NASA Space Flight Programs and Projects
Budget Elements

This document is intended to provide details about NASA programs and projects that would inform decadal survey recommendation and that may not be well-known by the heliophysics community.

In addition, it captures guidance on what a decadal survey can include in program and project recommendations to maximize their effectiveness and the ability for Agency implementation. The specification of intent and assumptions in recommended budgets is, in part, to enable Agency insight into the motivations and priorities in the case of rebalancing due to budgetary or programmatic realities.

Program Costs

NASA space flight programs are managed by program offices, which are located at NASA Centers (including Jet Propulsion Laboratory, JPL) and are delegated day-to-day management of projects by NASA Headquarters. This funding is outside of the project budgets and are set based on program requirements.

This funding level is specified by NASA on a program-by-program basis.

Pre-Project Costs

Before a project enters Phase A, NASA incurs preparatory costs. These costs include but are not limited to:

- technology development, either identified as necessary for mission success or recommended for risk avoidance and mitigation;
- community-based pre-formulation efforts (e.g. Science and Technology Definition Team);
- NASA-based pre-formulation efforts (e.g. preparation for KDP A); and
- mission competitions (e.g. Announcement of Opportunity).

When considering pre-Phase A costs, it is useful to distinguish projects based on management paradigm:

- Project where project management is assigned to a NASA Center, JPL, or Johns Hopkins University's Applied Physics Laboratory (JHU/APL) and a competition is held for investigations and the science payload (commonly called a "directed mission")
- Project where project management and full responsibility for implementation, including development and operation of the mission, is competed (commonly called a "PI-led mission")

Directed Missions

For a directed mission, NASA typically supported a community-based pre-formulation effort (such as a Science and Technology Definition Team, STDT) to update and refine the science objectives, identify high-level science requirements, and constraint top-level mission and measurement requirements. That effort may or may not include engineering support to develop a mission point design that can be used by NASA in subsequent pre-formulation efforts.

After this first step is completed, NASA stands up a pre-project office at the managing institution. This office typically works for about a year (although particular missions may require longer) on maturing the science and mission concept ahead of the first mission lifecycle review (Mission Concept Review, MCR) and Key Decision Point A (KDP A).

After a successful KDP A, the pre-project office transitions into a project office and begins Phase A work. In Phase A, NASA begins the acquisition processes. Although this includes all mission aspects (e.g. spacecraft, integration and testing [I&T], ground systems), the science community is most familiar with solicitations for mission investigations that include the delivery of space flight instruments (recently referred to as a Focused Mission of Opportunity).

The project Phase A work continues in parallel to this mission competition. After the competition, selected investigation teams join the project, and their development schedules are incorporated into the overall project schedule.

PI-led missions
For a PI-led mission, NASA does not typically engage in any project-specific pre-formulation effort. Instead of supporting pre-Phase A work, NASA releases the mission solicitation. The proposals are evaluated, and the mission selections are announced.

For single-step competitions, project Phase A budgets are based on the proposed budget. For two-step competitions, Phase A budgets are funded at a uniform level specified by the solicitation. Two-step competitions end in a downselection where a subset of Phase A studies proceed into Phase B, where full project budgets are based on the proposed budget.

Budgeting
To ensure that decadal survey mission program recommendations are implementable, these costs must be included in the mission program budgets but not in the associated project budget (funding per fiscal year).

Technology development and identified preparatory needs outside of the above costs should be budgeted as appropriate for decadal survey recommendations.

For directed missions, NASA is responsible for additional pre-formulation and early formulation costs outside of the expected project cost. The cost descriptions are below, and cost estimates (by relative to project KDP A) are in Table 1. The estimates in Table 1 are based on anticipated costs for typical pre-formulation efforts and for reviewing a typical number of investigation proposals.

- Community-based pre-formulation activities. NASA leverages the community's scientific and technical expertise to start the pre-formulation process and provide the starting point

for subsequent NASA-based pre-formulation activities. The most common such activity is a Science and Technology Definition Team (STDT).

- NASA-based pre-formulation activities: NASA conducts internal activities to start or continue the pre-formulation process, culminating in a MCR and KDP A. These activities usually are conducted within the scope of a Pre-Project Office, under the management of a Program Office at a NASA Center (including JPL).
- NASA-run investigation competition(s): NASA runs one or more solicitations to select the individuals and teams that will compose the project science team. The most common competition type is an Announcement of Opportunity, which solicits investigations that include the delivery of instrument flight units for integration onto the spacecraft.

After the completion of KDP A, a project enters the formulation phase and all subsequent project-level costs are captured within the project cost.

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Table 1. Pre-Formulation Costs, Directed Missions

Time Relative to Mission KDP A	Activity	Cost
3 Years Before	STDT	$3.5M
2 Years Before	STDT, Pre-Project	$8M
1 Year Before	Pre-Project	$10M
1 Year After	Competition	$2.5M

All costs are given in FY22$

For PI-led missions, NASA is responsible for the cost of the investigation competition, which is outside of the expected project cost. Table 2 gives estimates for the cost of a two-step Announcement of Opportunity competition for three different project classes. These estimates are based on anticipated costs for typical pre-formulation efforts and for reviewing a typical number of investigation proposals.

Table 2. Pre-Formulation Costs, PI-led Missions

Time Relative to Step-1 Selection	MO/SMEX	MIDEX	Moderate-scale and larger
1 Year Before	$2.5M	$3.5M	$4M
1 Year After	$3M	$5M	$6.5M

All costs are given in FY22$

Project Lifecycle Costs

A project's Lifecycle Cost (LCC) is the total cost to NASA for development and operations. This cost includes both project-level and program-level costs.

Decadal surveys have referred to the LCC as a project's "cost cap". This cost covers Phases A-D, prime Phase E, and the Phase F planned to follow prime Phase E. (The merit in and funding for continued operations, known as an extended mission, is assessed after prime Phase E and every three years afterwards in the Senior Review process.)

[Note: Although decadal surveys have referred to a LCC as a "cost cap", NASA does not use this term when discussing a decadal survey-provided figure for two main reasons. First, NASA treats that figure as an estimate or target for the enabling budget. Second, referring to that figure as a "cost cap" creates potential confusion with NASA's definition of "cost cap" in Announcements of Opportunity.]

The LCC is either estimated by the TRACE (Technical, Risk, and Cost Evaluation) process or specified for PI-defined/PI-led missions (e.g. Explorers).

To ensure that decadal survey mission program recommendations are implementable, the associated project LCCs must include the following elements:

- Project-managed mission cost, including project reserves
- NASA-offered incentives and optional components
    - e.g. Student Collaboration, Science Enhancement Option, Technology Demonstration Opportunity
- Communications and Outreach
- Launch costs
- Mission Directorate Unallocated Future Expenditures (MD-UFE)

To assist the Decadal Survey Committee, these elements are described in Appendix A. These descriptions address, for each element, what is covered and what current policy (e.g. funding level) is.

In order to provide the most complete input for NASA, the decadal survey should treat project Lifecycle Costs in the following ways:

- Explicitly states any assumptions and recommendations for NASA-offered incentives and optional components and for communications and outreach in the mission budgeting
- For each recommended project that does not undergo a separate TRACE assessment (e.g. SMEX, Mission of Opportunity), it explicitly budgets
    - NASA-offered incentives and optional components
    - Communications and outreach
    - Launch costs
    - MD-UFE in Phase C/D equal to 15% of Phase C/D costs
- For each recommended project that undergoes a TRACE assessment, it
    - States the assumptions of launch costs
    - Provides the cost for the 50% confidence level (Phase A-F, excluding launch costs, NASA-offered incentives and optional components, and communications and outreach)
    - Provides the cost for the 70% confidence level (Phase A-F, excluding launch costs, NASA-offered incentives and optional components, and communications and outreach)

    - Budgets the project LCC at the cost for the 70% confidence level (Phase A-F) plus launch costs, NASA-offered incentives and optional components, and communications and outreach
    - Specifies and discusses the basis for and impact of the significant cost threats, preferably with potential avoidance and mitigation strategies

Extended Mission Budgets

After successful completion of prime Phase E, missions are eligible for consideration for continued operations. This continuation is termed an extended mission, and the mission costs must be accounted for in NASA's budget.

Budgets are decreased in extended mission. There is no set policy that prescribes the schedule for this decrease, but historical data can show what happened to mission budgets in previous years. However, it must be remembered that each mission currently in continued operations has different specific needs, launched at different times, and experienced different budget realities.

Averaging over all missions and all years, historically, the budgets for individual extended missions have decreased ~6-7 percentage points (or the original Phase E budget) per year for the first five years of continued operations. After the sixth year, budget reductions have decreased to ~1-2 percentage points per year. After around fifteen years of continued operations, the budget no longer decreases (although that conclusion is based on a small number of missions). (Note: These figures are given in percentage points, not percentages. A budget that decreases 10 percentage points per year will have decreased 50% after five years, not 41%.)

In order to provide the most complete input for NASA, the decadal survey should treat extended missions in the following ways:

- Explicitly states any assumptions or recommendations that frame the funding for extended missions
- Explicitly states how extended missions are considered in the balance of the mission portfolio
- Includes the cost of extended missions, accounting for the need to support both
    - currently operating missions, and
    - missions entering continued operations during the decadal survey period of coverage
- Provides decision rules in the situation where budget realities deviate from the decadal survey's assumptions and recommendations, particularly with regards to
    - the balance of continued mission operations with a funded science investigation,
    - continued mission operations as HSO Infrastructure (per 2020 Heliophysics Senior Review), and
    - new mission starts
- Does not specify particular missions' continued operations or termination

Appendix A

Elements of Project Lifecycle Costs

Project-managed mission cost: The project-managed funding for the successful completion of the baseline investigation, including reserves. In SMD Announcements of Opportunity (AO; including Missions of Opportunity), this is referred to as the PI-Managed Mission Cost (PIMMC). For directed missions, this is the budget managed by the Project Office.

- *Policy*
    - At selection: SMD standard policy is to require at least 25% Phase B-D unencumbered reserves, although the 2018 Heliophysics Technology Demonstration required 30% reserves due to the nature of risk in that solicitation. (Phase E-F unencumbered reserves requirements are set by the needs of the solicitation. Some set a minimum amount while others require that proposals set and justify their own reserve posture.)
    - At confirmation: At KDP C, projects are typically assessed on the ability to meet or exceed the 50% confidence level within the project-managed mission cost.
        - The 2013 Solar and Space Physics Decadal Survey showed the Cost Risk Analysis S-Curve in the CATE Output Products (pages 373-376). This curve is a standard method of estimating the cost at a given confidence level. (Note: Those products include the Launch Vehicle, which is outside of this mission cost, and Threats, which are at least partially outside of this mission cost and discussed under *Mission Directorate Unallocated Future Expenditures* below.)

NASA-offered incentives and optional components: The funding that is managed by the project for NASA-approved mission components that are not necessary for the baseline investigation. Unless otherwise stated, their costs are outside of the project-managed mission cost.

- *Policy*
    - Student Collaboration: SMD Policy Document 31 (SPD-31) defines the high-level expectations for Student Collaborations. It states that SMD will provide an incentive outside of the project-managed mission cost. The incentive is typically 1% of that cost, but SPD-31 does not prescribe a minimum or maximum value. (Projects may propose a Student Collaboration that exceeds that inventive, but the amount in excess must be funded within the project-managed mission cost.)
    - Science Enhancement Option (SEO): SEOs are invited based on the needs and focus of a particular solicitation. SEOs may cover any scientific activity related to the mission, but are generally prohibited from including spaceflight hardware. There are no prescriptions or expectations for SEOs, but Phase E SEOs have been generally proposed at 5-10% (with some up to 50%) of the project-managed mission cost in Phase E/F.
        - Note: While AOs may mention Participating Scientist, Guest Investigator, Guest Observer, and similar programs, current Heliophysics Division policy is for those programs to be offered, funded, and managed by HQ and to be completely separate from the project.
    - Technology Development Option (TDO): TDOs are invited based on the needs and focus of a particular solicitation. TDOs are typically permitted to include an instrument, investigation, new technology, hardware, or software to be

demonstrated on either the flight system or the ground system. They may be defined by either the proposer or by NASA.

- NASA-defined TDOs are typically NASA-developed technologies that projects are encouraged to demonstrate in flight, and are offered for use in the Baseline Investigation. They are accompanied by a specific incentive that is provided to the project regardless of the cost they incur demonstrating the technology.
- Proposer-defined TDOs are accompanied by a proposed cost necessary for implementation, and must be separable from the Baseline and Threshold Investigations.

Communications and Outreach: The funding necessary to implement the project's Communication Plan (and Outreach Plan, if documented separately), as described in SPD-26. This funding is managed by the implementing center and is outside of the project-managed mission cost. There are no prescriptions or general expectations for communication and outreach, but it is typically estimated at 1-2% of the project-managed mission cost.

Launch costs: The funding level needed to launch a mission is specific to that mission, and is primarily driven by the mission and instrument risk classification, launch vehicle categorization, mission trajectory/orbital destination, and mission unique requirements. The procurement of launch services is managed by the Launch Services Program (LSP, NASA Kennedy Space Center), in coordination with the NASA space flight program.

- *Launch cost drivers*
  - **Mission risk classification** is defined following NPR 8705.4A, *Risk Classification for NASA Payloads*, in accordance with NPR 7120.5, *NASA Space Flight Program and Project Management Requirements*. Missions are given a classification from A to D, where Class A missions generally involve the highest launch costs and Class D generally involve the lower launch costs. (Note: Risk classifications are not applied to projects managed under NPR 7120.8.)
    - Class A: The lowest risk tolerance that is driven more by technical objectives. This would normally represent a very high-priority mission with very high complexity.
    - Class B: Low risk tolerance that is driven more by technical objectives. This would normally represent a high-priority mission with high complexity. [Example: Parker, MMS]
    - Class C: Moderate risk tolerance that is driven more by technical objectives. This would normally represent a medium-priority mission with medium complexity. [Example: GDC, IMAP]
    - Class D: High risk tolerance that is driven more by programmatic constraints. This would normally represent a lower priority mission with a medium to low complexity. [Example: SunRISE, GLIDE, PUNCH]
  - **Launch vehicle categorization** is defined by NPD 8610.7D, *Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions*, and addresses launch vehicle risk for launches to Earth orbit or beyond. NASA determines launch vehicle risk categories and mitigates risks through a launch vehicle certification process (NPD 8610.7D, Appendix A).

Category 3 launches are generally the highest cost and Category 1 launches are generally the lowest cost.
    - Category 1 (High Risk) is for Class D missions
    - Category 2 (Medium Risk) is for Class D, C, and (sometimes) B missions
    - Category 3 (Low Risk) can be used for all Classes of missions
  - **Mission trajectory/destination** is determined by the mission-specific needs. The cost is generally higher for those missions for which the launch vehicle is required to deliver them to atypical or highly tailored trajectories or final orbital destinations.
    - Low Earth Orbit (low/medium inclinations)
      - Mass: 0 - 15,000 kg
      - Cost: $60M - $230M
    - Lower Earth Orbit (high inclinations)
      - Mass: 0 - 11,000 kg
      - Cost: $60M - $160M
    - Elliptical (GEO/GTO)
      - Mass: 0 - 19,000 kg
      - Cost: $100M - $350M
    - Earth Escape (non-SLS)
      - Mass: 0 - 15,000 kg
      - Cost: $110M - $400M
- *Policy*
  - This cost is generally outside of the project-managed mission cost. A particular solicitation may, however, specify an incentive or cost for certain launch vehicle options that is within that mission cost.
  - SMD Policy Document 32 (SPD-32) states that excess capacity on launch vehicles for SMD primary payloads may be offered to rideshare payloads. NASA supports the cost rideshare payloads as part of the primary payload's launch vehicle costs (except for any rideshare's mission-unique costs). The cost for integrating rideshare payloads onto the launch vehicle depends on the launch vehicle and the involved payloads, but is estimated at $10M - $20M FY22 (with more payloads typically costing more to launch).
    - Note: Mission unique launch services typically fall within the rideshare payload's project-managed mission costs.

Mission Directorate Unallocated Future Expenditures (MD-UFE): The NASA-managed funding established at confirmation (KDP C) to ensure a 70% confidence level for the successful completion of a project's baseline investigation. This funding is outside of the project-managed mission cost.

- Note: In the 2013 Solar and Space Physics Decadal Survey's CATE Output Products (pages 373-376), the "Threats" category reflected the cost to reach the 70% confidence level (per MD-UFE practice).
- Note: For missions that do not go through the TRACE (formerly CATE) process, such as Explorers, the MD-UFE can be estimated as 15% of Phase C/D project-managed mission costs in those phases. There is no standard practice of MD-UFE for Phase E/F, but

missions with especially complex or risky Phase E operations may have MD-UFE budgeted.