

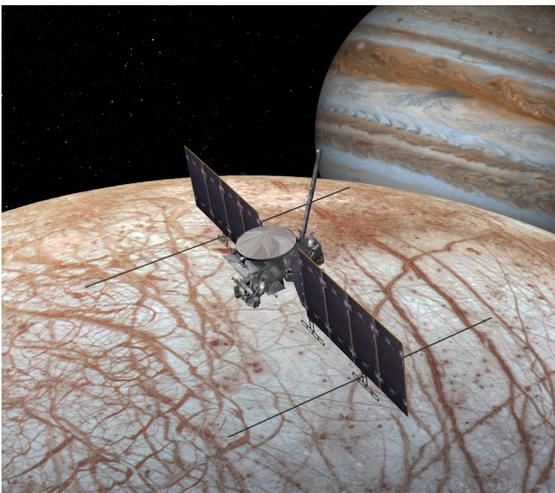


Visions into Voyages for Planetary Sciences in the Decade 2013-2022: A Midterm Review

In 2011, the National Academies of Sciences, Engineering, and Medicine published the report *Vision and Voyages for Planetary Science in the Decade 2013-2022*, generally referred to as the planetary science decadal survey. The purpose of the decadal survey was to prioritize planetary science goals and provide guidance for NASA's Planetary Science Division (PSD). In late 2016, NASA and its Science Mission Directorate requested a midterm review from the National Academies to examine NASA's progress toward achieving the decadal survey goals. This new report, *Visions into Voyages for Planetary Sciences in the Decade 2013-2022: A Midterm Review*, assesses NASA's progress so far and recommends further actions. In addition to evaluating the new missions NASA has undertaken in response to the decadal survey, the report also discusses the state of research and development, and the preparations necessary for the next planetary science decadal survey.

EXAMINATION OF FLAGSHIP, NEW FRONTIERS, AND DISCOVERY MISSIONS

There are three different classifications of missions within the PSD, divided by initial mission cost. Large strategic "flagship" missions are directed by the PSD, and generally have a cost in the low billion-dollar range. New Frontiers missions are medium class, led by a Principal Investigator (PI), and with a cost cap of \$1 billion, excluding launch vehicle cost. Discovery missions are small class missions, also PI led, and with a cost cap of around \$500 million, not including cost of launch or operations.



An artist's rendering of NASA's Europa Clipper spacecraft. This flagship mission will launch in the 2020s. SOURCE: NASA/JPL-Caltech

Overall, the committee is very pleased with the progress of the PSD at meeting the goals established in the decadal survey. NASA has initiated several missions in the last 5 years that respond to Vision and Voyages priorities (Europa Clipper, Mars 2020, Lucy, Psyche, and InSight). However, the recommended distribution of missions across the solar system has not been achieved due to a lagging cadence of missions. 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-sized and Neptune-sized exoplanets provides even greater urgency to initiate new missions to Venus and the Ice Giants.

Large Strategic (“Flagship”) Missions

The report finds that NASA has appropriately descoped the Jupiter Europa Orbiter (JEO) and Mars 2020 missions due to budget constraints. Europa and Mars sample-caching missions were both high priority large strategic missions in the decadal survey. A third high priority large strategic mission was a Uranus orbiter, which NASA has not yet undertaken. Both Uranus and Neptune are classified as “ice giants” and the decadal survey rated them equally in terms of compelling science. The midterm review recommends that NASA undertake a refocused ice giants study to better prepare for the next decadal survey. Additionally, the report commends the Planetary Science Division for recognizing that large strategic mission overruns can threaten to unbalance the entire program and seeking to maintain careful management of costs. The report recommends that in the future, the Planetary Science Division implement further cost-management measures regarding such large strategic 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 flagship missions to ensure that potential mission costs and cost risks are understood.

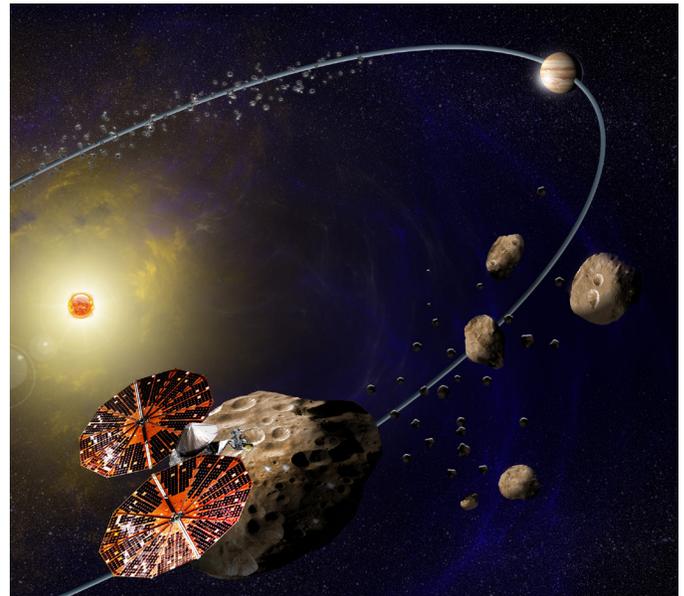
RECOMMENDATION: As a prospective flagship mission, the results of the NASA Europa lander studies should be evaluated and prioritized within the overall PSD program balance in the next decadal survey.

New Frontiers Missions

New Frontiers mission development is currently behind the recommended cadence of two missions per decade. (NASA is currently in the process of selecting the next New Frontiers mission.)

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).

If scientific discoveries or external factors compel NASA to reassess decadal survey priorities, NASA should evaluate these changes via the National Academies’ Committee on Astrobiology and Planetary Science (CAPS), and allow for input from the community as time permits.



An artist's rendering of NASA's Lucy mission, which will launch in 2021 and travel to the Trojan asteroids orbiting in tandem with Jupiter. SOURCE: Southwest Research Institute

Discovery Missions

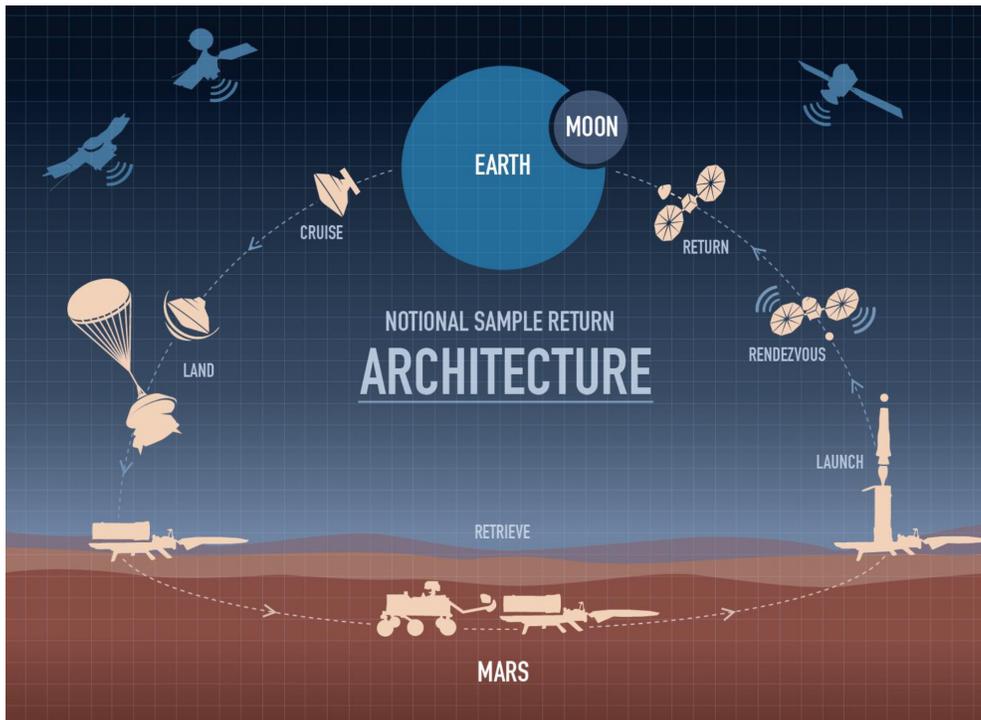
Discovery missions are also behind the cadence recommended in the decadal survey.

RECOMMENDATION: NASA should issue Discovery Announcements of Opportunity (AO) 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.

The report applauds NASA for eliminating operations funding and launch vehicle costs from Discovery Announcements of Opportunity – this has enabled greater consideration of outer solar system missions.

MARS EXPLORATION PROGRAM (MEP)

Mars holds a special place in planetary exploration as it is the only terrestrial planet besides Earth that preserves a readily accessible record of environments where life could have developed. Whether life did or did not develop there has implications for determining the range of conditions in which life can exist, and the probability that life might exist on small extrasolar terrestrial planets. The science goals of the Mars Exploration Program are to understand the formation and early evolution of Mars, the history of geological and climate processes that have shaped Mars, the potential for life, and surface environments relevant to



Notional sample return mission architecture. SOURCE: NASA

future exploration by humans. NASA has developed a “focused and rapid” Mars Sample Return framework, and is on track for developing technology that can help to achieve the goal of Mars Sample Return.

The report recommends that NASA work to reinvigorate international cooperation in Mars exploration, which has the potential to make the program both more effective and affordable. The agency achieved recent milestones regarding international Mars cooperation while the committee was finalizing its report. Additionally, the report recommends that planning for future sample return and analysis should be coordinated through NASA’s Curation and Analysis Planning Team for Extraterrestrial Materials.

The telecommunications infrastructure in orbit around Mars is aging, which may pose issues for future Mars missions. The Mars Exploration Program has not yet put forward a long-term, sustainable, strategic plan for continued Mars exploration, and the report recommends that NASA develop one.

RESEARCH & ANALYSIS, TECHNOLOGY, AND RESEARCH AND DEVELOPMENT

The PSD Research and Analysis (R&A) funding levels have exceeded the Vision and Voyages recommendation, rising 32% relative to FY11. However, the PSD does not track spending on R&A in the way the decadal survey defined, creating difficulty when attempting to track R&A funding across programs.

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) PI-led, competed, basic research and data analysis, (2) ground-based observations, (3) infrastructure and management, and (4) institutional and/or field center support. Also, the next decadal survey should be unambiguous when stipulating programs and recommended levels of spending.

The Planetary Science Division’s technology funding has also exceeded the decadal recom-

mendation of 6-8% of the PSD budget, and is estimated to be at about 10% for FY18-FY22. The report commends NASA for achieving R&A and technology funding goals established by the decadal survey. In addition, the restarting of Pu-238 production, which is essential for many space missions, particularly those to the outer planets, is a positive development.

The report finds that NASA has done an excellent job of fostering technology growth, specifically through two new programs: Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) for Technology Readiness Level (TRL) 1-3, and Maturation of Instruments for Solar System Exploration (MatISEE) for TRL 4-6. These programs enable new mission proposals to utilize these new technologies without the financial burden of developing the technologies themselves.

Additionally, NASA has fully embraced the decadal survey recommendation regarding utilization of electric propulsion and advanced solar arrays, and is developing both. NASA is also investing in HotTech and ColdTech technologies, as well as technologies underlying aerocapture. These are all technologies that will allow for an increase in mission range and data-gathering capabilities. NASA has also upgraded the Deep Space Network (DSN) communication system, which currently supports over 35 missions and maintains 99% reliability. Going forward, it is recommended that the DSN continue to be upgraded with Ka-band upload abilities at all three sites (Spain, Australia, and California).

EDUCATION AND PUBLIC OUTREACH

NASA has made advancements in education and outreach with the STEM Activation program, created in response to the decadal survey recommendations. However, this program needs to be re-oriented, with more equitable outreach from all PI-led programs, and more Activation educators working directly with program scientists.

STEPS FOR THE NEXT DECADAL

Prior to the next decadal survey, currently scheduled to get underway in 2020, NASA should sponsor eight to ten mission concept studies based upon a list produced by CAPS in 2017, prioritized with input from the assessment and analysis groups. Furthermore, NASA should consider priorities and pathways for advancing the state-of-the-art for CubeSat and small-sat technologies, and find ways to leverage emerging capabilities in science-driven planetary small mission concepts.

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