Planetary Science Midterm Study

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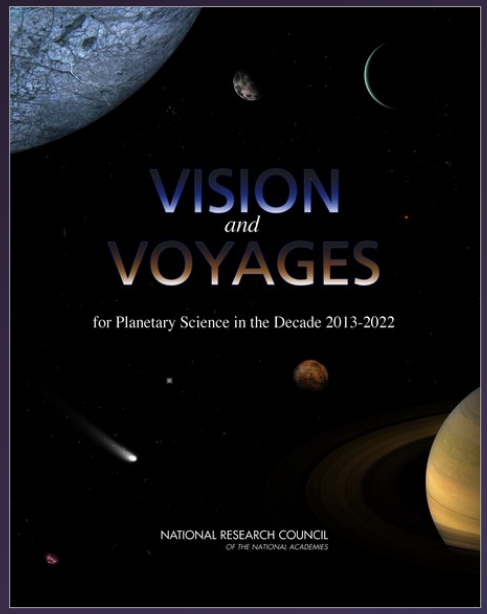
What is a Decadal Survey?

Mechanism by which NASA and other Federal Agencies gauge the research priorities of the scientific community and aid in the selection and design of science projects

- Prepared by National Academy of Sciences for Congress and NASA
- Written by leaders in the field of planetary science, with input from relevant science communities
- All Science Mission Directorates have them (Astrophysics, Earth Science, Heliophysics, Planetary Science)
- They are advice only; the NASA Directorates can fully embrace the recommendations, partially implement them, or ignore them, but…
- The Decadal Surveys do have a lot of influence with Congress and OMB

The 2013 Planetary Decadal Survey

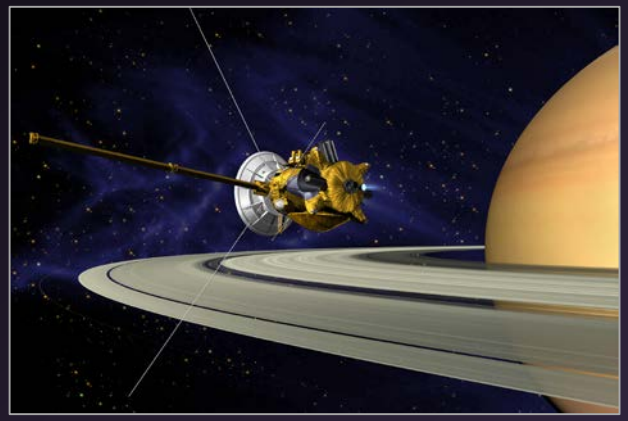
- The ”Vision and Voyages” report represents the official consensus on the top priority scientific goals for planetary science, and the missions required to satisfy them, for the ten-year span between 2013 and 2022
- Steve Squyres (Cornell Univ.) was the Survey Chair
- Organization included a steering committee and five subpanels
  - Terrestrial planets (inc. Moon)
  - Giant planets
  - Small bodies
  - Mars
  - Satellites
- The vice chair from each subpanel sat on the steering committee, among others
- Community members gave input via white papers
- Input was also received from the NASA Analysis and Assessment Groups



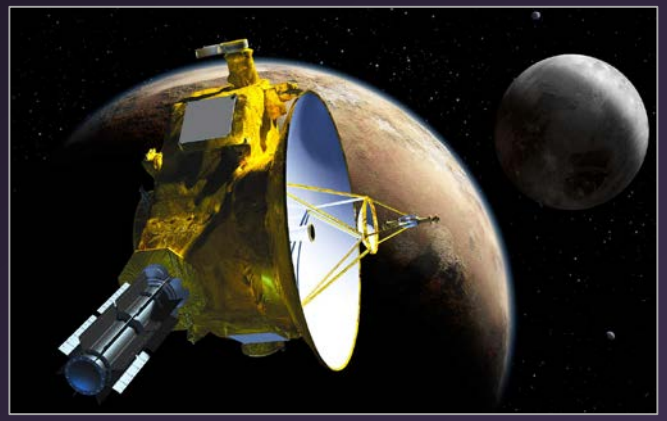
NASA Activities

NASA's Planetary Science Division conducts several activities and missions, including:

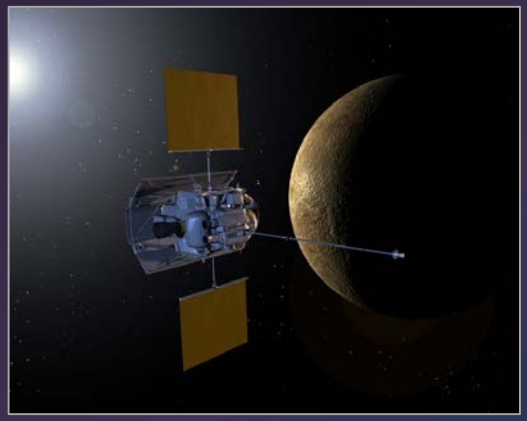
- Flagship missions (large class (>1B+), directed)
- New Frontiers missions (medium class (~$1B), competed)
- Discovery missions (small class ($0.5B), competed)
- Research and Analysis (R&A)
- Technology development
- Mars program



Cassini (flagship class)



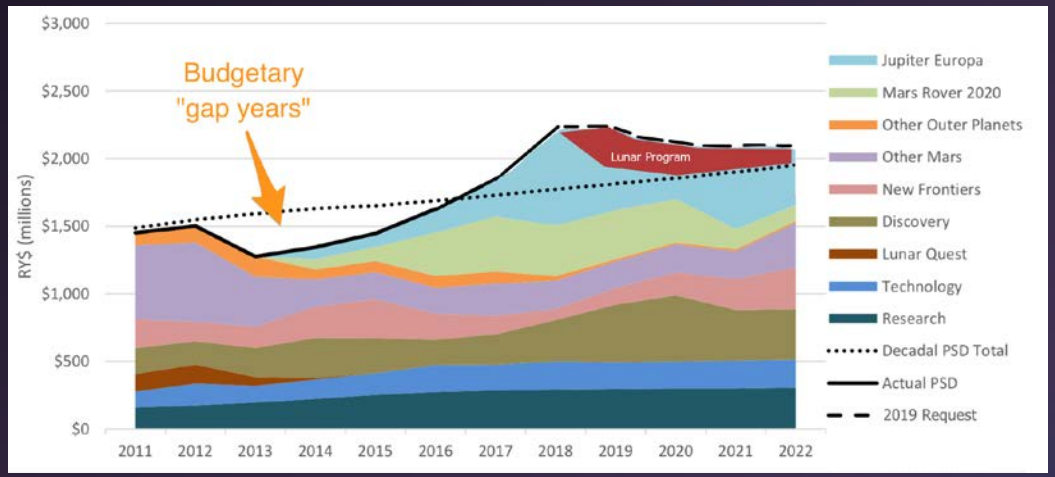
New Horizons (New Frontiers class)



MESSENGER (Discovery class)

The 2013 Planetary Decadal Survey

- The current Planetary Decadal recommended a balanced program of solar system exploration, across mission types and mission targets
- The main recommendations of the Planetary Decadal were:
  - R&A be increased at 5% above inflation at the beginning of the decade, and at the inflation rate every year beyond that
  - 6-8% of the budget should be invested in technology development
  - Discovery missions should be flown every 2 years if possible
  - Two New Frontiers missions should be selected this decade, if possible
  - A Mars sample return mission should be initiated this decade
  - If certain conditions could be met, a Europa orbital mission should be flown
- Several budget scenarios were envisaged; in reality, the budget at the start of the decade was lower than the worst-case scenario



National Academy of Sciences / Casey Dreier

The purpose of the mid-term Decadal Report

- NASA is required by law to conduct a mid-term assessment of each of its Decadal reports
- The purpose is to
  - Assess how well the agency is doing in meeting the recommendations
  - Assess whether any new discoveries warrant a change to NASA's current implementation
- Funding allocated to NASA by Congress is partly based on Decadal recommendations, so lawmakers want to ensure that funds are being spent appropriately
- The mid-term review is NOT to change any priorities from the Decadal, or set new ones

Statement of Task

- Describe significant scientific discoveries, technical advances, and relevant programmatic changes in planetary sciences since Vision & Voyages (V&V)
- Assess degree to which NASA's current planetary science program addresses the strategies, goals, and priorities outlined in V&V and other NRC and Academies reports
- Assess NASA's progress and effectiveness towards realizing these matters and the effectiveness in maintaining program balance
- With respect to the Mars program, the committee's assessment will include:
  - Planetary Science Division's (PSD) Mars exploration architecture and its responsiveness to the strategies, priorities, and guidelines put forward by the National Academies' V&V and other relevant National Academies Mars-related reports
  - Long-term goals of the PSD's Mars Exploration Program and its ability to optimize the science return, given the current fiscal posture
  - Mars exploration architecture's relationship to Mars-related activities to be undertaken by foreign agencies and organizations
  - Extent to which the Mars exploration architecture represents a reasonably balanced mission portfolio
- Recommend actions that optimize science value, how to take into account emergent discoveries
- Provide guidance for V&V's recommended mission portfolio and decision rules for the remaining years of current decadal survey
- Recommend actions that will prepare for the next decadal survey:
  - Community discussion of science goals
  - Potential missions
  - Programmatic balance
  - NASA support of potential mission concept studies

Committee on the Review of Progress toward Implementing the Decadal Survey Vision and Voyages for Planetary Sciences Meetings

Meeting # 1: May 4-5, 2017
Keck Center, Washington, D.C.

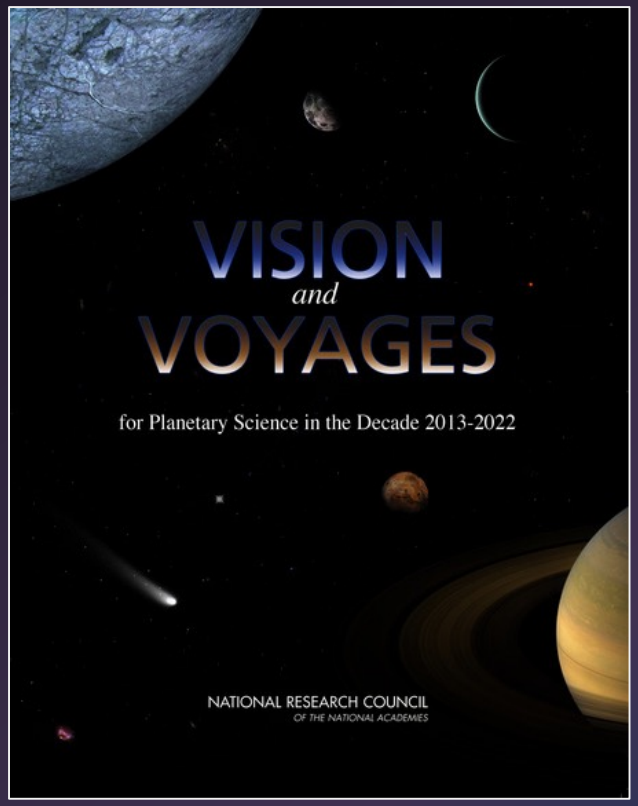
Meeting # 2: July 11-13, 2017
California Institute of Technology, Pasadena, CA

Meeting # 3: August 28-30, 2017
Woods Hole, MA

Meeting # 4: November 29-Dec 1
Beckman Center, Irvine, CA

Meeting # 5: February 26-28
Washington, DC

Delivery: July, 2018



Committee

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Key Issues

- Cadence of competed missions
- R&A and Technology spending
- Mars 2020 – does it meet the decadal guidance?
- Europa Clipper – does it meet the decadal guidance?
- Are the above programs on budget/schedule, or do they pose a risk to programmatic balance?
- Europa Lander
- Adding Ocean Worlds to New Frontiers
- Is the overall program still balanced?
- What is the status of the Mars Exploration Program?
- The “focused and rapid Mars sample return” proposal

Large Strategic (Flagship) Missions

Europa Clipper

Finding: Europa was called out as a very high priority target in the last two planetary decadal surveys because of its high astrobiological potential. The Europa Clipper concept currently in phase B is reduced in cost from the Jupiter Europa Orbiter mission that was proposed to Vision and Voyages. New funding has been allocated by Congress for this mission. This committee finds that the Europa Clipper mission addresses most of the recommendations laid out by Vision and Voyages.

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

Large Strategic (Flagship) Missions

Europa Lander

Finding: NASA is currently working to define the scientific goals and assess the feasibility of implementation, the mission concept, and the estimated cost of a Europa lander.

Finding: A lander was not prioritized within the previous decadal survey (Vision and Voyages).

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

Large Strategic (Flagship) Missions

Ice Giants

Finding: Exoplanet discoveries further enhance the importance of an ice giants mission, already recognized as a high priority in Vision and Voyages.

Finding: The notional ice giants mission described in Vision and Voyages would address a broad range of ice giant science objectives using mature instrumentation.

Finding: The objectives of the mission concept described in the 2017 ice giants predecadal study have been changed significantly from the original Vision and Voyages science objectives. The scientific payload carries significant risk of failing to make the measurements proposed in Vision and Voyages. Furthermore, if the Doppler imager were not successful scientifically, a large part of the revised science objectives would be degraded or lost.

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

Large Strategic (Flagship) Missions

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

Small and Medium-Class Missions
Discovery

Finding: NASA's decision to eliminate phase E funding and launch vehicle cost from the Discovery AO has been enabling for missions to the outer solar system.

Finding: Although two Discovery missions were selected from the 2014 AO, the next AO will not be issued until 2019. NASA will not have met the Vision and Voyages goal of a Discovery AO release every 24 months unless three missions are selected from the two potential future AOs.

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

Balance Across the Program

Finding: NASA has initiated several missions in the last 5 years that respond to the *Vision and Voyages* priorities (Europa Clipper, Mars 2020, OSIRIS-REx, Lucy, Psyche, and InSight). However, the recommended balance across the solar system and among mission classes has not been fully achieved. This lack of balance undermines the compelling comparative planetology investigations recommended by the decadal survey, particularly for the terrestrial planets. The discovery of numerous Earth-size and Neptune-size exoplanets provides even greater urgency to initiate new missions to Venus and the ice giants.

Small and Medium-Class Missions
New Frontiers

Finding: The pace of New Frontiers class missions is behind the recommended cadence of 2 per decade, with only 1 mission likely this decade.

Finding: Given the current cadence for New Frontiers, the New Frontiers 5 call may occur while the next decadal survey is under way, but both Lunar Geophysical Network and Io Volcanic Observer were recommended by Vision and Voyages for New Frontiers 5 and the committee believes they still remain valid missions for New Frontiers 5.

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

Small and Medium-Class Missions
New Frontiers

Finding: New Ocean Worlds targets were introduced into the New Frontiers 4 call. This addition to the list of allowed New Frontiers missions was made outside the decadal survey process. While the Outer Planets Assessment Group (OPAG) supported the addition, the Lunar Exploration Analysis Group (LEAG), Small Bodies Assessment Group (SBAG), Venus Exploration Analysis Group (VEXAG), and Mars Exploration Analysis Group (MEPAG) did not support this change (as per presentations to this committee). Such a process could undermine the scientific priorities of the decadal survey and community support for them.

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

NASA's Mars Exploration Program (MEP)

Finding: Mars 2020 will fulfill the mandate of Vision and Voyages that "a critical next step [to Mars Sample Return] … would be provided through the analysis of carefully selected samples from geologically diverse and well characterized sites."

Finding: The "focused and rapid" conceptual approach to a Fetch Rover/MAV and an SRO described by NASA to the committee is on track to be fully responsive to completing the Vision and Voyages highest-priority large strategic (flagship)-class science, Mars Sample Return (MSR). The detailed architecture including specific international involvement is still under conceptual development. The FY 2019 budget, approved by Congress and signed by the president during the writing of this report, appears to provide funding to continue development and plan implementation.

NASA's Mars Exploration Program (MEP)

Finding: NASA is making substantial progress on technology development that will be required for MSR. This includes, but s not limited to, the MAV propulsion system, the Sample Return Capsule, and the approach to orbital rendezvous and capture. A sample analysis and curation facility will also be required.

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

NASA's Mars Exploration Program (MEP)

Finding: There is a risk that ongoing and soon-to-be landed assets on Mars will be left without telecommunications support because of the aging orbiters. The Mars telecommunications relay network is marginally able in its present form to service current and planned surface missions. The system is fragile and aging. The loss of even one of the three U.S. orbiters capable of relay communications (Mars Odyssey, MRO, MAVEN) would create tactical challenges for continued operation of current and planned landed missions beyond 2021, and compromise the ability of the MEP to continue its science return. The committee was not presented with and did not evaluate the possibility of commercially provided telecommunications capabilities to supplant telecommunications capabilities being used. Also, despite the hardware capability, there is no plan for the European Space Agency (ESA)'s Trace Gas Orbiter (TGO) to be used as a relay asset in the immediate future.

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

NASA's Mars Exploration Program (MEP)

Finding: Missions to Mars being led by non-U.S. entities (including ExoMars, Trace Gas Orbiter, Mars HOPE, and Mars Moon Explorer) benefit and significantly augment the U.S. Mars Exploration Program and lead to a broader scientific exploration of Mars.

Recommendation: NASA should immediately work to reinvigorate international cooperation to help implement Mars exploration more effectively and affordably. This could involve international contributions of instruments, other hardware, or whole missions that complement what the United States is providing or leading, as suggested in Visions and Voyages and as proposed in the "focused and rapid" concept for Mars Sample Return.

NASA's Mars Exploration Program (MEP)

Finding: There are strong arguments for continuing Mars exploration through a program rather than as a series of independent, unconnected missions. Although the current MEP has a broad focus across most areas of Mars as a system, the program going forward beyond Mars 2020 is focused entirely on sample return. There is currently no vision for a program beyond sample return, either for scientific investigation or to prepare for future human exploration.

Finding: There are no plans at present to replace the site characterization and monitoring capabilities of MRO that have proven important for landing-site certification and strategic planning of landed science.

Finding: The MEP has not yet put forward a complete architecture and attendant strategic plan that addresses the long-term goals of Mars exploration and optimizes science return across the spectrum of past, current, and future missions.

NASA's Mars Exploration Program (MEP)

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

Telescopes and Planetary Science

Finding: The Arecibo observatory is uniquely important for radar studies of asteroids, including characterization of potentially hazardous asteroids.

Finding: The loss of the unique capabilities of the Hubble Space Telescope (HST) will leave fewer opportunities for space-based telescope time allocated to solar system targets. The James Webb Space Telescope (JWST) will obtain limited observations of solar system targets but will not have the spectral coverage of HST.

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

Research and Analysis

Finding: This analysis was challenging, since PSD does not track spending on R&A and technology in the way the decadal survey defined them. This can create misunderstandings within the science community.

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

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

Technology Research and Development

Finding: The PSD has to date met and is expected to continue to fully meet the decadal survey's technology investment recommendation.

Finding: The NASA technology priorities are responsive to the list established in Vision and Voyages and the Science Mission Directorate (SMD) and the Space Technology Mission Directorate (STMD) are working collaboratively to advance these technologies toward meeting mission needs. Such partnerships can benefit the Science Mission Directorate.

Finding: NASA has implemented cost-effective ways to bring the new technology up to TRL 6 and above, including taking proactive steps to educate PI teams on the available technology and providing incentives in the announcement of opportunity for the incorporation of the technology in their proposed missions.

Technology Research and Development

Finding: The currently forecast Pu-238 and clad production rates are expected to fully meet with margins the NASA currently envisioned mission needs for MMRTGs over the next 10-15 years.

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

Technology Research and Development

Finding: The Planetary Science Division has embraced the decadal survey's technology recommendations, and they have constructed a rational and comprehensive technology portfolio that can enable new and more challenging planetary science missions in the next decade.

Finding: NASA has fully embraced the Vision and Voyages recommendations concerning electric propulsion and advanced solar arrays, and is making significant technology development progress in both.

Finding: NASA is investing in the underlying technologies for aerocapture, including a potential flight demonstration. Aerocapture system-level design and development however, is destination-specific, and when there is a specific mission requirement, the investment will need to be increased.

Finding: NASA has fully embraced the Vision and Voyages recommendation and is making meaningful investment in advanced communications technology development and flight demonstration.

Technology Research and Development

Finding: NASA created the PICASSO and MatISSE programs to provide a sustained, broad-based science instrument development through TRL 6, as recommended by Vision and Voyages. The high number of proposals submitted to these programs, relative to the funding available, shows a strong community demand for these programs.

Finding: NASA is making a focused investment in the COLDTech and HOTTech programs to address the spacecraft bus, instrument, and in situ systems survival and operations in extreme environment as recommended by Vision and Voyages.

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

Infrastructure and Laboratory Support

Finding: The Curation and Analysis Planning Team for Extraterrestrial Materials (CAPTEM) committee fulfills the decadal requirements for a single advisory group to provide input on curation and management of planetary samples. In addition to its allocation responsibilities for all extraterrestrial samples under NASA control, CAPTEM is a community-based, interdisciplinary forum for discussion and analysis of matters concerning the collection and curation of extraterrestrial samples, including planning future sample return missions. As such, it provides a crucial function for the sample community to participate in planning activities. However, the Mars 2020 project is proceeding with its own sample-advisory board; although this board may be coordinating with JSC curation, the board itself is operating outside of CAPTEM.

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

Infrastructure and Laboratory Support

Finding: NASA established the Laboratory Analysis of Returned Samples (LARS) program to advance sample analysis techniques and develop analytical capabilities for future sample return missions. The recent report on the reorganization of R&A funding (Review of the Restructured Research and Analysis Programs of NASA's Planetary Science Division) showed that sample-based studies continue to have a home for funding within NASA R&A programs as well. NASA recently commissioned a study by the National Academies of Sciences, Engineering, and Medicine on the available laboratory facilities for sample analysis and strategies for continued investment. This study is ongoing at the time of writing.

Infrastructure and Laboratory Support

Finding: The 2014 Discovery AO and 2017 New Frontiers AO require early planning and coordination for sample return missions. The actual costs for all aspects of curation, from planning through distribution and storage, including all required laboratory construction or modification, are required to be borne by the mission from inception to two years following sample return. Therefore, curation activities (and their associated costs) during phases A-D fall under the AO cost cap, and activities during phase E fall under the principal investigator (PI)-Managed Mission Cost (but not the AO cost cap). Whereas long cruise missions can defer such costs to phase E, this situation penalizes short missions that have to include curation and laboratory costs in phases B-D.

Recommendation: NASA should consider the budget for curation by sample-return missions, as developed in the AO-required Curation Planning documents, a phase E cost, regardless of the phase in which the costs are actually incurred. This would ensure that sample return missions are on equal footing with other mission proposals and discourage unrealistically low budgets for sample curation.

Infrastructure and Laboratory Support

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

Education and Public Outreach

Finding: The intent of the Vision and Voyages endorsement of 1 percent of mission budgets going toward education and public outreach activities was to have scientists who are involved in NASA's missions directing and participating in public education and outreach activities. Currently, the STEM Activation program is not uniformly engaging NASA missions; some missions are not being engaged at all. Furthermore, the STEM Activation program is not utilizing the mission scientists to define or provide science content; therefore, the critically important connections between the mission scientists and these education programs have been greatly reduced. While NASA center-managed public engagement efforts are connecting with some missions, in other cases there is no direct tie between missions that are producing results for the programs and the work of the NASA education program.

Education and Public Outreach

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

Preparing for the Next Decadal Survey

Finding: Even though the actual implementation of a large strategic (flagship) or New Frontiers mission may differ substantially from a mission concept, a concept study has value for the decadal survey. It enables science objectives to be defined, the overall mission scope (i.e., whether it is a large strategic (flagship)- or a New Frontiers-class mission) to be determined, and the community to begin preparing for the next funding opportunities.

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

Preparing for the Next Decadal Survey

Finding: Aside from requirements derived from the competitively selected SIMPLEx and PSDS3 mission concepts, there is not a clear pathway for prioritizing development of the key CubeSat and SmallSat technologies and planetary deployment and operational architectures that would enable operations beyond the Earth-Moon environment. These include, but are not limited to, destination delivery approaches, propulsion, telecommunications, and deployable elements to provide power generation or instrument aperture.

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

Preparing for the Next Decadal Survey

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

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

Questions?