Powering Science - NASA’s Large Strategic Science Missions

Large strategic space science missions, such as the James Webb Space Telescope and the Curiosity Rover, are the highest-profile and most costly missions operated by NASA’s Science Mission Directorate (SMD). Large strategic missions, often referred to as “flagship” missions, tend to travel to hard-to-reach destinations or challenging environments and carry more scientific instruments than smaller missions with fixed science programs. Because these billion-dollar missions typically have longer lifetimes, they operate with an evolving science program that can change in response to new data as the mission proceeds. In 2016 NASA asked the National Academies of Sciences, Engineering, and Medicine to examine the role of large strategic missions within NASA and develop principles for dividing a limited budget between large, medium, and small missions. The committee was asked to provide recommendations to help guide NASA in future prioritization of large strategic missions and to analyze the relationship between scientific returns and cost for several recent missions.

The James Webb Space Telescope undergoing testing at the Goddard Space Flight Center in March 2017. SOURCE: NASA.
The National Academies finds that large strategic missions are an essential part of NASA’s science divisions and are necessary for maintaining the United States’ global leadership in space exploration. These large missions capture science data that cannot be obtained in any other way and contribute to extensive data archives used by many researchers. They also symbolically represent NASA’s science program as a whole and provide opportunities for international cooperation. In terms of workforce development, large missions are more advantageous than smaller missions because they have the budgets, the scientific breadth, and the longevity to support more researchers. In light of these benefits, the report recommends that NASA continue to plan for large strategic missions as part of a balanced program that also includes smaller missions.

IMPROVING BUDGET ESTIMATION

During the past decade, missions such as the James Webb Space Telescope have been scrutinized because significant cost growth adversely affected the entire division portfolio. The large increase in costs for the mission had an impact upon the entire astrophysics program as well as the Science Mission Directorate as a whole and delayed the mission’s launch by many years. Some stakeholders believe that these cost overruns have created a lingering stigma for large strategic missions. In addition to actual cost overruns, NASA sometimes faces scrutiny because of false impressions of cost growth. It is not uncommon for the public, the press, and the scientific community to cite low-fidelity cost estimates made prior to the officially established baseline budget, thus creating a false impression that a mission’s costs have grown substantially. However, the reality is that the early “estimates” were not actual estimates, or were made by project advocates rather than an independent authority.

To aid with these two problems, NASA has introduced numerous cost control and cost evaluation mechanisms in the last decade, which are vital for preserving overall programmatic balance. NASA should continue to use its various cost estimation tools to assess and control the costs of large strategic missions to ensure that they remain a viable option. As new technologies and new missions arise, NASA should support the development of new tools to perform robust cost estimates and risk assessment.

CREATING A BALANCED PROGRAM

Decadal surveys, organized by the National Academies, bring together experts from across the scientific community to identify the most important scientific goals in their field for the upcoming decade. The sur-
veys provide specific recommendations for how NASA should go about achieving these goals, and NASA’s progress is assessed five years after the release of the survey during a mid-term review. These decadal surveys are NASA’s best resource for determining how large strategic missions fit into their programs. Therefore, when faced with a tradeoff between the development and operation of large strategic missions and smaller missions within their portfolios, NASA’s SMD divisions should look first to the relevant decadal surveys and mid-term reviews for guidance.

Science is the primary focus of the decadal surveys, and all of the recent decadal surveys have described in detail the highest priority science questions and frontiers. While the science questions and opportunities change over time, the technology to address that science changes over time as well. Thus, the committee recommends that budget constraints should be included in the development of a decadal scientific program and decadal surveys should be informed by, but not narrowly restricted to, future projections of available budgets. Better knowledge of available budgets may help decadal surveys develop scientific programs that are flexible enough to allow for reductions in mission scope or changes in mission priority when faced with cost overruns or insurmountable technical barriers. Alternatively, missions that are made more feasible as new technological or other opportunities arise should be given higher priority.

The National Academies recommends that large strategic mission proposal teams provide decadal survey committees with minimum science goals, maximum budgets, and a breakdown of what science goals are prioritized at different budget levels. This approach could allow the scientific community and NASA to develop less expensive implementation strategies for mission concepts while remaining within budget. Additionally, before the start of the decadal survey, NASA should conduct robust mission studies on potential large strategic missions that allow for trade-offs (including science, risk, cost, performance, and schedule).

In addition to proposal teams providing different possible goals and budgets for their missions, the decadal survey should include mission concept variants and methods to assess the boundaries of cost and technical risk. This will enable further refinement of mission concepts when pursuing the scientific priorities identified by the decadal surveys. By providing NASA a range of options at varying levels of science, complexity, and cost, a decadal survey can assist the agency in examining options within a balanced portfolio, making trades against budgetary constraints, and prioritizing science goals within the coming decade.

**NASA CAN PUBLICLY MAKE A BETTER CASE**

NASA can best highlight the scientific productivity of different size missions by publicly presenting the voluminous amount of data already collected by the agency for various purposes. The National Academies recommends that NASA develop a publicly accessible database, updated at least annually, that tracks basic data related to all confirmed missions in development as well as operational and past missions from each of the SMD divisions. This data should be of sufficient quality to enable basic analyses related to the costs, scientific productivity, and contributions made by each mission. For example, including data about the cost of servicing the Hubble Space Telescope may be valuable for informing future missions that may include servicing as well. While establishing such a public database is no small task, it would enable NASA to communicate the value of its missions as a whole rather than relying on periodic press releases or talks at scientific conferences.

![The Hubble Space Telescope in orbit. SOURCE: NASA](image)
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