

Extending Science

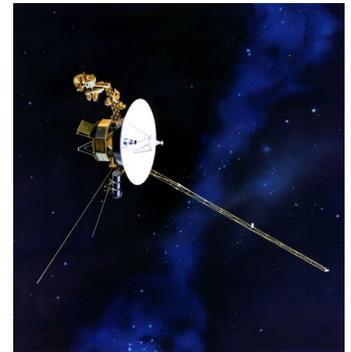
NASA's Space Science Mission Extensions and the Senior Review Process

When NASA spacecraft are first launched, they enter the prime phase of their mission where measurements are focused on achieving a specific set of high-priority scientific objectives over the course of a predetermined timeframe. After a mission completes its prime phase, NASA's Science Mission Directorate (SMD) can choose to operate the spacecraft beyond its designed lifetime as an extended mission. Of the several dozen NASA spacecraft in Earth orbit and beyond, three quarters are extended missions. These extended missions provide excellent science for relatively low cost because they are already operating successfully and no longer require the large upfront development or launch costs associated with a new mission. Extended science missions are responsible for many major contributions to scientific discovery over the past decades. Famous examples include the two Voyager spacecraft that continue to produce scientific data about the edge of the heliopause more than three decades after completing their original missions and the Opportunity rover that has collected data for more than a dozen years when it was expected to last only ninety days and has provided insights into the existence of water on Mars. At the request of NASA, this report of the National Academies of Sciences, Engineering, and Medicine evaluates the scientific benefits of mission extensions and provides suggestions for how to improve the process and requirements for extending missions. Currently, NASA is mandated by law to conduct Senior Reviews of missions entering or in extended phase. The committee concluded that NASA performs an excellent Senior Review process that ensures that the nation's civil space science assets provide the best possible return on investment. The committee determined that in order to maximize science productivity and value, NASA should conduct such reviews every three years, and should be provided with flexibility to conduct reviews in between the regular review process as necessary.

EXTENDED MISSIONS ARE AN IMPORTANT PART OF NASA'S PORTFOLIO

Although 75% of NASA's operating science missions are extended missions, they expend only around 12% of the Science Mission Directorate's budget and constitute a substantial return on investment for NASA and the United States taxpayers.

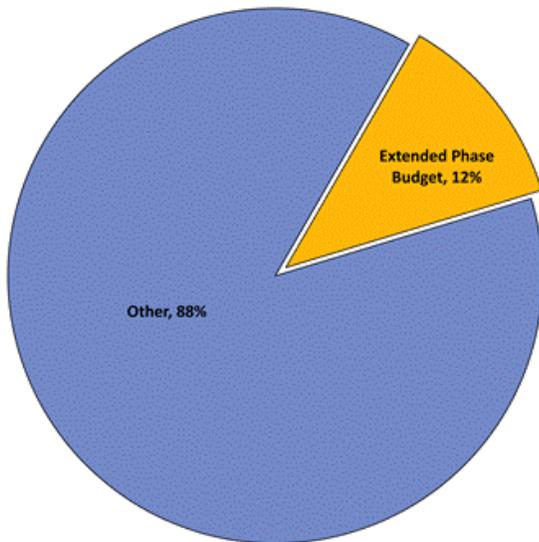
RECOMMENDATION: NASA should continue to provide resources required to promote a balanced portfolio, including a vibrant program of extended missions.



An artist's concept of NASA's Voyager spacecraft. Image Credit: NASA/JPL-Caltech

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NASA SMD Budget



Repurposing extended missions to perform new science observations and missions is an extremely cost effective approach for addressing new science opportunities and national interests. Many extended science missions have made important discoveries via new destinations, observation types or targets, and/or data analysis methods. Moreover, continuous coverage, long baseline data sets, and statistically significant observations of infrequent events that require continuity of measurement over years or decades are best provided through missions in extended phase.

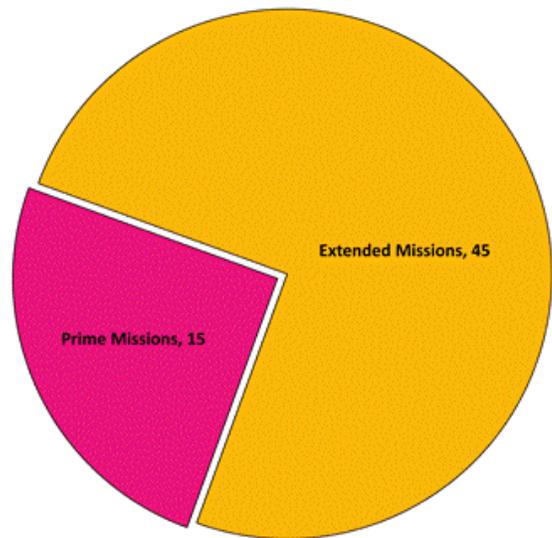
RECOMMENDATION: NASA should continue to encourage and support extended missions that target new approaches for science and/or for national needs, as well as extended missions that expand their original science objectives and build on discoveries from the prime phase mission.

RECOMMENDATION: In order to obtain best value for money, NASA should encourage extended mission proposals to propose any combination of new, ground-breaking, and/or continuity science objectives.

Some NASA Divisions permit missions entering into or already in extended phase to accept increased risk, which is an inevitable consequence for aging spacecraft and science instruments. However, while budgets typically decrease significantly when a mission enters extended phase, additional funding cuts could increase the risk to the spacecraft and its ability to meet the mission's scientific goals.

RECOMMENDATION: NASA should continue to assess and accept increased risk for extended missions on a case-by-case basis. The headquarters division, center management, and the extended-mission project should discuss risk posture during technical reviews and as part of the extended

NASA SMD Missions



mission and subsequent Senior Review proposal preparation process and should make all parties fully aware of all cost, risk, and science tradeoffs.

PLANNING AHEAD FOR EXTENDED MISSIONS

Many extended missions have adopted innovative planning and operations approaches that translate to best practices that may be applicable to other missions. Some missions have chosen to co-locate their operations centers to increase efficiency and reduce costs, while others have generated staffing plans in preparation for the reduced budget of an extended phase.

RECOMMENDATION: NASA should provide open communications and dissemination of information based on actual experience with extended missions so that all missions are aware of and able to draw upon prior effective practices and procedures, applying them during development of ground systems and flight procedures, as well as when formulating staffing and budgetary plans for the prime and extended mission phases.

With the expectation that most missions will be eligible for extension, developing standard procedures and templates during the prime phase can be a highly effective way to control long-term operations costs and limit the risks introduced by implementing new procedures specifically developed for extended operations. NASA's current approach to establishing requirements and designs for prime phase and budgeting for extended missions has many positive attributes and provides a very high return on investment.

RECOMMENDATION: NASA should strongly support a robust portfolio of extended phase science missions. This

support should include advance planning and sufficient funding to optimize the scientific return from continued operation of the missions.

RECOMMENDATION: NASA's Science Mission Directorate policy documents should formally articulate the intent to maximize science return by operating spacecraft beyond their prime mission provided the spacecraft are capable of producing valuable science data and funding can be identified within the SMD budget.

RECOMMENDATION: NASA should continue anticipating that missions are likely to be extended, and identify funding for extended missions in the longer-term budget projections.

After the first few years of extended operations, most missions have implemented all (or almost all) practical steps to reduce costs. Further budget cuts often result in disproportionate cuts to project-funded science activities, increasing the risks that science will be diminished or not performed at all.

RECOMMENDATION: Given the demonstrated science return from extended missions, NASA should continue to recognize their scientific importance and, subject to assessments and recommendations from the Senior Reviews, ensure that after the first two Senior Reviews, both operations and science for high-performing missions are funded at roughly constant levels including adjustments for inflation.

IMPROVING THE SENIOR REVIEW PROCESS

For spacecraft missions that continue to operate beyond their prime phase, the Senior Review is a valuable peer review process for recommending future support based on assessments of the mission's scientific accomplishments and future projections, as well as its ability to meet national and related interagency needs. NASA uses Senior Review recommendations as a major consideration when deciding upon mission extensions.

Forming Senior Review Panels

While the Senior Review process can vary between NASA divisions due to differing goals and needs, there are several criteria for Senior Review panel membership that could be implemented and standardized across divisions.

RECOMMENDATION: NASA SMD should assemble Senior Review panels that:

- Are comprised primarily of senior scientists knowledgeable about and experienced in mission operations so as to ensure that the operational context of the science being proposed and evaluated is considered in the review (individuals with operations and/

or programmatic expertise may also be included as needed)

- Are assembled early to avoid or accommodate conflicts of interest, and ensure availability of appropriate expertise
- Include some continuity of membership from the preceding Senior Review to reap advantage of corporate memory
- Include some early-career members to introduce new and important perspectives and enable them to gain experience for future Senior Reviews

The Senior Review Timeline

The exact manner in which NASA conducts its Senior Reviews is based upon the specific needs of each Division. In some divisions there is greater prioritization of new or groundbreaking science, whereas other divisions may emphasize continuity of observations. While no single template can be effectively applied to all of the Divisions, at times the Senior Review process has become too compressed with NASA allocating insufficient time for some of the essential stages for Senior Review.

RECOMMENDATION: Each of the divisions should ensure that their timelines allocate sufficient time for each stage of the Senior Review process, including a minimum of six to eight weeks from distribution of proposals to the panels until the panel meets with the mission teams. The panels should have at least four weeks to review the proposals and to formulate questions for the mission teams, and the mission teams should be allocated at least two weeks to generate their responses to the panel questions.

Regular reviews of operating missions are essential, and NASA is required by law to review its extended science missions every two years. However, the current two-year cadence creates an excessive burden on NASA, mission teams, and the Senior Review panels. A three-year cadence would ease this burden, while still enabling timely assessment of the quality of data returned from these missions and their potential for continued productivity.

RECOMMENDATION: NASA should conduct full Senior Reviews of science missions in extended operations on a three-year cadence. This will require a change in authorizing language, and NASA should request such a change from Congress. The Earth Science Division conducts annual technical reviews. The other divisions should assess their current technical evaluation processes, which may already be sufficient, in order to ensure that the divisions are fully aware of the projected health of their spacecraft, while keeping these technical reviews moderate in scope and focused on changes since the preceding review.

Adding Flexibility

Reduced budgets for extended missions in recent years have become a key concern. Depending on budget realities, it may be necessary to reduce the scope of an extended mission in order to enable ongoing operation.

RECOMMENDATION: If the Senior Review recommends termination of a mission due to funding limitations rather than limited science return, NASA should allow the team to re-propose with an innovative, possibly less scientifically ambitious, approach at reduced operational cost and increased risk.

Flexibility in scheduling the Senior Reviews, such as the ability to change the timing of individual reviews to avoid mission-critical events, is valuable for NASA's science divisions.

RECOMMENDATION: NASA science divisions should be allowed to conduct reviews out of phase to allow for special circumstances and should have the added flexibility in organizing their reviews to take advantage of unique attributes of each division's approach to science.

Improving the Senior Review Process in the Future

As NASA divisions perform more Senior Reviews, the details of the process are becoming more stable from cycle to cycle. Maintaining best practices through regular interactions and feedback between NASA Headquarters, the mission teams, and review panels will help to ensure that this consistency is maintained while also providing opportunities for incremental improvements in the process.

RECOMMENDATION: NASA SMD division directors should continue to communicate among themselves to identify and incorporate best practices across the divisions into the Senior Review proposal requirements and review processes and procedures.

RECOMMENDATION: In its guidelines to the proposal teams and the Senior Review panels, NASA should state its intention to solicit feedback from its proposal teams and review panels about the suitability of the proposal content and review process. After obtaining such feedback, NASA should respond and iterate as needed with stakeholders to improve the review process, where possible.

COMMITTEE ON NASA SCIENCE MISSION EXTENSIONS: Victoria E. Hamilton, Southwest Research Institute, *Co-Chair*; Harvey D. Tananbaum, Smithsonian Astrophysical Observatory, *Co-Chair*; Alice Bowman, Johns Hopkins University, Applied Physics Laboratory; John R. Casani, Jet Propulsion Laboratory (retired); James H. Clemmons, The Aerospace Corporation; Neil Gehrels, NASA Goddard Space Flight Center; Fiona A. Harrison, California Institute of Technology; Michael D. King, University of Colorado, Boulder; Margaret G. Kivelson, University of California, Los Angeles; Ramon E. Lopez, The University of Texas at Arlington; Amy Mainzer, Jet Propulsion Laboratory; Alfred S. McEwen, University of Arizona; Deborah Vane, Jet Propulsion Laboratory

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