systems investments in the advanced Ultraflex solar array technology that will provide higher power at greater efficiency, and aerocapture to enable efficient orbit insertion around bodies with atmospheres."

Response
NASA concurs with the recommendations with the following clarification. Our continued use of incentives will be for targeted technologies that have been developed through a NASA technology program, selected to be featured in specific AOs as appropriate, and demonstrate a maturity level consistent with TRL 6 before the mission PDR. Higher-power solar arrays and aerocapture technology will be given careful consideration when developing the technology investment and infusion plan for the next decade. In the case of aerocapture, NASA may make investments through the OCT. In that case, PSD will partner with OCT to maximize return on investment of technology funds in a similar fashion to the current collaboration for a potential high-mach parachute for Mars entry, descent, and landing.

36. (11-6) **Facilitating insertion of new technology**
"NASA should encourage the intelligent use of new technologies in its competed missions. NASA should also put mechanisms in place to ensure that new capabilities are properly transferred to the scientific community for application to competed missions."

Response
NASA will encourage the intelligent use of new technologies in competed missions by funding those instrument development activities (through TRL 6) with the highest potential for making new discoveries, based upon the recommendations of the Decadal Survey and the results of future mission studies. Other important mission-enabling technologies developed through NASA's new technology programs will also be made available for use in competitive missions (such as the recent incentives for the use of NEXT, AMBR, Aerocapture, or ASRG in the Discovery and New Frontiers' AOs).

As described in NASA's responses to recommendations elsewhere in this document, NASA intends to continue and expand its program of future mission studies with the goal of identifying technology drivers, common technology needs, and priorities for maturation, demonstration, and infusion. These studies will include assessments of the sensitivities of new mission capabilities to technology advancements in order to identify investments that open up new science capabilities and mission options, or that allow missions to be conducted for significantly lower cost (*e.g.*, New Frontiers science at Discovery costs).

37. (11-7) **MSR technology development**
"During the decade of 2013-2022, NASA should establish an aggressive, focused technology development and validation initiative to provide the capabilities required to complete the challenging MSR campaign."

Response
NASA agrees with this recommendation. The Mars Exploration Program is continuing the current early investment in Mars Ascent Vehicle (MAV) technologies. Early in the decade, the PSD will begin to support the timely development of the other technologies required to complete the MSR campaign. This will be fully coordinated with our international partners to assure complementary investments.

38. (11-7) **Technology for High Radiation Environments**
"A supporting instrument technology program aimed specifically at the issue of acquiring meaningful scientific data in a high radiation environment would be extremely valuable, both for JEO and for any other missions that will explore Jupiter and its moons in the future. "

Response
NASA concurs with this recommendation. PSD intends to expand the capabilities of both instrument and spacecraft technologies for extreme environments such as the high-radiation Jovian environment, through awards selected from open competitive calls and funded through the Technology Development program.

39. (11-8) **Balanced Program**

"The committee strongly recommends that NASA strive to achieve balance in its technology investment programs by addressing both the near-term missions cited specifically in this report, as well as the longer-term missions that will be studied and prioritized in the future. "

Response

NASA concurs with this recommendation and will routinely assess the need for new technology to enable future PSD missions, as well as the progress and maturity of current investments to meet the needs of near-term missions. Assessment mechanisms may include future mission studies as described elsewhere in this response, workshops on emerging science capabilities or focused technical areas, and input from the NAC structure (*e.g.*, Science Committee, Subcommittees, and Analysis Groups).

40. (11-10) **Instrument Technology Development**

"The committee recommends that a broad-based, sustained program of science instrument technology development be undertaken, and that this development include new instrument concepts as well as improvements of existing instruments. This instrument technology program should include the funding of development through TRL-6 for those instruments with the highest potential for making new discoveries."

Response

NASA agrees with the Committee's recommendation to undertake a broad-based, sustained program of science instrument technology development that includes new instrument concepts as well as improvements of existing instruments. Additionally, NASA agrees with the Committee's recommendation that this instrument technology program include the funding of development through TRL 6 for those instruments with high potential for making new discoveries, as identified through mission studies and/or through peer review. NASA has several current programs that competitively select and fund instrument technology development, and is assessing improvements in how to structure and aggregate these activities.

41. (11-10) **Expanding the applicability of instruments**

"The committee recommends that, as part of a balanced portfolio, a significant percentage of the Planetary Science Division technology funding be set aside for expanding the environmental applicability of existing engineering and science instrument capabilities."

Response

NASA concurs with this recommendation and will seek to feature the expansion of existing technology to new environments (temperature, pressure, and radiation) and applications in future instrument technology calls. For engineering capabilities, NASA intends to use mission studies, workshops, and inputs through the NAC structure (*e.g.*,

Science Committee, Subcommittees, and Analysis Groups) to help identify and prioritize technologies and environments for future competitive solicitations. For instrument capabilities, NASA is currently assessing how best to restructure and aggregate instrument technology development efforts, and is considering whether it is better to add the expansion of the environmental envelope of existing instrumentation as an option within a larger solicitation or solicit such expansions as a separate opportunity.