GROUNDRULES FOR COMET SURFACE SAMPLE RETURN MISSION STUDY

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Date	Sections Changed	Reason for Change	Revision
6/27/07	All	First release	Version 1
9/10/07	3, 4, 6	Updated study parameters (in blue)	Version 2

GROUNDRULES FOR COMET SURFACE SAMPLE RETURN MISSION STUDY

NASA Headquarters is commissioning a study of a Comet Surface Sample Return (CSSR) mission, which is a medium class mission to return samples from a comet. The purpose of this concept study is to further refine the concept described in the Decadal Survey (New Frontiers in the Solar System: An Integrated Exploration Strategy, 2003) by defining science objectives, exploring the mission trade space, and pursuing a single mission concept to a greater level of detail. The study results will include a pre-phase A fidelity plan to implement the mission concept, evaluating the cost, schedule and risk. A Science Definition Team (SDT) will be appointed by NASA Headquarters to work with mission designers and technologists. The study will take recent activities into account, assess opportunity and technological readiness, and provide estimated costs.

To facilitate the review of the study results, a standard for the content and final product the study is required. The intent is to describe the overall process and presentation of results while allowing the implementing institution to utilize its own processes to meet the overall approach. This document describes the standard for the study content and final product, guiding assumptions and critical definitions for the study.

The study may undergo independent technical and scientific review. If so, the review panel will examine the final report and other documentation provided by the study teams and will also conduct an oral review with formal presentations from the members of the study team. The review panel will have the opportunity to question the study teams at the oral reviews.

STUDY SCOPE

The study will be comprised of 2 basic parts. Phase I will focus on gaining consensus on the science objectives, exploring architectural options for meeting those objectives, conducting preliminary trade studies, and the narrowing down of potential options to the 1 or 2 most promising mission concepts for further study. Phase II will focus on further refinement of the concepts(s) to explore implementation issues and allow for option costing. The overall study approach is shown in Figure 1. The processes used to implement this approach are at the discretion of the study teams but should be described in the report to enough detail to allow NASA to validate the end mission concept(s).

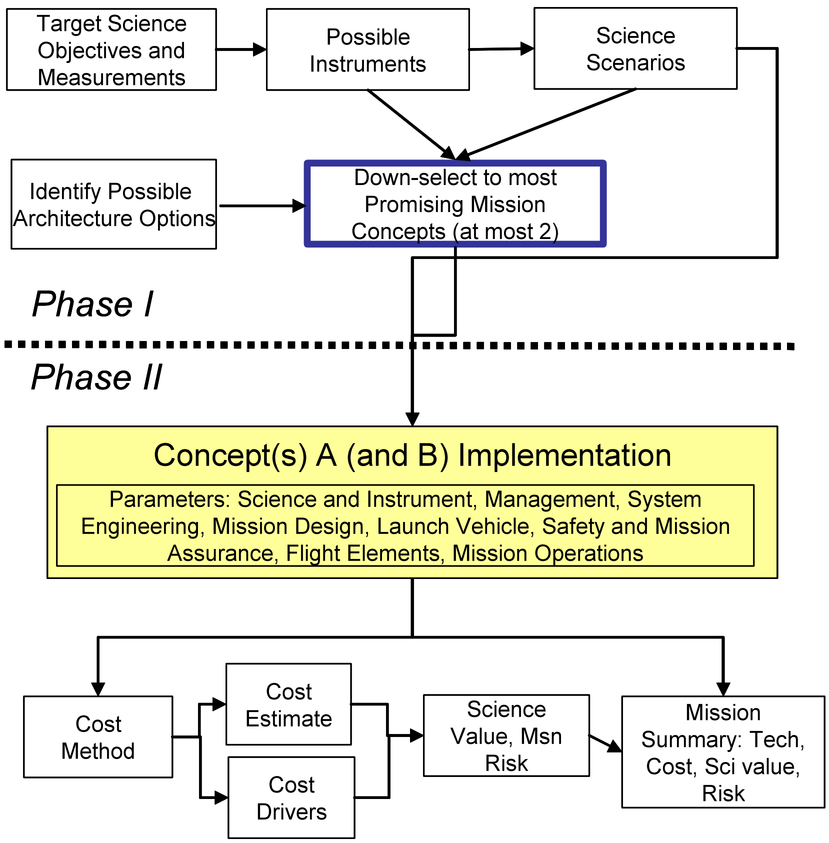

Figure 1 - Structured Approach for CSSR mission concept study

GROUNDRULES

To simplify the execution and review of the CSSR study, the study must follow the groundrules described below. The groundrules provide common simplifying assumptions for the study. They are not intended to prescribe how the study should be conducted; NASA relies on the institution(s) involved in the study to use their best practices in conduct of the work.

1. Radioisotope Power Systems (RPS)

   The study should assume three types of RPS will be available: the Multi-mission Radioisotope Thermoelectric Generator (MMRTG), the Advanced Radioisotope Thermoelectric Generator (ARTG), and the Advanced Stirling Radioisotope Generator (ASRG). Two versions of the ASRG operating at different hot side temperatures are available: one operating at 650° (ASRG 650) and one at 850° (ASRG 850). Information on cost, availability, and performance characteristics to be used during these studies are summarized in summary sheets (RPS_Spec_Sheets_Rev09-Final.doc) provided by the RPS Program Executive Alan Harmon.
2. Planetary Protection

   Formal planetary protection guidelines have not been set for comets. The NASA Planetary Protection Officer, Dr. Catharine Conley (cassie.conley@nasa.gov, (202)358-3912), is available to provide further guidance on the planetary protection categorization, requirements, and, strategy for the study. NASA requirements for Planetary Protection are found in NPD 8020.7F, Biological Contamination Control for Outbound and Inbound Planetary Spacecraft, and the subsidiary documents NPR 8020.12C, Planetary Protection Provisions for Robotic Extraterrestrial Missions, and NPR 5340.1C, NASA Standard Procedures for the Microbial Examination of Space Hardware, or revisions. Categorizations are determined on a mission-by-mission basis, applying the most current scientific information, with advice from the Planetary Protection Subcommittee of the NASA Advisory Council and considering recommendations made by the Space Studies Board of the National Research Council.

   2.1. For all missions, end-of-mission scenarios that account for the disposition of a radioisotope power source (RPS) may choose to demonstrate orbital lifetime beyond the effective lifetime of the heat source, a burn-up/break-up analysis demonstrating that the RPS would not create a biological contamination concern, or directed disposal of the spacecraft into an object that is not of concern for biological contamination.

   2.2. Sample return missions from targets that may contain liquid water must sterilize returned samples to be considered for an 'Unrestricted Earth Return' categorization, or fulfill all requirements for samples considered 'Restricted Earth Return' which include full biohazard and contamination control in an appropriate (but currently nonexistent) facility upon landing.
3. Cost Cap

   The cost cap for the mission concept will be approximately $820M in FY07$.
4. Launch Vehicles and Cost

   The mission concept is limited to using EELV-class launch vehicles. For the Delta IV Heavy and Atlas 5 launch vehicles, the cost information below should be used. Information on performance and cost for these launch vehicles was obtained from POC Norm Beck of Kennedy Space Center (norman.m.beck@nasa.gov, (321)867-6348). Table 1 shows the estimated costs for launch services for each of the launch vehicles to be considered for this study. Assumptions and performance information is given in Appendix 2. If the team wishes Atlas 5 or Delta IV Heavy variants not in Table 1 it should contact Norm Beck (and cc Curt Niebur).

LV and Services	Cost ($FY06M)

A 401	$125
A 501	$130
A 511	$140
A 521	$150
A 531	$160
A 541	$170
A 551	$180
D IVH	$475

Table 1. ROM Launch Services costs for Atlas 5 and Delta IV Heavy launch vehicles. These are estimates only. Costs should be spread starting at Launch-27 months. There are additional costs of $11M for nuclear payloads.

5. Technology Philosophy

   Funding for technology development is limited, and as a result technology programs are focused on providing capabilities that are broadly applicable for solar system exploration. No new technology efforts dedicated to outer solar system uses are expected in the near to mid term. In light of this, the study should adopt a conservative approach to the use of new technologies. Development plans with supporting rationale, schedules, and cost estimates should be provided. A discussion of the impact to the mission should the technology be unavailable should also be provided.

6. Launch Dates

   A 2016 launch date (+/- 1 year) should be assumed.

7. DSN Capability

   A new architecture is planned for the DSN for the mission lifetime used for this study. Detailed plans for this new architecture are not yet complete, and a firm schedule and budget commitment are not in place. As a result, DSN performance expectations for this timeframe are not well defined and could be over optimistic. The study should confine themselves to the broad assumptions below.

   7.1. Study team should assume that Ka band (32 GHz; 500 MHz bandwidth) is available for downlink from the spacecraft. Tests with New Horizons show using both right hand circular and left hand circular polarization in the downlink can increase data return by a factor of 2.

   7.2. By 2015, the study team should assume that the 70 m antennas will be replaced by arrays of smaller antennas. Details on this new system are not yet determined, but it is expected that the new arrays will at least replicate the capabilities of the 70 m antennas they are replacing. Combined with the capabilities provided by use of Ka band, a conservative estimate for these studies is for the DSN to have the equivalent of 4x the current 70 m capability. The study should assume that the existing 34 m antenna array is available.

   7.3. The study should assume the DSN ground system can handle a throughput of 100 Mbits/sec.

   7.4. Ed Luers (JPL, edward.b.luers@nasa.gov, (818)354-8206) will serve as the POC for scheduling and costing DSN use.

8. International Contributions

   Although international participation is an optional and important component of any flagship mission, for the purposes of this study it should be assumed that no international collaborations or contributions are available.

9. In-Space Propulsion Technology

   The study team may benefit from advanced spacecraft propulsion technologies under development by In-Space Propulsion Technology (ISPT) project, funded out of NASA

Science Mission Directorate (SMD). Technologies under development by the ISPT project that are available to the study teams are Aerocapture, Advanced Chemical Propulsion, Electric Propulsion, and Solar Sails. ISPT has also invested in support tools such as a suite of low-thrust trajectory tools and supporting mission /system studies. The ISPT project can support the study team by providing briefings and updated information on any of these technologies. The ISPT project can also provide experts to participate on the team in a more involved fashion if so desired. To discuss these options please contact the ISPT project manager, Tibor Kremic at 216/433-5003 and he will facilitate the support.

FINAL REPORT

The study team should prepare a final written report following the outline below. If specific areas were not addressed during the study, provide the section title and a brief statement of the rationale for omission (i.e. not applicable to this concept, don't have depth of design to address, no stressing requirements identified, didn't have time to investigate etc.).

1.0 Executive Summary
2.0 Target Body Science Goal and Objectives
3.0 Mission Architecture Assessment
4.0 Mission Concept A Implementation
- 4.1 Architecture Overview
- 4.2 Science Investigation
- 4.3 Mission Design
- 4.4 Flight System Design and Development
- 4.5 Operational Scenario
- 4.6 Planetary Protection
- 4.7 Major Open Issues or Trades
- 4.8 Technology Needs
- 4.9 Technical Risk Assessment
- 4.10 Schedule
- 4.11 Cost

5.0 Mission Concept B Implementation (if applicable)
- Repeat as above

6.0 Summary

The following sections provide a more detailed discussion of the content of each section.

1.0 Executive Summary

The Executive Summary is to be a summary of the study and is to include an overview of each mission concept discussed including its scientific objectives and technical implementation.

2.0 Target Body Science Goal and Objective

This section should describe the Science Goals and Objectives as confirmed by the SDT. If possible, the relative priorities of objectives and/or sub-objectives should be noted and process for gaining consensus should be described. The traceability of the Goals and Objectives to measurement requirements objectives to mission requirements should be described and included in a traceability matrix. The traceability of the Goals and Objectives to relevant NASA strategic documents should also be included. These documents include the 2003 Decadal Survey, the 2006 NASA Solar System Exploration Roadmap, and the 2006 OPAG Goals and Pathways report. An approach to measuring relative science value for different mission concepts should be developed and discussed here.

3.0 Mission Architecture Assessment

This section should briefly describe each architecture investigated and the process by which architectural options were identified and evaluated. The process and selection criteria for choosing the 1 or 2 architectures for further analysis in Phase II should be clearly detailed.

4.0 Mission Concept A Implementation

4.1. Architecture Overview

This section should provide a brief overview of the technical approach including its key challenges and elements.

4.2. Science Investigation

This section should further align the science objectives and measurement objectives to mission requirements and instrument requirements. If only a subset of the science objectives are met by the mission architecture, clearly show which objective subset is addressed by this architecture and discuss rationale for its selection. The derivation of the strawman payload should be described along with how the payload meets the science objectives. The draft Level 1 science requirements of the investigation must be clearly identified in this section. A discussion of the performance floor (the level of science descope beyond which the mission should be cancelled) should be included. A description of the descope options available, their phasing, and their effect on meeting the scientific objectives of the investigation as it is descoped from the Baseline to the Performance Floor must be included. Discuss the relevant decision points (e.g., PDR, CDR) for consideration of descope options, and describe any cost savings achieved, specified at each decision point if applicable.

Show how the characteristics and requirements of the science implementation are traceable to the objectives, requirements, and constraints of the investigation.

This section must describe the science implementation for the investigation, including instruments, sample acquisition and processing system (if needed), and other relevant items. Technology readiness level of these items should be briefly discussed. The discussion of flight heritage or rationale should include basic assumptions about availability of components and the heritage of the overall instrument design. Assumptions about potential cost savings that result from heritage should be quantified and included in the Cost section. Additional implementation details should be provided for items with heritage to systems that have not yet been successfully demonstrated in space.

Instrument performance necessary to achieve science objectives must be described. Brief descriptions of datasets generated by instruments and needed to achieve science objectives should be provided. Subsystem characteristics and requirements must be described. Such characteristics and requirements include: mass, volume, and power requirements; unique computing and data resource requirements, driving pointing requirements; and new developments needed. Include any available block diagrams, layouts, calibration plans, and operational and control considerations. Any design features incorporated to affect cost savings should be identified. The effects of mission environments including radiation, thermal, etc. on the design should be discussed.

4.3. Mission Design

This section should fully describe the operational phase of the mission from launch to end of mission. It should include information on the key driving requirements, proposed launch date (including any launch date flexibility), launch vehicle, launch energy (C3), trajectories, delta-v requirements, orbit characteristics, encounter geometry (orbiter, flyby, lander, etc.) and characteristics (flyby altitude and speed, orbital period, etc.), mission duration, and a preliminary mission timeline indicating periods of data acquisition, data downlink, etc. It should also include an analysis of all phases of the trajectory/orbit design including total delta-v and trajectory correction maneuvers. The rationale for the selection of launch vehicle should be included. The concept study should identify any innovative features of the mission design that minimize total mission costs. The key characteristics of the communications links should be described including link margins, data rate and volume, and required power for communications for each key link. This should also describe any assumptions and key requirements for the Deep Space Network (DSN) or other communications network to be used.

4.4. Flight System Design and Development

This section should describe the basic flight system design/development approach, particularly as it relates to new versus existing hardware and software and redundancy/fault tolerance approach (single vs dual string, etc.). It should identify the flight system elements and describe their key characteristics and driving requirements. A description of the flight system design with a block diagram showing the subsystems and their interfaces should be included, along with a description of the flight software capability assumed including basic level of autonomy. The discussion of flight heritage or rationale should include basic assumptions about availability of components and the heritage of the overall system design. Assumptions about potential cost savings that result from heritage should be quantified and included in the Cost section. Additional implementation details should be provided for items with heritage to systems that have not yet been successfully demonstrated in space.

Key subsystem characteristics, requirements, and expected performance should be described to the extent possible. These subsystems include: structural/mechanical, solar array/power supply (and batteries), electrical, thermal control, propulsion, communications, attitude control, command, and data handling, etc. Key characteristics include current best estimate and contingency for: mass, volume (if critical), and power requirements; performance; pointing knowledge and accuracy; and new developments needed. The effects of mission environments including radiation, thermal, etc. on the design should be discussed. Include subsystem block diagrams if available.

A summary of the resource elements of the flight systems design concept, including key contingencies and margins, should be provided. The rationale for, and derivation of, contingencies and margin allocations including mass, power, communication link performance (data and carrier), pointing accuracy, etc., should be provided. Those design margins that drive costs should be identified and a discussion of how they are used within the cost estimation processes should be included in the cost section. A Master Equipment List should summarize mass and power information for all hardware subsystems of the flight elements (e.g., spacecraft, probes, canisters, and individual instruments).

This section should characterize any stressing interfaces between the instruments and the flight system. These include, but are not limited to: volumetric envelope, fields of view, mass, power requirements, thermal requirements, command and telemetry requirements, sensitivity to or generation of contamination (e.g., electromagnetic interference, gaseous effluents, etc.), data processing and storage requirements.

This section should provide a very brief overview of Assembly, Test, and Launch Operations (ATLO), summarizing at a high level the approach and any special considerations or facilities. Briefly describe flight system assembly, test, and launch operations, and identify any stressing requirements.

Show how the characteristics of and requirements on the flight elements are traceable to the objectives, requirements, and constraints of the investigation.

4.5. Operational Scenario

This section should describe the operational scenario envisioned for each driving operational mode. Each scenario should include power profile; data flow including data collection, reduction, storage and downlink; instrument usage assumptions; and necessary commanding or on-board autonomy requirements and should explicitly discuss how the scenario addresses the key requirements for the mode. This section should also address the key operational requirements which are stressing the system or are unique to this mission concept.

4.6. Planetary Protection

This section should provide an approach to planetary protection consistent with the Groundrules outlined later in this document for each target. The discussion should provide enough detail so that NASA can validate that the team has a good understanding of the requirements and an appropriate implementation for costing. Outline any special requirements on personnel, instrumentation, spacecraft assembly, facilities, launch configuration, and mission operations.

4.7. Major Open Issues or Trades

This section should discuss any major open issues or trades which were identified but not resolved during this study. A description of potential impacts to mission concept should be included.

4.8. Technology Needs

The Technology Assessment section should discuss the technology needs for the mission. Key technologies should be identified and their potential sources indicated. The current level of technology readiness, modifications necessary in order to utilize the technology for the mission, and development plans (including estimated schedules and development costs) to achieve the necessary level of technology readiness should be presented. Impacts to the mission if key technologies are unavailable should be presented, as well as possible alternatives if the key technology cannot be made ready.

4.9. Technical Risk Assessment

This section should provide an overall assessment of at least the top 3 technical risks associated with the development aspects of the concept and an assessment of at least the top 2 technical operational risks associated with the concept. This assessment should include discussion of potential mitigation strategies and cost/schedule/performance impacts.

4.10. Schedule

This section should provide a project lifecycle schedule to at least WBS level 2. Schedules for all major reviews, key decision points, and activities, interdependencies between major items, deliveries of substantial end items, critical paths, and schedule margins should be identified and discussed. Any essential technology developments should be included.

4.11. Cost

This section shall include an estimated cost of the mission concept that encompasses all proposed activities, including all applicable mission phases, launch vehicles and services , development of the ground data system, implementation of E/PO, power sources etc. In particular, where NASA provided services are assumed, NASA Civil Service labor and supporting NASA center infrastructure must be costed on a full-cost accounting basis. Technology developments should be included in the cost estimate but should be clearly indicated and shown below the line. Costs should be presented as shown in provided Excel spreadsheet template.

Costs associated with Radioisotope Power Sources and launch vehicles/services should be per the Groundrules section of this document and appropriate reserves should be applied. If additional information beyond that contained in this document is required, the POC should be contacted to provide additional information. All deviations from costs contained in this document must be explained in this section.

The methodology used to estimate the cost, for example, grass-roots estimates, specific cost models, past performance, and/or cost estimating relationships from analogous missions must be discussed. The approach to validating the estimated cost should be discussed, and if independent assessments are conducted, a summary of the results should be provided. Budget reserve strategy, including budget reserve levels as a function of mission phase, must be identified by mission phase and discussed. All assumptions used in developing cost estimates to help facilitate reviewer understanding the proposed cost estimates must be provided. If costs models are used, they should be identified, and the input tables for those models should be included. It must be clear whether Current Best Estimate (CBE), CBE plus contingency, CBE plus contingency plus margin or other is used for each input value.

Cost risk and the uncertainties in the baseline cost estimate must be discussed.

A summary of reserves in cost and schedule should be identified by Phase and by major element and the rationale for them discussed.

5.0 Mission Concept B Implementation (if applicable)

Repeat outline above. If there are sections which are identical for each architecture, then that can be stated by just referring to other section.

6.0 Summary

This section should summarize the science value, risk and cost associated with the described mission concepts.

Each team should supply a signed original (SDT co-chairs, study lead, and necessary institution management) with 8 hardcopies with accompanying CDs with electronic copies. Reports should be searchable PDF. Excel spreadsheets with cost tables should be included. Any presentation material (Powerpoint, etc.) should also be included on CD.

APPENDIX 1: DEFINITIONS

Contingency and Margin

Contingency (or *Reserve*), when added to a resource, results in the maximum expected value for that resource. Percent contingency is the value of the contingency divided by the value of the resource less the contingency.
Margin is the difference between the maximum possible value of a resource (the physical limit or the agreed-to limit) and the maximum expected value for a resource. Percent margin for a resource is the available margin divided by its maximum expected value.
Example: A payload in the design phase has a currently estimated mass of 115 kg including a mass reserve of 15 kg. There is no other payload on the Expendable Launch Vehicle (ELV) and the ELV provider plans to allot the full capability of the vehicle, if needed. The ELV capability is 200 kg. The mass reserve is 15/(115-15) = 15%, and the mass margin is 85 kg or 85/115 = 74%. Example: The end-of-mission life capability of a spacecraft power system is 200 Watts. The proposed instrument is expected to use 40 Watts, and a 25% contingency is planned. If 75 Watts is allotted by the satellite provider, the reserve is (.25x40) =10 Watts while the margin is 75 – (40+10) =25 Watts, or 25/50 = 50%.

Using the term contingency equivalently to the term reserve, and acknowledging that the maximum expected resource value is equal to the maximum proposed resource value (including contingency), the above technical terms can be expressed in equation form as:

$$\text{Contingency} = \text{Max Expected Resource Value} - \text{Proposed Resource Value}$$

$$\%\ \text{Contingency} = \frac{\text{Contingency}}{\text{Max Expected Resource Value} - \text{Contingency}} \times 100$$

$$\text{Margin} = \text{Max Possible Resource Value} - \text{Max Expected Resource Value}$$

$$\%\ \text{Margin} = \frac{\text{Margin}}{\text{Max Expected Resource Value}} \times 100$$

Cost Elements

This is a short dictionary of definitions for the cost elements used in the tables.

Project Management/Mission Analysis/Systems Engineering - Project management costs include all efforts assocated with project level planning and directing of prime and subcontractor efforts and interactions, as well as project-level functions such as quality control and product assurance. Mission Analysis includes preflight trajectory analysis and ephemeris development. Systems engineering is the project-level engineering required to ensure that all satellite subsystems and payloads function properly achieve system goals and requirements. This cost element also includes the data/report generation activities required to produce internal and deliverable documentation. Project management for phase E is to be shown as a separate line item under Phase E (Operations).

Instruments - Instrument costs include costs incurred to design, develop and fabricate the individual scientific instruments or instrument systems through delivery of the instruments to the spacecraft for integration. Costs for instrument integration, assembly, and test are to be shown separately from instrument development. Costs incurred for integration of the instruments to the spacecraft are included in the Spacecraft Integration, Assembly & Test cost element (see below).

Flight Element - Flight element costs include costs incurred to design, develop, and fabricate (or procure) the flight element subsystems and system testbeds. Costs for integration and assembly are not included in this element. System tests are included in IA&T (see below).

Integration, Assembly & Test (IA&T) - IA&T is the process of integrating all flight element subsystems and payloads into a fully tested, operational spacecraft system. The total cost of IA&T includes requirements specification, design and scheduling analysis of IA&T procedures, ground support equipment, systems test and evaluation, and test data analyses. Typical system tests include thermal vacuum, thermal cycle, electrical and mechanical functional, acoustic, vibration, electromagnetic compatibility/interference, and pyroshock.

Launch Checkout & Orbital Operations - Launch checkout and orbital operations support costs are those involving pre-launch planning, launch site support, launch-vehicle integration (flight element portion), and the first 30 days of flight operations.

Pre-Launch Science Team Support - Includes all Phase C/D (pre-launch) support costs for the science team. (See below for post-launch component.)

Pre-Launch GDS/MOS Development - Includes costs associated with development and acquisition of the ground infrastructure used to transport and deliver the telemetry and other data to/from the Mission Operations Center and the Payload Operations Center. Includes development of science data processing and analysis capability. Also includes pre-launch training of the command team, development and execution of operations simulations, sequence development, and flight control software. This element includes any mission-unique tracking network development costs.

Mission Operations (MO) - *This cost element refers only to Phase E (post-launch).* Mission operations comprises all activities required to plan and execute the science objectives, including spacecraft and instrument operations, navigation, control, pointing, health monitoring, and calibration. Costs include all post-launch costs for people, procedures, services, hardware and software to carry out these activities.

Data Analysis (DA) - *This cost element refers only to Phase E (post-launch).* Data analysis activities include collecting, processing, distributing and archiving the scientific data in the appropriate data archive. Costs include all post-launch costs for people, procedures, services, hardware and software to carry out these activities. Includes science team support costs post-launch.

Deep Space Network (DSN) or Other Tracking Services - DSN tracking services for communications between the flight element and Earth control center and station complexes are acquired through JPL. Ground Network (GN) and Space Network (SN) tracking and communication services are acquired through GSFC. This line item includes all costs associated with this DSN, GN, and SN services for the specific proposed mission profile.

Education and Public Outreach - Includes all costs associated with developing and implementing the proposed project's programs for education and public outreach.

Project-Unique Facilities - If the proposed concept requires construction or lease of any ground facilities, include here only the portion of costs to be borne by the proposed project, with description of the nature and extent of any cost-sharing arrangements assumed.

Launch Services - Launch vehicles and services are procured and provided by NASA. The launch service price included in the Groundrules above includes procurement of the ELV, nuclear payload costs, flight element-to-launch vehicle integration, placement of flight element into designated orbit, analysis, post-flight mission data evaluation, oversight of the launch service and coordination of mission-specific integration activities.

Reserves - Reserves should include those funds that are not allocated specifically to estimated resources, but are held against contingencies or underestimation of resources to mitigate the investigation risk. Appropriate reserves should be applied and discussed for all mission concept elements.

Technology Development – If the proposed mission concept requires technology development, an estimate of the development costs and required reserves should be included in this line.