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National Aeronautics and Space Administration

Criteria and Requirements for the Phase A Concept Study Report

2025 ASTROPHYSICS SMALL EXPLORER (SMEX)

Draft

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2025 ASTROPHYSICS SMALL EXPLORER ANNOUNCEMENT OF OPPORTUNITY (NNH25ZDA***O) CRITERIA AND REQUIREMENTS FOR THE PHASE A CONCEPT STUDY

INTRODUCTION

As the outcome of the Astrophysics Small Explorer (SMEX) Announcement of Opportunity (NNH23ZDA021O, hereafter, the "AO") Step-1 competition, NASA selected **** investigations that the Agency will fund to perform concept studies. The concept study for each selected investigation will constitute the investigation's Concept and Technology Development Phase (Phase A) of the Formulation process as outlined in NPR 7120.5, *NASA Space Flight Program and Project Requirements*.

Documents available through the Astrophysics SMEX Program Library at https://explorers.larc.nasa.gov/APSMEX25/SMEX/programlibrary.html are intended to provide guidance for selected investigations. This website is hereafter referred to as the Program Library. Note that new documents have been added to the Program Library for this Step-2 competition, and some documents have been updated. Concept Study Teams are responsible for reviewing these documents to ensure they address all applicable requirements for the versions noted.

Concept studies are intended to provide NASA with more definitive information regarding the cost, risk, and feasibility of the investigations, as well as small business subcontracting plans, optional Student Collaborations (SCs), and Science Enhancement Options (SEOs), if proposed, before final down-selection for implementation.

The product of a concept study is a Concept Study Report (CSR), to be delivered to NASA approximately twelve months after the Concept Study Kick-Off Meeting (see below). This document provides criteria and requirements for preparing a CSR. All program constraints, guidelines, definitions, and requirements specified in the AO are applicable to the CSR, except as noted herein.

Items that were deferred from Step 1 that must be provided in the CSR are shown in Table 1 below:

Table 1. Items Deferred from Step 1

AO Requirement Description	AO Section	AO Requirement(s)	C&R Reference
Independent Verification and Validation of Software	4.6.1	N/A	N/A
Planetary Protection	5.1.6	17	Appendix L.9, Requirement CS-119
Science Enhancement Option and its cost, if proposed	5.1.7	18 and 19	Requirement CS-31
Demonstration of maximum channel bandwidth	5.2.7.2	39	Requirement CS-42

Discussion of critical event coverage capabilities	5.2.8	43	Requirement CS-42
Detailed plan for orbital debris and disposal	5.2.9, J.9	44, B-65 thru B-69	Appendix L.10
Non-AMMOS system use and description	5.2.11	46	Appendix L.23, Requirement CS-143
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Ground system data flow diagram	5.2.13	48	Requirement CS-42
Justification of EVM reimbursement	5.3.7	58	Requirement CS-57
Student Collaborations and their cost, if proposed	5.5.2	66, 67, B-54	Requirement CS-100 thru Requirement CS-102
Discussion of cost estimate error and uncertainty	5.6.3	76	Requirement CS-80
Requirements for real year dollar costs	5.6.2	B-14, B-52, B-53	Requirement CS-84 Cost templates

CSRs and all required and optional files are due to the Astrophysics SMEX Program Scientist, Doris Daou, by 4 p.m. U.S. Eastern time on the following dates by the method specified in Requirement CS-11:

Initial Proposal Participants list .....October **, 2026
Final Proposal Participants list.....With CSR
Deadline for CSR with all Appendices .....January **, 2027
Deadline for Augmented Submission ..... Jaunary **, 2027 + 1 week
Deadline for draft SOWs (Appendix M.4) .....Site Visit date

PART I of this document describes the evaluation criteria for CSRs. PART II provides guidelines for preparing CSRs; every requirement in these guidelines must be addressed in the section in which the requirement appears. An explanation and justification must be provided for any requirement that is not fully addressed in the CSR. PART III describes other factors that are not required and will not be evaluated, but will need to be provided by the project shortly after a continuation decision (*i.e.*, "down-selection").

Phase A contracts for all selected investigations will include a six-month priced option for a Bridge Phase, that will be exercised for the down-selected investigation. The focus of the Bridge Phase will be:

1. participation in the Explorers Program Office project kick-off meeting;
2. work with the Explorers Program Office to negotiate and award the balance of Phase B;
3. other interactions with the Explorers Program Office as necessary; and
4. other project work planned for the first six months of Phase B.

For each investigation selected in Step 1, the Explorers Program Office at the NASA Goddard Space Flight Center (GSFC) will negotiate a priced option for the Bridge Phase into the Phase A contracts. After they are notified of the Phase A selection, organizations to be awarded a Phase A contract will receive a Request for Proposal (RFP) for a detailed cost proposal that includes the effort to complete Phase A and as a separately priced Phase B Bridge option.

Since evaluation of CSRs is a major part of Step 2 in the acquisition process, NASA will assemble an evaluation team of scientific and technical peers to carefully consider each CSR.

Because members of this evaluation team may not have reviewed, nor will be provided access to, Step-1 proposals, each CSR package (the CSR together with all required and optional files) must be a self-contained submission.

The CSR evaluation process will include visits (either in person, virtual, or hybrid) by the evaluation team to each investigation team's chosen site, to hear oral briefings and, if needed, to receive updates and clarification of material in the CSRs. These briefings will be conducted approximately three months following submission of the CSRs; scheduling and expectations for the Site Visits will be addressed at the Concept Study Kick-Off Meeting. NASA may identify significant weaknesses, questions, and requests for information, and ask that the investigation team respond to these either prior to, during, or after the Site Visit. Any additional information provided to NASA by the investigation team will be considered during the evaluation and treated as updates and clarifications to the CSR.

Investigation teams are responsible for the content and quality of their CSRs, Site Visit presentations, and responses to weaknesses and questions, including parts that may be prepared by partner organizations or by any other individual. All assumptions and calculations should be carefully documented in the CSR and agreed to by the Principal Investigator (PI) and their team, to ensure that they are accurate and that they will satisfy NASA requirements. Investigation teams are also responsible for ensuring that all requirements specified in Part II of this document are addressed.

As the outcome of Step 2, it is anticipated that the Selection Official, the Associate Administrator of the Science Mission Directorate (SMD) at NASA Headquarters or their designee, plans to continue up to one investigation into the subsequent phases of mission development for flight and operations (*i.e.*, Phases B-F). The target date for this down-selection is approximately five months after the CSRs are due to NASA.

Upon the down-selection decision, NASA will execute the Bridge Phase option and begin to provide Phase B funding for any project that is continued beyond the Phase A Concept Study. During the Bridge Phase, NASA and the continued project(s) will negotiate and sign a contract modification necessary for the remaining portion of Phase B, on the basis of information provided in the CSR (*e.g.*, Sections H, I, and L.4). The Bridge Phase is intended to initiate Phase B and to provide continuity while negotiations are completed to modify the contract to include Phases C/D and E/F.

For those investigations that are not continued, the contracts will be allowed to terminate without further expense to NASA. Every investigation team will be offered a debriefing of the evaluation of its CSR.

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PART I - EVALUATION CRITERIA

The evaluation of CSRs is very similar to the evaluation of Step-1 proposals, as described in Section 7.1 of the AO. The evaluation criteria and their factors, specified in Section 7.2 of the AO, apply fully to CSRs. However, all factors related to the probability of mission success and to the realism of the proposed costs to NASA will be considered in greater depth of detail. Additional factors, such as implementation plans for Student Collaborations and small business subcontracting, will also be evaluated. In case of conflict between the AO and the *Criteria and Requirements for the Phase A Concept Study (C&R)*, the C&R document takes precedence.

All information relevant to the evaluation will be considered during the evaluation of Step 2 concept studies, including information contained in the CSR, information presented during the Site Visit, and information provided in response to potential weaknesses, clarifying questions, and other requests for information.

Each CSR must be a self-contained submission and must not refer to information contained in the Step-1 proposal and associated clarification documents. Except for compliance checking by NASA (*e.g.*, that the PI-Managed Mission Cost (PIMMC) has not grown by more than 20%) and for determining if re-evaluation of the *Scientific Merit of the Proposed Investigation* is required (as described below), the Step-1 proposals will not be used in the Step-2 evaluation.

The evaluation criteria for the Step-2 evaluation are:

A. Scientific Merit of the Proposed Investigation (Form A);
B. Scientific Implementation Merit and Feasibility of the Proposed Investigation (Form B);
C. Technical, Management and Cost (TMC) Feasibility of the Proposed Mission Implementation (Form C);
D. Merit of the Student Collaboration Plan (Form D); and
E. Merit of the Small Business Subcontracting Plan (Form E).

A. SCIENTIFIC MERIT OF THE PROPOSED INVESTIGATION

The Astrophysics SMEX Program Scientist will determine whether any issues that may have emerged in the course of the concept study have resulted in significant changes to the science objectives or other aspects of the proposed Baseline and Threshold Science Investigations (see Requirement CS-20 in PART II of this document) in such a manner as to have impacted the basis for the evaluation of the scientific merit of the investigation as determined by the peer review panel for the Step-1 proposal. If there are no significant changes to the proposed investigation that undermine the basis of this rating, the peer review panel rating for scientific merit of the Step-1 proposal will be the rating for scientific merit of the CSR. If there are significant changes, the Program Scientist may convene a peer review panel to re-evaluate the *Scientific Merit of the Proposed Investigation* in light of these changes. The factors for re-evaluating this criterion will be the same as those used for the Step-1 proposal review (Section 7.2.2 of the AO).

B. SCIENTIFIC IMPLEMENTATION MERIT AND FEASIBILITY OF THE PROPOSED INVESTIGATION

All of the factors defined in Section 7.2.3 of the AO also apply to the evaluation of the CSR. *New factors and details added to Step-1 AO factor definitions for the evaluation of the CSR are highlighted using blue italicized text.*

- Factor B-1. Merit of the instruments and mission design for addressing the science goals and objectives. This factor includes the degree to which the proposed mission will address the goals and objectives; the appropriateness of the selected instruments and mission design for addressing the goals and objectives; the degree to which the proposed instruments and mission can provide the necessary data; and the sufficiency of the data gathered to complete the scientific investigation.
- Factor B-2. Probability of technical success. This factor includes the maturity and technical readiness of the instruments or demonstration of a clear path to achieve necessary maturity; the adequacy of the plan to develop the instruments within the proposed cost and schedule; the robustness of those plans, including recognition of risks and mitigation plans for retiring those risks; the likelihood of success in developing any new technology that represents an untested advance in the state of the art; the ability of the development team—both institutions and individuals—to successfully implement those plans; and the likelihood of success for both the development and the operation of the instruments within the mission design. *This factor includes assessment of technology readiness, heritage, environmental concerns, accommodation, and complexity of interfaces for the instrument design*.
- Factor B-3. Merit of the Open Science and Data Management Plan including data analysis, Data Management Plan, Software Management Plan, and Open Science Plan. This factor includes the merit of plans for data analysis and data archiving to meet the goals and objectives of the investigation; to result in the publication of science discoveries in the professional literature; and to preserve data and analysis of value to the science community. Considerations in this factor include assessment of planning and budget adequacy and evidence of plans for well-documented, high-level data products and software usable to the entire science community; assessment of adequate resources for physical interpretation of data; reporting scientific results in the professional literature (e.g., refereed journals); and assessment of the proposed plan for the timely release of the data to the public domain for enlarging its science impact.
- Factor B-4. Science resiliency. This factor includes both developmental and operational resiliency. Developmental resiliency includes the approach to descoping the Baseline Science Investigation to the Threshold Science Investigation in the event that development problems force reductions in scope. Operational resiliency includes the ability to withstand adverse circumstances, the capability to degrade gracefully, and the potential to recover from anomalies in flight.
- Factor B-5. Probability of science team success. This factor will be evaluated by assessing the experience, expertise, and organizational structure of the science team and the mission design in light of any proposed instruments. The *scientific* expertise of the PI

will be evaluated but not their experience with NASA missions. The role of each Co-Investigator will be evaluated for necessary contributions to the proposed investigation; the inclusion of Co-Is who do not have a well-defined and appropriate role may be cause for downgrading during evaluation. *The inclusion of career development opportunities to train the next generation of science leaders will also be evaluated*.

- *Factor B-6. Maturity of proposed Level 1 and Level 2 requirements. This factor includes assessment of whether the Level 1 requirements are sufficient and mature enough to guide the achievement of the objectives of the Baseline Science Investigation and the Threshold Science Investigation, and whether the Level 2 requirements are a sufficient decomposition of the Level 1 requirements. The Levels 1 and 2 requirements will be evaluated for whether they are stated in unambiguous, objective, quantifiable, and verifiable terms that do not conflict and for whether they are traceable to the science objectives. They will be evaluated for their adequacy, sufficiency, and completeness, including their utility for evaluating the capability of the instruments and other systems to achieve the mission objectives. The stability of the Level 1 science requirements and Level 2 project requirements will be assessed including whether the requirements are ready, upon initiation of Phase B, to be placed under configuration control with little or no expected modifications for the lifecycle of the mission.*
- *Factor B-7. Scientific Implementation Merit and Feasibility of any Science Enhancement Options (SEOs), if proposed. This factor includes assessing the potential and appropriateness of the selected activities to enlarge the science impact of the mission and the costing of the selected activities. Although evaluated by the same panel as the balance of Scientific Implementation Merit and Feasibility factors, this factor will not be considered in the overall criterion rating. The panel will provide comments to NASA on their findings for this factor.*

C. TMC FEASIBILITY OF THE PROPOSED MISSION IMPLEMENTATION

All of the factors defined in Section 7.2.4 of the AO apply to the evaluation of the CSR. All of these factors are interpreted as including an assessment as to whether technical, management, and cost feasibility are at least at a Phase A level of maturity. *New factors and details added to Step-1 AO factor definitions are highlighted using blue italicized text.*

Note that the risk management aspects of the Step-1 AO Factor C-4, Adequacy and robustness of the management approach and schedule, including the capability of the management team, have been removed from Factor C-4 and included in a new evaluation Factor C-6, Adequacy of the risk management plan.

- Factor C-1. Adequacy and robustness of the instrument implementation plan. The maturity and technical readiness of the instrument complement will be assessed, as will the ability of the instruments to meet investigation requirements. This factor includes an assessment of the instrument design, accommodation, interface, heritage, and technology readiness. This factor includes an assessment of the instrument hardware and software designs, heritage, and margins. This factor includes an assessment of the processes, products, and activities required to accomplish development and integration of the

instrument complement, including where applicable the approach to multiple builds. If multiple builds are proposed, this factor includes the ability to build, test, and integrate the required number of instrument flight units with repeatable quality and performance standards and the system design's impact on the repeat manufacturability. This factor also includes adequacy of the plans for instrument systems engineering and for dealing with environmental concerns. This factor includes an assessment of plans for the development and use of new instrument technology and plans for advanced engineering developments *and the adequacy of backup plans* to mature systems within the proposed cost and schedule when systems having a TRL less than 6 are proposed.

- Factor C-2. Adequacy and robustness of the mission design and plan for mission operations. This factor includes an assessment of the overall mission design and mission architecture, the spacecraft design and design margins (including margins for launch mass, delta-v, and propellant), the concept for mission operations (including communication *ground systems, navigation/tracking/trajectory analysis, operational scenarios and timelines for each mission phase, operations team roles and responsibilities,* and, if applicable, constellation management), and the plans for launch services. This factor includes mission resiliency—the flexibility to recover from problems during both development and operations—including the technical resource reserves and margins, system and subsystem redundancy, and reductions and other changes that can be implemented without impact to the Baseline Science Investigation.

- Factor C-3. Adequacy and robustness of the flight systems. This factor includes an assessment of the flight hardware and software designs, heritage, and margins. This factor includes an assessment of the plans, *processes*, products, and activities required to accomplish maturation, development, integration, and verification of all elements of the flight system, including the approach to multiple builds if applicable. If multiple builds are proposed, this factor includes the ability to build, test, and integrate the required number of flight system flight units with repeatable quality and performance standards and the system design's impact on the repeat manufacturability. This factor includes an assessment of the adequacy of all elements of flight system resiliency, including flight software/hardware fault management, system and subsystem redundancy, and hardware reliability. This factor includes an assessment of the adequacy of the plans for *spacecraft systems engineering, qualification, verification,* mission assurance*, and launch operations*. This factor includes the plans for the development and use of new technology, plans for advanced engineering developments, and the adequacy *of backup plans,* to ensure success of the investigation when systems having a TRL less than 6 are proposed. The maturity and technical readiness of the spacecraft, subsystems, *and operations systems* will be assessed. *The adequacy of the plan to mature systems within the proposed cost and schedule, the robustness of those plans, including recognition of risks and mitigation plans for retiring those risks, and the likelihood of success in developing any new technologies will be assessed.*

- Factor C-4. Adequacy and robustness of the management approach and schedule, including the capability of the management team. This factor includes: the adequacy of the proposed organizational structure *and Work Breakdown Structure (WBS); project level systems engineering*; the management approach including the roles; the commitment, qualifications, and experience of ~~any~~ *the PI, PM, PSE, and other* named

Key Management Team members, the implementing organization, and ~~the~~ known partners; ~~the expected commitment, qualifications and experience of the Key Management Team members not named~~; the spaceflight experience of ~~any~~ *the PM, PSE, and all other* named Key Management Team members (PI excepted); *relevant performance of* the implementing organization and known partners against the needs of the investigation; the prior working relationships of the implementing organization and known partners; the commitments of partners and contributors; and the scope of work covering all elements of the project, including contributions. Also evaluated under this factor is the approach to managing commercial suppliers that will use their own S&MA practices. ~~Also evaluated under this factor is the adequacy of the proposed risk management approach, including any risk mitigation plans for new technologies, any long-lead items, and the adequacy and availability of any required manufacturing, test, or other facilities.~~ If multiple builds are proposed, this factor includes the proposer's management of any subcontracted manufacturer, and the ability to capture and apply lessons learned for the effective production of subsequent units. ~~The management of the risk of contributed critical goods and services will be assessed, including the plans for any international participation, the commitment of partners and contributors, as documented in Letters of Commitment, and the technical adequacy of contingency plans, where they exist, for coping with the failure of a proposed cooperative arrangement or contribution.~~ This factor also includes assessment of elements such as the relationship of the work to the project schedule, the project element interdependencies including the resiliency of the production and test schedule to problems appearing in multiple-unit builds if applicable, the associated schedule margins, and an assessment of the likelihood of meeting the proposed launch readiness date. Also evaluated under this factor are the proposed project and schedule management tools to be used on the project.

The capability of the management team will be evaluated as a whole, as opposed to assessing the capabilities of each of the Key Team Members independently.

- Factor C-5. Adequacy and robustness of the cost plan, including cost feasibility and cost risk. This factor includes elements such as cost, cost risk, cost realism, and cost completeness including assessment of the basis of estimate, the adequacy of the approach used to develop the estimated cost (including how multiple unit builds are costed), the discussion of cost risks, the adequacy and allocation of cost reserves by phase, and the scope of work. The adequacy of the cost reserves and understanding of the cost risks will be assessed. This factor also includes an assessment of the proposed cost relative to estimates generated by the evaluation team using parametric models and analogies. *Also evaluated under this factor are the proposed cost management tools to be used on the project.*

When appropriate, Factor C-2 will include an assessment of proposed planetary protection provisions to avoid potential biological contamination (forward and backward) that may be associated with the mission. An evaluation of the implementation of these provisions in the preparation or processing of proposed instruments, the development of the flight system, in project management and to proposed costs will be included in the evaluations of Factors C-1, C-3, C-4, and C-5, as appropriate.

- Factor C-6. Adequacy of the risk management plan. The adequacy of the proposed risk management approach will be assessed, including any risk mitigation plans for new technologies*;* any long-lead items; and the adequacy and availability of any required manufacturing, test, or other facilities. *The approach to any proposed descoping of mission capabilities will be assessed.* The management of the risk of contributed critical goods and services will be assessed, including the plans for any international participation, the commitment of partners and contributors, as documented in Letters of Commitment, and the technical adequacy of contingency plans, where they exist, for coping with the failure of a proposed cooperative arrangement or contribution*; when no mitigation is possible, this should be explicitly acknowledged. The stability and reliability of proposed partners, and the appropriateness of any proposed contribution, is not assessed as a management risk but will be assessed by SMD as a programmatic risk element of the investigation.*
- Factor C-7. Ground systems. *This factor includes an assessment, including heritage and planned new development, of the proposed operations facilities, hardware, and software (i.e., those for mission operations and science operations), and a telecommunications analysis, ground network capability and utilization plan, and navigation plans*.
- Factor C-8. Approach and feasibility for completing Phase B. *This factor includes the completeness of Phase B plans and the adequacy of the Phase B approach. This assessment will include evaluation of the activities/products, the organizations responsible for those activities/products, and the schedule to accomplish the activities/products.*

Any impact to the primary mission due to the inclusion of SEO(s) and/or SC(s) will also be included in the factors above. The AO specifies that the CSR shall demonstrate that any proposed SC is clearly separable from the proposed Baseline and Threshold Science Missions; will not increase the mission development risk; and will not impact the science investigation in the event that any SC is not funded, fails during flight operations, or encounters technical, schedule, or cost problems during development. Details of the SEO(s) and SC(s) evaluations are given in Sections E.7 and Section K.

The panel evaluating the *TMC Feasibility of the Proposed Mission Implementation* may also provide comments to NASA on topics relating to programmatic considerations, for example regarding the size and nature of contributions, the fraction of PIMMC expended prior to KDP C, the flexibility to launch configuration, the extent to which the proposed investigation provides career development opportunities to train the next generation of engineering and management leaders. While these comments will not be considered in the evaluation, they may be considered during down-selection.

D. MERIT OF THE STUDENT COLLABORATION AND SMALL BUSINESS SUBCONTRACTING PLANS

The following are new evaluation factors that are not described in the AO and therefore were not evaluated for Step-1 proposals. These factors will be evaluated for CSRs.

- *Merit of the Student Collaboration, if proposed (Form D). This factor will include an assessment of whether the scope of the SC follows the guidelines in Section 5.5.2 of the AO. The criteria to be used to evaluate the SC component and a discussion of those criteria are described in SPD-31 available through the Program Library.*
- *Merit of the Small Business Subcontracting Plans (Form E). This factor will be evaluated on the participation goals and quality and level of work performed by small business concerns overall, as well as that performed by the various categories of small business concerns listed in FAR 52.219-9.*

WEIGHTING OF CRITERIA

The percent weighting indicates the approximate relative significance of each evaluation criterion in the Selection Official's consideration:

- Scientific merit of the proposed investigation: approximately 20%;
- Scientific implementation merit and feasibility of the proposed investigation: approximately 40%; and
- TMC feasibility of the proposed mission implementation: approximately 40%.

Merit of the plans for Small Business Subcontracting, and for an optional Student Collaboration, if proposed, will be evaluated as separate factors and considered by the Selection Official during the down-selection process.

ADDITIONAL SELECTION FACTORS

Considering the critical role of the PI, PM, PSE and their institutions, demonstrated capability (especially in meeting cost and schedule constraints in past projects) will be an important factor in the down-selection of an investigation.

In the down-selection process, the Selection Official may consider a wide range of programmatic factors in deciding whether to down-select any CSRs, including, but not limited to, planning and policy considerations, available funding, career development opportunities, programmatic merit and risk of any proposed partnerships, the size and nature of contributions, the distribution of work across NASA Centers and JPL, and maintaining a programmatic and scientific balance across SMD. While SMD develops and evaluates its program strategy in close consultation with the scientific community through a wide variety of groups, SMD programs are evolving activities that ultimately depend upon the most current Administration policies and budgets, as well as program objectives and priorities that can change based on, among other things, new discoveries from ongoing investigations.

PART II – CONCEPT STUDY REPORT OUTLINE AND REQUIREMENTS

Successful implementation of an Astrophysics SMEX investigation demands that the investigation be achievable within established constraints on cost and schedule. The information requested in PART II of this document will enable the evaluation team to assess how well each Concept Study Team understands the complexity of its proposed investigation, its technical risks, and any weaknesses that will require specific action during Phase B. Concept Study Teams are cautioned that omissions or inaccurate or inadequate responses to any of the following requirements will negatively affect the overall evaluation.

Requirement CS-1. The CSR shall be written in English and shall employ metric (SI) and/or standard astronomical units, as applicable. It shall contain all data and other information that will be necessary for scientific and technical evaluations; provision by reference to external sources, such as Internet websites, of additional material that is required for evaluation of the CSR is prohibited.

Requirement CS-2. The CSR page size shall be either American standard 8.5 x 11 inches or European standard A4. Foldout pages (11 x 17 inches or A3) may be employed at the study team's discretion but see Requirement CS-5 for assessment of foldout pages against the page limit.

Requirement CS-3. The CSR text shall not exceed 5.5 lines per vertical inch (6.5 lines per 3 vertical centimeters) and page numbers shall be specified. Margins at the top, both sides, and bottom of each page shall be no less than 1 inch if formatted for 8.5 x 11 inch paper; no less than 2.5 cm at the top and both sides, and 4 cm at the bottom, if formatted for A4 paper. Single-column or double-column formats are acceptable for text pages. Fonts for text and figure captions shall be no smaller than 12-point and no more than 15 characters per horizontal inch (six characters per horizontal centimeter). Fonts used within figures shall be no smaller than 8-point and no more than 10 characters per horizontal inch (4 characters per horizontal centimeter).

Requirement CS-4. CSRs written in their entirety by non-government institutions are not mandated to follow Controlled Unclassified Information (CUI) marking instructions.CSRs that are written fully or partially by government institutions shall include CUI markings. For those CSRs, it is mandatory to include a banner marking at the top of each page that contains CUI, to alert the reader. For example, pages with export-controlled information would get a "CUI//SP-EXPT" banner. Though not required except for NASA Export-Controlled information, portion marking is highly encouraged and can be accomplished by including a bordered box, as shown in the document *CUI_Portion_Marking_Sample.pdf* in the Program Library. Portion marking can be done according to the proposer's government agency institutional CUI practices or the National Archives

and Records Administration CUI Marking Handbook at: https://www.archives.gov/files/cui/documents/20161206-cui-marking-handbook-v1-1-20190524.pdf.

Requirement CS-5. CSRs shall conform to the page limits specified in the CSR Structure and Page Limits table (Table 2). A page quota higher than that in the Step-1 proposal has been allotted to accommodate an expected greater maturity of detail.

- Three extra pages are allotted for each additional separate, non-identical science instrument;
- Two extra pages are allotted for each additional separate, non-identical flight element (*e.g.*, spacecraft);
- Six extra pages are allotted for all science enhancement options (SEOs), in the Science Implementation Section, if proposed; and
- Five extra pages are allotted for student collaboration (SC), if one is proposed.

Different instruments on identical spacecraft will only be allotted extra pages for additional non-identical science instruments; no extra pages will be allotted for the resulting additional non-identical flight elements. An example of additional separate, non-identical flight elements in the Mission Implementation and Management Sections (Sections F and G) is separate spacecraft. Pages allocated for the proposed SC and/or SEO shall not be used for any other purpose; otherwise, where extra pages are allotted in a given section, all pages may be used within that section as the Study Team chooses.

The total number of extra pages allotted for additional science instruments and flight elements in Sections E-H shall not exceed a maximum of 15 extra pages regardless of the number of science instruments and flight elements. Every side of a page upon which printing would appear will count against the page limits unless specifically exempted (*e.g.*, Requirement CS-51 and Requirement CS-84), each foldout page will count as two pages against the page limits as appropriate for its area (*e.g.*, a fold-out with the total area of two standard pages counts as two pages, *etc.*). Schedule Foldouts do not count against the page limits. Excess pages will be removed from the end of any applicable Section where the limits have been violated.

Table 2. CSR Structure and Page Limits

Section	Page Limits
A. Cover Page and Investigation Summary	No page limit; brevity encouraged.
B. Fact Sheet and Executive Summary	2 pages for Fact Sheet and 6 pages for Executive Summary
C. CSR Table of Contents	No page limit

D. Science Investigation	34 pages (one STM foldout or 2 STM pages do not count)
E. Science Implementation (including SEOs, if proposed) F. Mission Implementation G. Management K. Optional SC (if proposed) H. Preliminary Design & Technology Completion (Phase B) Plan	110 pages *Note allowed* additional *pages in Requirement CS-5*
I. Cost Proposal [Optional Volume 2] J. Justification and Cost Proposal for optional SEO, if applicable	No page limit, but data must be presented in formats described; brevity is encouraged.
L. Appendices (no other appendices permitted) L.1 Letters of Commitment L.2 Relevant Experience and Past Performance L.3 Resumes L.4 Phase B Contract Implementation Data [Optional Volume 2] L.5 Data Management and Software Management Plans L.6 Incentive Plan(s) L.7 Technical Content of Any International Agreements L.8 International Participation Plans L.9 Planetary Protection Plan, if applicable L.10 Requirements Related to of Orbital Debris, Collision Avoidance, and End of Mission L.11 Compliance with Procurement Regulations by NASA PI Proposals L.12 Master Equipment List L.13 Heritage L.14 Classified Materials* L.15 Small Business Subcontracting Plan L.16 Additional Cost Data to Assist Validation [Optional Volume 2] L.17 Science Change Matrix L.18 Communications Design Data L.19 Project Protection Plan L.20 Cybersecurity L.21 Draft Mission Definition Requirements Agreement L.22 Draft MAIP and MAR Compliance Matrix L.23 Justification for the use of non-AMMOS MOS/GDS L.24 Acronyms and Abbreviations L.25 References and Management Standards List	No page limit, but brevity is encouraged. * Submitted separately.

Requirement CS-6. The CSR shall consist of unlocked, bookmarked, searchable Adobe Portable Document Format (PDF) file(s) including the main body of the CSR, all tables, and all applicable CSR appendices (see Section L). The CSR shall consist of no more than two volumes divided into readily identifiable sections. Each file should be no larger than 120 MB for ease of display and navigation. If two volumes are submitted, the second volume should contain the cost proposal (Section I) and any cost appendices (*e.g.*, L.4, L.6, L.16) and the first volume should contain the remainder of Sections A-L. Images (*e.g.*, figures and scans) shall be

converted into machine-encoded text using optical character recognition. Audio, video, or embedded animations shall not be included. Links to other parts of the CSR are permitted, but links to materials outside of the CSR are not.

Requirement CS-7. The CSR submissions shall include the CSR file(s) specified in Requirement CS-6 and shall additionally include files listed below.

- Final list of CSR participants in MS-Excel format (Requirement CS-9)
- Fact Sheet in PDF format (Requirement CS-16)

In addition, the augmented submission shall include the electronic files listed below, by the deadline for augmented submissions:

- Trajectory supplement, if applicable (Requirement CS-37 and Requirement CS-38)
- Schedule in MS-Project format (Requirement CS-52)
- Master Equipment List (MEL) in MS-Excel format (Requirement CS-126)
- Program and Project Management Standard References (Requirement CS-145)
- Cost Tables in MS-Excel format (Requirement CS-90, Requirement CS-91, and Requirement CS-97)
- Excel spreadsheets or model files to accompany the additional cost data to assist in validation, if applicable (See Section L.16 of this document)

Requirement CS-8. The Concept Study Team shall redact all materials in the CSR submission identified as containing export-controlled material, per Section 5.8.3 of the AO. The Concept Study Team shall redact these materials into separate versions of files that are collected in a "Redacted" folder.

Requirement CS-9. The Concept Study Team shall provide a list of the individuals who have participated in the concept study (*e.g.*, individuals who worked on the CSR, any CSR contributor, Red Team member, reviewer, *etc.*) and/or whom they are proposing to provide work should the mission be down-selected. Additionally, the Study Team shall provide a list of all organizations named in the CSR, or providing developmental or research services, including the lead organization, subcontractors, vendors and contributing organizations who have an interest in the mission. The Study Team shall provide the draft list of the participants as a Microsoft Excel spreadsheet document to the point-of-contact (POC, see AO Section 6.1.5) three months prior to the due date of the CSR, using the Microsoft Excel spreadsheet template in the Program Library. This list is to be updated and a final revision shall be included in a separate electronic file at the time of CSR submission.

The purpose of this requirement is to avoid placing people on the CSR evaluation team who have conflicts of interest. One of the objectives of this requirement is to obtain a list of organizations

and individuals who would otherwise be unknown to NASA as having or causing a conflict, *e.g.*, independent consultants or consulting organizations who helped with the CSR, or academic colleagues who were Red Team members for the CSR.

Requirement CS-10. The Concept Study Team shall create a separate document that contains a table with all of the requirements (Requirement CS-1 through Requirement CS-146) and the page, section, or table number that is the main place in the CSR where the requirement is addressed. Provide this table as a separate PDF document to the point-of-contact for the AO by email no later than seven calendar days after the CSRs are due**.**

Requirement CS-11. The Concept Study Team shall electronically submit the CSR and all required and optional files by the deadlines specified in the Introduction section, via the NASA Box service, which is Federal Information Processing Standards (FIPS) 140-2 certified for Data-in-Transit (DIT) and Data-at-Rest (DAR). To submit the CSR and the associated files through Box, the Study Team shall provide an email list of no more than three (3) individuals requiring access to Box to submit files. This email list shall be provided to the POC no less than fourteen calendar days before the CSRs are due. NASA will email the individuals on the list an invitation with a secure link to Box. The Concept Study Team is encouraged to submit a test file using the secure link to Box to ensure functionality prior to CSR submittal.

The required uniform format and contents of the CSR are detailed below. Failure to follow this outline may impede the evaluation process.

A. COVER PAGE AND SUMMARY INFORMATION

Requirement CS-12. A Graphic Cover Page and Summary Information, prepared as directed below, shall preface the CSR. These pages will not be counted against the page limits.

Requirement CS-13. The Graphic Cover Page shall contain, at a minimum, the following information and elements displayed on the cover page of the CSR:

- The investigation title;
- The name of the proposing organization;
- The name of the PI;
- The name and title of an official who is authorized to commit the proposing organization through the submission of the CSR; and
- The images of signatures of the PI and the authorizing official (unless these signatures appear on the CSR Summary Information).

Optionally, the Graphic Cover Page may also contain:

- Any illustrations or graphic elements of the proposer’s choice; and

- Any additional information of the proposer's choice that is nonproprietary and that does not provide additional content beyond what is in the proposal.

Requirement CS-14. The following Summary Information shall be included in this Section:

1. Names and institutions of all participants in the investigation;
2. The Enhanced PI-Managed Mission Cost of the investigation ($FY2025);
3. The proposed contributions and contributing organizations, and
4. A summary of the investigation, not to exceed 300 words. The CSR Summary shall not contain proprietary or confidential information that the submitters wish to protect from public disclosure.

Requirement CS-15. If the CSR contains export-controlled material, the material shall be presented in a red font or enclosed in a red-bordered box, and the following statement shall be prominently displayed in Section A of the CSR (following the Cover Page and Investigation Summary Information):

> "The information (data) contained in [insert page numbers or other identification] of this Concept Study is (are) subject to U.S. export laws and regulations. It is furnished to the Government with the understanding that it will not be exported without the prior approval of the proposer under the terms of an applicable export license or technical assistance agreement. The identified information (data) is (are) printed in a red font and figure(s) and table(s) containing the identified information (data) is (are) placed in a red-bordered box."

Note that it is the proposer's responsibility to determine whether any CSR information is subject to the provisions of ITAR or EAR. Information regarding U.S. export regulations is available at https://www.pmddtc.state.gov/ddtc_public and http://www.bis.doc.gov/.

Proposers should be aware that the evaluators of *Scientific Implementation Merit and Feasibility* (Criterion B) will review a version of the CSR in which any export-controlled material has been redacted.

B. FACT SHEET AND EXECUTIVE SUMMARY

Requirement CS-16. The CSR shall include a fact sheet that provides a brief summary of the investigation. Information conveyed on this fact sheet shall include:

1. Science objectives (including the importance of the science to the program science goals);
2. Mission overview;
3. Instrument complement;
4. Key spacecraft characteristics;
5. Project management and participating organizations (including teaming arrangements and all named key personnel);
6. Schedule summary;
7. The proposed PIMMC in Real Year dollars (RY$) and in Fiscal Year 2025 dollars (FY25$) from *Cost Table Template 1*; and

8. The proposed Total Cost, including a breakdown of any contributed costs by contributing organization, in RY$ and in FY25$ from *Cost Table Template 2*.

Requirement CS-17. The Executive Summary shall summarize the contents of the CSR and shall include an overview of the proposed baseline investigation, including its scientific objectives, technical approach, management plan, cost estimate, SC if proposed, and small business subcontracting plans.

C. CSR TABLE OF CONTENTS

Requirement CS-18. The CSR shall contain a Table of Contents that parallels the outline provided in Sections D through L of this document. A separate index of figures and tables shall also be included.

See the CSR Structure and Page Limits table above (Table 2) and Requirement CS-5 for page limits on Sections D through L.

D. SCIENCE INVESTIGATION

Requirement CS-19. The Science Investigation section shall describe the science investigation as specified by Requirements B-20 through B-26 in Appendix B of the AO. If there are no changes from the Step-1 proposal, including no Form A Potential Major Weakness (PMW) clarifications, this section shall be reproduced identically from the Step-1 proposal, with a statement that there have been no changes. Such a statement may be inserted before the first page of this section or it may be included in Appendix L.17 of the CSR. Any updates to the original (submitted) Step-1 proposal section (including those made in response to Step-1 Form A PMW clarifications) shall be incorporated in the Science Investigation section of the CSR.

Requirement CS-20. The Science Investigation section shall identify any changes to the Baseline and Threshold Science Investigations defined in the original (submitted) Step-1 proposal (proposal and updates from the Step 1 clarification process) and shall provide the rationale for the change(s). Such changes to the science investigation shall be highlighted via typographic emphasis (*e.g.*, bold, italics) and/or font color, with column marking for easy identification. In addition, for any change affecting science objectives or their associated requirements, a change matrix shall be provided as an appendix (see Section L.17 of this document) to show the original (submitted Step-1 proposal) text, any new or revised text, rationale for the change(s), and location(s) within the CSR. Corrections (*e.g.*, typos, incorrect references) and nominal updates (*e.g.*, revised references, clarified sentences) to this section, that do not constitute a change to the proposed science investigation (*i.e.*, no change to science mission objectives, requirements, implementation details, measurements,

data, *etc.*) are not required to be individually identified and tracked; however, a summary of such changes shall be provided.

Science Change Matrix Example, available in the Program Library, provides an example format for Appendix L.18 (under "Entries in Science Change Matrix"). This format documents Section D changes and provides rationale for those changes.

E. SCIENCE IMPLEMENTATION (INCLUDING SCIENCE ENHANCEMENT OPTIONS IF ANY)

E.1. *Level 1 and Level 2 Requirements*

The Level 1 requirements identify the mission, science, and programmatic requirements and constraints imposed on the project. Consistent with NPR 7120.5, both baseline and threshold requirements are to be described. Baseline requirements are those necessary to achieve the science objectives of the Baseline Science Investigation. Threshold requirements are those necessary to achieve the science objectives of the Threshold Science Investigation, as defined in AO Section D.3.

The Level 1 requirements define the key scientific determinations and/or results that would represent completion of the investigation science objectives. These requirements do not specify any particular mission implementation (including mission capabilities) but must decompose into the project's Level 2 (mission implementation) requirements. They are achieved through the analysis of the investigation's anticipated data sets, as defined by the investigation research plan. When the Level 1 requirements are all met, the project will have provided the expected return on NASA's investment even with no further mission operations or scientific analysis. The Level 1 requirements may also identify additional requirements or constraints beyond those necessary for the science investigation (*e.g.*, returned sample curation, NASA-added access to space constraints). Level 1 requirements are referred to as program-level requirements (in NPR 7120.5) and are controlled by NASA.

Level 2 requirements define the first level of project-specific mission implementation requirements. They specify requirements and constraints on scientific measurements, mission and spacecraft performance, prime mission lifetime, and any other project requirements or constraints that need to be controlled. The Level 2 requirements flow down from and flow up to the Level 1 requirements: for example, Level 2 requirements, when completed together, deliver the full investigation data sets that enable the scientific analysis necessary to complete the science Level 1 requirements. Level 2 requirements are referred to as project-level requirements and are controlled by the project.

The Level 1 requirements are criteria used to evaluate whether a project should be called for a termination review (in the case of degraded project performance) and the level of scientific success against the investigation objectives (as part of project closeout). The Program Library provides examples of Level 1 requirements (within the Program Level Requirements Appendix (PLRA) documents), examples of Level 2 requirements (within the Mission Definition Requirements Agreement [MDRA] documents), and presentation slides on Level 1 and Level 2

requirements given at the Phase A kickoff meeting and previous PI Masters Forums (https://soma.larc.nasa.gov/pi-masters-forums/).

Requirement CS-21. The CSR shall provide a set of proposed Level 1 requirements and a set of proposed Level 2 requirements. Both baseline and threshold Level 1 requirements shall be identified. The Level 1 science requirements shall be scientific determinations and/or results clearly traceable to the science objectives and sufficient to represent completion of the science objectives. The Level 2 requirements shall be adequate, sufficient, and complete to guide the design, development, and operation of the mission. Lower-level requirements shall be provided to the extent that they are known and necessary to explain and justify the design concept including instrument capability, instrument performance, and other aspects of the system architecture that enable the accomplishment of the investigation objectives. The requirements shall be stated in unambiguous, objective, quantifiable, and verifiable terms. Requirements shall not conflict with each other. The Level 1 requirements shall be listed in this section. The Level 2 requirements shall be listed in Appendix L.21, Draft Mission Definition Requirements Agreement (MDRA).

E.2. *Science Mission Profile*

Requirement CS-22. This section shall discuss the science observing profile, including all mission-relevant parameters, such as orbit, navigation accuracy, operational timelines (including observing periods, data transmission periods and techniques, and time-critical events), *etc.* The science observation strategy shall also be described in sufficient detail to understand the complexity of science operations, *i.e.*, are the operations regular re-iteration of data collection sequences, thereby establishing a routine flow, or are there numerous, uniquely planned events thereby requiring repeated planning, testing, and upload cycles. The observation planning and decision-making processes shall be outlined including any priorities assigned to specific observations or measurements and any plans to update the observing strategy based on early observations. The schedule and workforce associated with science planning shall also be described. If science operations involve an ebb and flow of personnel to reduce costs during cruise or "quiet" phases, this section shall describe plans for maintaining sufficient trained personnel and for how they will be moved off and then back on the project. The manner in which the proposed investigation objectives, selected instruments, and measurement requirements drive the proposed mission design and operations plan shall be included in this discussion.

E.3. *Instrumentation*

Requirement CS-23. This section shall describe the instrumentation and the rationale for its selection. It shall identify instrument systems (*i.e.*, individual instruments), instrument subsystems, instrument components, and sample collection and preservation system as applicable, including their characteristics and requirements, and indicate items that are proposed for development, as well as any existing instrumentation or design/flight heritage. It shall provide a clear understanding of how the concept will provide the required data, show how it can be accommodated by the spacecraft, demonstrate that instruments have the necessary unobstructed fields-of-view over the measurement period required, describe the technology readiness levels and the approach to bring each instrument to Technology Readiness Level (TRL) 6 by Preliminary Design Review (PDR). If no development plan is needed, the reasons for this shall be explicitly stated and the rationale shall be described. A preliminary description of each instrument design, with a block diagram showing the instrument subsystems and components, and their interfaces, along with a description of the estimated performance of the instrument, including the assumptions made in deriving the estimated performance, shall be included. These performance characteristics (which shall be considered as requirements on the flight system) shall include mass, power, volume, data rate(s), thermal, pointing (such as control, stability, jitter, drift, accuracy, *etc.*), spatial and spectral resolution, observable precision, retrieved parameter sensitivity and accuracy, and calibration requirements. This section shall demonstrate that the instrumentation can meet the measurement requirements, including factors such as retrieval results for each remote sensor, error analysis of the information in all sensors, vertical and horizontal resolution, signal-to-noise (S/N) calculations, *etc*. It shall also discuss environmental effects, such as radiation (including Total Ionizing Dose [TID], Total Non-Ionizing Dose [NTID], and Single Event Effects [SEE]), temperature, and contamination, on each instrument's measurement capabilities as a function of mission time.

Requirement CS-24. The following information shall be provided for each science instrument proposed:

1. Mass (include lower-level breakouts);
2. Viewing direction(s) in body coordinates;
3. Pointing accuracy and stability requirements;
4. Operational modes;
5. Operational mode timeline;
6. Data demand for each instrument operational mode;
7. Onboard data processing and storage required from spacecraft;
8. Power demand for each instrument operational mode including peak, average, and stand-by power;
9. Instrument thermal control capability;
10. Applicable instrument diagrams (*e.g.*, optical path); and

11. Characteristics of relevant instrument components (*e.g.*, listing of size of optics) in the MEL.

E.4. *Data Sufficiency*

Requirement CS-25. This section shall discuss the quality and quantity of data to be generated by each instrument, as they relate to the proposed science investigation goals and objectives. The flow-down from science investigation goals to measurement objectives and instrument performance shall be stated clearly and supported by quantitative analysis.

E.5. *Data Analysis, Management, Archiving, and Software Plans*

Requirement CS-26. This section shall describe a data analysis plan including approaches for data retrieval, validation, and preliminary analysis shall be described. The science products (*e.g.*, flight data, ancillary or calibration data, theoretical calculations, higher order analytical or data products, laboratory data, etc.) shall be identified, including a list of the specific data products and the individual team members responsible for the data products.

As a Federal agency, NASA requires prompt public disclosure of the results of its sponsored research to generate knowledge that benefits the Nation. Thus, it is NASA's intent that all knowledge developed under awards resulting from this solicitation be shared broadly.

Requirement CS-27. This section shall describe a Data Management Plan (DMP), including approaches for the release of peer-reviewed publications, the release of the science data that underlie the results and findings in peer-reviewed publications, and the archiving of all science products; a schedule-based end-to-end draft of the Data Management Plan shall be provided in Appendix L.5. The DMP shall be in compliance with requirements and the guidelines in the *NASA Plan for Increasing Access to the Results of Scientific Research*, with the applicable version of SPD-41, and APD Policy-13: *Astrophysics Scientific Information Management Policy*, or a justification shall be provided that this is not necessary given the nature of the work proposed (see AO Section 4.4). This section shall identify the science products (e.g., flight data, ancillary or calibration data, theoretical calculations, higher order analytical or data products, laboratory data, etc.), including a list of the specific data products and the individual team members responsible for the data products. The DMP description shall include a discussion and justification of any data latency period. This section shall identify the calibration and measurement algorithm document, including a list of the individual team members responsible for the document.

Requirement CS-28. This section shall describe a Software Management Plan covering the scientific software and tools to be developed (including their current status), the software and tool documentation, the planned release under a permissive or less restrictive open-source license from inception, the open repository planned for use, the process for testing and management, and the individual team members responsible for the software and tools; a schedule-based end-to-end draft of the Software Management Plan shall be provided in Appendix L.5.

E.6. *Science Team*

Requirement CS-29. This section shall describe the organizational structure and management approach for the science team and its execution of the investigation, including the identification of each member and their roles and responsibilities. Resumes or curricula vitae of science team members shall be included as appendices to the CSR (see Section L.3 of this document). The role of the PI and each Co-investigator (Co-I) shall be explicitly defined and the necessity of that role shall be justified, The role of each collaborator shall be described and justified. The funding source (NASA and/or contributed) for each science team member shall be noted.

Requirement CS-30. This section shall also include a summary table, with columns for

1. Science team member name;
2. Their roles and responsibilities on the mission;
3. Their time commitment, in Full Time Equivalents (FTEs) or Work Year Equivalents (WYEs), for each mission Phase, A through F (as specified in Requirement CS-90 to Requirement CS-97); and
4. Funding source(s).

E.7. *Plan for SEO*

Requirement CS-31. If an SEO is proposed, this section shall define and describe plans for the proposed activities (see AO Section 5.1.7). The SEO shall be directly related to the mission (*i.e.*, analyze mission data, not enhance theory). The SEO shall be clearly separable from the Baseline Science Investigation and Threshold Science Investigation. Additionally, a justification and a cost plan for SEO activities are required in Section J of this document.

F. MISSION IMPLEMENTATION

The goal of this section is to demonstrate the feasibility of the mission implementation designed to meet the scientific objectives of the investigation, at a level sufficient to demonstrate maturity consistent with the end of Phase A, and to provide a complete scope for scheduling and cost bases. To this end, each section should explicitly address the unique and driving aspects of the

mission implementation, such as (where applicable): multiple-builds and constellation management, design for rideshare launch opportunity, interfaces with external organizations, *etc*.

F.1. *General Requirements and Mission Traceability*

Requirement CS-32. This section shall provide a description of the spaceflight mission that is proposed to enable the science investigation.

In some areas (*e.g.*, instruments), the data requested may have already been presented in another section of the CSR (*e.g.*, the Science Implementation section). In such a case, a CSR may provide a reference to that section and need not repeat the data in this section.

Requirement CS-33. This section shall provide the Key Driving Requirements (KDR) that the science goals and objectives impose on the mission design, instrument accommodation, driving environments, spacecraft design, required launch vehicle capability, ground systems, communications approach, and mission operations plan, in tabular form and supported by narrative discussion. Table B2 in the Program Library, or in Appendix B of the AO, provides an example of a tabular Mission Traceability Matrix (MTM), with examples of matrix elements. Specific information that describes how the science investigation imposes unique requirements on these mission design elements shall be included.

This MTM, along with the Science Traceability Matrix (STM) in Table B1, provides the reference points and tools needed to track overall mission requirements, provides systems engineers with fundamental requirements needed to design the mission, shows clearly the effects of any descoping or losses of mission elements, and facilitates identification of any resulting degradation to the science.

F.2. *Mission Concept Descriptions*

Requirement CS-34. This section shall describe designs for all elements of the mission in sufficient detail to demonstrate that the proposed concept meets all of the basic requirements for a space flight mission, including mission design, spacecraft design, and supporting mission operations and ground systems. Discussion of how the various mission elements meet the Key Driving Requirements shall be included. At a minimum, the following mission elements shall be addressed: mission design, flight system capabilities including instrument accommodation, mission operations, ground systems, and any additional elements. It shall also discuss environmental effects, such as radiation (including Total Ionizing Dose [TID], Total Non-Ionizing Dose [NTID], and Single Event Effects [SEE]), temperature, and contamination, on the flight systems.

Requirement CS-35. Mission Design: This section shall address the following elements of the mission design to the extent that they are applicable to the proposed mission. Any additional elements that are applicable to explaining the mission and demonstrating its feasibility shall also be addressed.

1. Launch readiness date;
2. Launch window, and launch date flexibility;
3. Mission duration;
4. Orbit type (Earth orbit, heliocentric, *etc.*) and orbit parameters (semi-major axis, eccentricity, inclination, node time of day, argument of perigee, altitude, allowable dispersions), and/or trajectory design, and trajectory parameters for ballistic and low-thrust trajectories to permit independent validation, as applicable to the proposed investigation;
5. Critical events, which includes LV separation telemetry (per NPR 8705.4 Appendix D);
6. Telecomm link summary for all communication modes (based on requirements identified in Appendix L.18, Communications Design Data);
7. Ground station(s) usage (*e.g.*, location(s) and transmitting and receiving communication parameters); and
8. Space system's fault management approach and design.

Requirement CS-36. Launch Services and Launch Vehicle Compatibility: compatibility with the proposed launch vehicle shall be demonstrated by providing in the appropriate CSR section the launch site; fairing size; spacecraft mass; launch mass margins; and mission orbit characteristics such as altitude (km – circular or apogee/perigee), inclination, C3, heliocentric and/or declination (DLA). Any known non-standard requirements such as additional fairing doors, cleanliness and purge requirements, planetary protection, *etc*. shall be described. The packaged flight system in the proposed fairing, with critical clearance dimensions, and preliminary estimates of launch loads and structural margins shall be included.

Astrophysics SMEX Phase A concept study teams are to continue to use the LV performance classes described in Section 5.9.2 of the AO and in the Program Library, with the same associated cost impacts. Astrophysics SMEX Phase A concept study teams should work with Genevieve Futch, Mission Manager, genevieve.futch@nasa.gov, for Launch Services Program support.

Requirement CS-37. Trajectory for non-Electric Propulsion: For any mission that will perform Phase E operations beyond Geostationary Earth Orbit (GEO) to achieve its science orbit, the following information shall be provided in a file or files along with the CSR submission as part of a trajectory supplement. This information is optional for missions that remain within Earth orbit at or below GEO. Any graphical references, tables, figures, *etc.* shall be presented in a minimum of 150 dots per inch (dpi).

1. Checkout Duration: The minimum duration allocated after launch before the primary propulsion system will be commanded to provide required delta-v.
2. Initial Mass Assumptions: Provide the initial mass used for generation of the trajectories including propellant loading assumptions.
3. Event Basics: Provide the date/time of each trajectory event with a brief event description (*e.g.*, Launch, Gravity Assist, Fly-by, Rendezvous, Mid-Course Burn) and the appropriate data for the event (*e.g.*, flyby altitude, flyby angle, flyby/intercept velocity, delta-v magnitude). These data should be included for three different scenarios corresponding to the Open, Middle, and Closing of the proposed launch window.
4. Event Body Ephemeris: Provide ephemeris data for all event bodies (fly-by planet, asteroid fly-by, comet rendezvous, *etc*.). Include the source of the ephemeris data and the epoch for the actual ephemeris point used for a particular event.
5. Any other trajectory specific information not called out above that would be relevant to reviewers attempting to validate the trajectory.

Requirement CS-38. Trajectory for Electric Propulsion (EP): For any investigation using Electric propulsion, the following information shall be provided in a file or files along with the CSR submission as part of a trajectory supplement. Any graphical references, tables, figures, *etc.* shall be presented in a minimum of 150 dots per inch (dpi).

1. Checkout Duration: The minimum duration allocated after launch before the primary propulsion system will be commanded to provide required delta-V.
2. Initial Mass Assumptions: Provide the initial mass used for generation of the trajectories including propellant loading assumptions.
3. Event Basics: Provide the date/time of each trajectory event with a brief event description (*e.g.*, Launch, Gravity Assist, Fly-by, Rendezvous, Mid-Course Burn) and the appropriate data for the event (*e.g.*, flyby altitude, flyby angle, flyby/intercept velocity, delta-v magnitude). These data should be included for three different scenarios corresponding to the Open, Middle, and Closing of the proposed launch window.
4. EP Throttling Model: Provide the throttling model used to generate EP engine performance at any point during the trajectory and a brief explanation of the approach.
5. Assumed Engine Duty Cycle: Provide the overall Duty Cycle for the EP engines and if applicable provide the duty cycle over each trajectory segment.
6. Number of Engines: Provide the maximum number of engines on the spacecraft that could be operating simultaneously. In addition, provide the number of engines operating throughout each phase of the trajectory.

7. Any other trajectory specific information not called out above that would be relevant to reviewers attempting to validate the EP aspects of the trajectory and orbit.

Requirement CS-39. Flight System Capabilities: This section shall address the following flight system capabilities, to the extent that they are applicable to the proposed mission, accounting for the environmental effects such as radiation, temperature, and contamination. Any additional elements that are applicable to explaining the mission and demonstrating its feasibility shall also be addressed. Note that the heritage of the components and subsystems are to be discussed in Appendix L.13.

1. Spacecraft Parameters:
   a. Figure of the complete spacecraft/instrument system, on the launch vehicle and in flight, with major components labeled and approximate overall dimensions.
   b. Block diagram of the spacecraft subsystems and their components.
2. Subsystem descriptions including structure, telecommunications, thermal, power, propulsion (if required), attitude determination and control, command and data handling, in-flight fault management, flight software, and ground software. (Note that the discussion of the telecommunications subsystem should be limited to specifications, design, and proposed component hardware – discussion of the link performance is addressed as part of Appendix L.18). Subsystem detail shall include the following information:
   a. Propulsion, including:
      i. A list of all specific events of the proposed delta-v budget (including 3-sigma values for stochastic maneuvers);
      ii. For each propulsion mode type (monopropellant, bi-propellant, dual-mode, solar electric, *etc*.), engines and thrust levels, and specific impulse;
      iii. Propellant allocation (impulse vs. attitude control system); and
      iv. Propellant margins, including nominal (to meet delta-v requirement) and additional (to meet mass growth).
   b. Command and Data Handling, including:
      i. Spacecraft housekeeping data rates for nominal and safing strategy;
      ii. Data storage unit size (Mbits); and
      iii. Maximum storage record and playback rate.
   c. Power, solar-powered missions:
      i. expected power requirement and margins for each operational mission phase;
      ii. type of array structure (rigid, flexible, body mounted);
      iii. solar array axes of rotation (vector projected in spacecraft coordinates);
      iv. array size;
      v. solar cell type and efficiency;

vi. expected power generation at Beginning of Life and End of Life;
vii. worst case Sun incidence angle to solar panels for each operational mission phase;
viii. battery type, storage capacity, and expected degradation;
ix. phased and worst-case battery Depth of Discharge (DOD); and
x. spacecraft bus voltage.

d. Attitude Determination and Control, including system pointing requirements and capabilities. Describe or define the following:
   i. each spacecraft operational mode, including the sensors and actuators used, control method, and safing and/or contingency modes;
   ii. attitude determination methodology and estimate of accuracy, including identifying whether ground post-processing is required to meet science needs;
   iii. agility requirements for slews or scanning;
   iv. appendage pointing requirements, including articulation control methods and deployment accommodations;
   v. sensor selection and performance, including identifying mounting location and field-of-view (FOV);
   vi. actuator selection and sizing, including identifying mounting location(s);
   vii. translationalmaneuver (delta-v) control and accuracy;
   viii. momentum management approach and mitigation of impacts on navigation accuracy, if applicable;
   ix. on-orbit calibrations, if required, including expected accuracy; and
   x. attitude control requirements for the spacecraft pointing control, pointing knowledge (at the instrument interface), pointing stability, or jitter.
e. Thermal control, including:
   i. temperature requirements including allowable temperature ranges;
   ii. temperature control approach (i.e., passive vs. active);
   iii. cooling loads; and
   iv. special thermal design considerations (e.g., cryogenic instrument requirements).
f. Structures, including:
   i. requirements;
   ii. governing load cases and margins;
   iii. chosen materials; and
   iv. their qualification testing.
g. Flight software, including:
   i. a description of the software architecture including the operating system, development language, and the major

software modules to a sufficient depth to demonstrate how this software architecture supports the proposed mission functions;

ii. the logical lines of code by Computer Software Configuration Item (CSCI) and the basis for these estimates;
iii. a description of the functionality for each CSCI;
iv. code counts categorized as either New, Modified, Full Reuse, or Autogenerated;
v. the development method (spiral, waterfall, agile, *etc.*);
vi. the development approach for any major new algorithms to be incorporated in the flight software; and
vii. the approach for interface management and plans for software verification and validation.

Requirement CS-40. Additional Mission Elements: This section shall address any other major mission elements (*e.g.*, upper-stage, *etc.*) to the extent that they are applicable to the proposed mission. Any additional elements that are applicable to explaining the mission and demonstrating its feasibility shall also be discussed.

- Provide a block diagram and description of relevant subsystems; and
- Demonstrate that the proposed design can accomplish the mission within the allocated resources.

Requirement CS-41. Flight System Contingencies and Margins: This section shall summarize contingencies and margins of all key flight systems resources. It shall provide the Study Team's assessment of the maximum possible value for each key resource for the proposed mission, estimates of implementation performance, and resulting design margins with respect to the required performance. At a minimum, it shall include the following:

1. Dry mass;
2. Launch mass usable by the proposed mission;
3. Propellants;
4. Power (including energy storage);
5. CPU utilization;
6. Data (including storage and downlink volume);
7. Attitude control;
8. Thermal; and
9. Any other driving mission element requirements derived from the Key Driving Requirements.

See the table following Requirement B-36 of the AO for definitions of contingency and margin.

Requirement CS-42. Mission Operations: This section shall address, at a minimum, the following elements of mission operations and communication to the extent they are applicable to the proposed mission. Any additional elements that are applicable to explaining the mission operations and demonstrating their feasibility shall also be addressed.

1. Operational concept that includes the following:

a. Operational Scenarios with a description of each mission phase from launch through end of mission and an integrated description of the ground, spacecraft, and payload events for key mission phases, including proposed GO cadence if applicable;
b. Timelines for each mission phase; containing spacecraft, payload, and ground events, as well as ground processing and timeline margins.
c. Data flow diagrams which clearly show the major operational facilities and key software components utilized for both the uplink and downlink processes, including interfaces for the GO program if applicable;
d. A Phase E Organization diagram and Team Responsibilities clearly indicating the key manager for each of the project facilities in the data flow diagram, including the Mission Operations Center (MOC) and Science Operations Center (SOC);
e. Interface between the Flight Operations Team and the Conjunction Assessment Risk Analysis (CARA) team at NASA Goddard Space Flight Center (GSFC) for Earth-orbiting missions and the Multi-mission Automated Deepspace Conjunction Assesssment Process (MADCAP) team at the Jet Propulsion Laboratory for NASA spacecraft not orbiting the Earth.

2. Description of ground systems and facilities, including:
   a. Supporting ground software at the MOC and at the SOC required for development, testing, and operations;
   b. Identification of the heritage of each project facility including the software and hardware within that facility and the identification of the percentage of new, modified or no changes for each major software element;
   c. A plan for required maintenance and refresh of vendor supplied ground systems (hardware and software) during extended cruise operations, if applicable; and
   d. A plan for retention of adequate development and test resources, spacecraft and Ground Support Equipment (GSE) test beds, *etc.* during Phase E that addresses the impact of operations development and testing on routine and contingency mission operations.
3. Telecommunications, Tracking, and Navigation including:
   a. downlink information and data volume;
   b. uplink information;
   c. for all transmit and receive modes: mode timeline, data rate(s), durations, and planning for compliance with spectrum limitations, including compliance with maximum channel bandwidth;
   d. ground network utilization plan including ground stations, downlink parameters (frequencies, periods, capacities, margins, *etc.*), and retransmission capability; and

e. approach for acquiring and returning data, including clear identification of procurement and costing for supplemental resources (*e.g.*, mobile ground stations) if such are needed.

4. Operations plan feasibility, including:
   a. operations center development;
   b. team training and availability of spacecraft experts for operations; and
   c. a quantitative discussion of nominal sequence planning and commanding showing the ability of the Mission Operations and Ground Data System (GDS) to analyze the spacecraft and payload data and to generate the necessary sequences to enable the spacecraft to meet the planned mission timelines.

For missions proposing the use of NASA network facilities, a Letter of Commitment from the NASA network provider describing the network's ability to deliver the required capabilities and capacities and the cost for doing so must be included in Appendix L.1. Where the use of NASA's network services may not be within the capabilities and capacities described in the NASA's Mission Operations and Communications Services document, early discussions should be initiated with the POC named in that document.

Requirement CS-43. This section shall provide a clear statement of NASA Space Communication and Navigation (SCaN) network support requirements in tabular format. The table shall show all mission phases (*e.g.*, launch and early orbital operations, cruise, flybys, orbit insertion, orbital operations, data return), the year in which support is needed, station(s) required, pass lengths, number of passes each week, and the number of weeks for which this support is required.

No new mission will be allowed the use of Tracking and Data Relay Satellite Services (TDRSS). Proposers should be advised that NASA is moving to commercial providers of communications services and is actively working to validate commercial alternatives for TDRSS-like capabilities. Missions that are considering proposing specialized services previously offered by TDRSS, such as demand access services, should work with SCaN to understand the potential commercial service alternatives.

F.3. *Development Approach*

The CSR must describe how all development challenges, including those associated with new technology, will be addressed. The development approach discussions must include roles and responsibilities and should focus on any unique aspects of the proposed mission that pose unusual challenges.

Requirement CS-44. This section shall describe the development plan. This description shall include the following items:

1. The systems engineering approach shall be specifically discussed, including the definition, flow-down, tracking, control, and verification

of design requirements; resource allocation and control; interface requirements; and hardware and software configuration control. The discussion of the systems engineering approach shall include roles and responsibilities and any unique aspects of the proposed mission that pose unusual system engineering challenges;

2. Identification of instrument-to-spacecraft interfaces, as well as roles and responsibilities for the interface management process as specified in NPR 7123.1;
3. Essential trade studies completed in Phase A, including considered options and conclusions;
4. Essential trade studies to be conducted in Phase B, including considered options and driving requirements;
5. Identification of the key Technical Performance Measures (TPMs)—as specified in NPR 7123.1—and descriptions of how margins are to be allocated, tracked, and monitored, with what tools and by whom, and who will have the authority to release the associated reserves and margins;
6. Descriptions of when contracts are required, the acquisition strategy, including any incentive strategy;
7. Management and closure of action items, hardware discrepancies, test anomalies, *etc.*; and
8. Plan for handling special processes (*e.g.*, if radioactive sources are proposed, the approach to supporting the development, submittal, and approval of the necessary National Environmental Policy Act (NEPA) process and the Nuclear Flight Safety (NFS) process).

Requirement CS-45. This section shall describe the software engineering development approach. This description shall include the following items:

1. Roles and responsibilities for the software management process—as specified in NPR 7150.2—and product development responsibilities;
2. A description of how the flight and ground software will be developed and maintained;
3. Software assurance approach;
4. Identification of the key technical resource metrics—as specified in NPR 7150.2—and associated margins allocation, tracking and management;
5. Description of static analysis to be used during the software development and testing; and
6. Software coding standard to be used for each of the software programming langauges being used on the project.

Requirement CS-46. This section shall describe the plan for mission assurance, including product assurance, reliability and approach to mitigating the effects of radiation. Any impacts to the concept of operations, lifetime and fault management due to parts selection shall be addressed. Plans for using reliability tools, such as fault tree analysis, probabilistic risk assessments, and failure modes and effects analyses, shall be described. Other mission

assurance activities such as fault tolerance, reliability (*e.g.*, use or non-use of redundancy, requirements for burn-in of parts, and requirements for total operating time without failure prior to flight) shall be described. Processes for identifying and tracking the correction of failures, both hardware and software, from the piece part to the system level shall be described. This section shall also describe the proposed policies and procedures for parts selection, screening, and usage for each major partner.

Requirement CS-47. This section shall indicate any expected tailoring from the recommended mission assurance requirements in Appendix C of NPR 8705.4 for Class D. Tailoring below the *SMD Standard Mission Assurance Requirements for Payload Classification D* (SMD Policy Document SPD-39) shall not be proposed, even for individual flight elements within a constellation. The section shall describe the proposed management approach to ensuring Safety and Mission Assurance (S&MA) practices at all partner and hardware institutions will meet the needs of the mission. The section shall discuss any enhancement of the S&MA requirements necessary and appropriate for the proposed mission.

F.4. *New Technologies/Advanced Engineering Developments*

Requirement CS-48. This section shall describe any proposed new technologies and/or advanced engineering developments and the approaches that will be taken to reduce associated risks. Descriptions shall address, at a minimum, the following topics:

1. Identification and justification of the TRL for each proposed system (level 3 WBS payload developments and level 3 WBS spacecraft elements) incorporating new technology and/or advanced engineering development at the time the CSR is submitted (for TRL definitions, see NPR 7123.1, *NASA Systems Engineering Processes and Requirements*, Appendix E);
2. Rationale for combining the TRL values of components and subsystems to derive each full system TRL as proposed, appropriately considering TRL states of integration (see *NASA Systems Engineering Handbook*);
3. Rationale for the stated TRL value of an element that is an adaptation of an existing element of known TRL;
4. The approach for maturing each of the proposed systems to a minimum of TRL 6 by PDR:
    a. Demonstration (testing) in a relevant environment can be accomplished at the system level or at lower level(s);
    b. If applicable, justify what demonstration(s) in a relevant environment at lower level(s) (subsystem and/or subsystem-to-subsystem) would be sufficient to meet system level TRL 6, considering:

i. where any new technology is to be inserted;
ii. the magnitude of engineering development to integrate elements;
iii. any inherent interdependencies between elements (*e.g.*, critical alignments); and/or;
iv. the complexity of interfaces. See the Program Library for examples; and

c. Include discussion of simulations, prototyping, demonstration in a relevant environment, life testing, *etc.*, as appropriate.

5. An estimate of the resources (staffing, cost, and schedule) required to complete the technology and/or advanced engineering development; and
6. A description of any approaches to fallbacks/alternatives that exist and are planned, a description of the cost, decision date(s) for fallbacks/alternatives, relevant development schedules, and performance liens they impose on the baseline design, and the decision milestones for their implementation.
7. Demonstration of, system TRL 6 or above at the time of CSR submission if no new technologies or advanced engineering development is required.

The Program Library provides examples of TRL-6 assessments and demonstrations relevant to AOs.

F.5. *Assembly, Integration, & Test, and Verification & Validation*

Requirement CS-49. This section shall describe the mission unique aspects of the Assembly, Integration and Test (AI&T) approach and how it supports full Verification &Validation. Flow diagrams, narrative text, and/or other relevant data may be used to convey this information. Elements of the approach that pose special challenges for the project (*e.g.*, mission critical performance or functional requirements that cannot be tested on the ground, multiple-unit builds, special facilities that may be required for testing, large scale simulation tools that are required to be developed and how they will be validated, critical path items, *etc.*) shall be emphasized. Any tools used to facilitate multiple builds, such as special facilities, additional GSE, special AI&T staffing approach, and/or automation tools, shall be included. The AI&T description shall demonstrate the credibility of the overall AI&T approach, as reflected by consistency between the described test plans and the schedule, cost, and other resources needed to carry them out. The testing and verification of the space system's fault management approach and implementation shall be discussed.

Requirement CS-50. An illustration of the time-phased flow of the AI&T plan shall be presented. It shall include the key facilities, testbeds, and team members involved in the AI&T plan.

F.6. *Schedule*

Requirement CS-51. This section shall provide project schedule foldout(s) covering all phases of the investigation. The schedule shall go to at least WBS Level 3 for the spacecraft elements (one level below the spacecraft), and Level 4 for payload elements (one level below each instrument), except where greater detail is necessary to identify critical paths, as well as significant TRL or engineering development activities and events. Schedule foldout(s) will not be counted against the page limits. The schedule format shall indicate the month and year of each milestone, have a corresponding table of dates, and follow standard NASA WBS elements for task descriptions as prescribed in NPR 7120.5 and the NASA WBS Handbook. The schedule foldout(s) and accompanying narrative shall address proposed major milestones including, at a minimum, the following items:

1. Spacecraft development, integration and test, and major review dates;
2. Instrument development and major review dates, including instrument-to-spacecraft/host integration and test;
3. Major deliverables (*e.g.*, Interface Control Documents (ICDs), simulators, engineering models, flight models, *etc.*);
4. Activities for advancement to TRL 6, and other key engineering development activities;
5. Any early risk-reduction testing (*e.g.*, TRL-6 demonstration; use of prototypes; EMs or ETUs for multiple-unit build production planning; *etc.*);
6. Ground systems development and major review dates (*e.g.*, mission operations and data analysis development schedule);
7. Launch vehicle integration and launch readiness;
8. Compliance with NEPA and Nuclear Flight Safety processes, if appropriate;
9. Long-lead item development paths, and their impacts to schedule;
10. Development schedule for Student Collaborations (SCs) and/or Science Enhancement Options (SEOs), if any;
11. Schedule critical paths identification, including any significant secondary critical paths;
12. Funded schedule reserve, with indications of appropriate reserves associated with major milestones and deliverables, including allocated critical path reserves; and

Requirement CS-52. The project schedule shall be additionally provided in a Microsoft Project format as part of the augmented submission. Although the project schedule foldout(s) in Requirement CS-51 does not need to have been generated in Microsoft Project, the project schedule provided in the electronic submission shall address the items specified in Requirement CS-51 at a level of detail commensurate with that of the graphical foldout. The Microsoft Project schedule shall be a fully Integrated Master Schedule for the project that provides a quantified data set that will facilitate understanding of the proposed flow of development activities,

timelines, milestones, schedule reserves, and risk. Tasks in this schedule and the level of linkage detail must be complete enough to substantiate the assignment of the primary critical path and any significant secondary critical path(s) in the graphical foldout(s). Task links are also needed to identify points of assembly, integration, and testing in the schedule and links to major milestones. A Phase B schedule consistent with the plans detailed in Section H shall be included in the file.

G. MANAGEMENT

Requirement CS-53. This section shall present the investigation's proposed management approach. The management organization chart shall be provided and the decision-making authority, and the teaming arrangement and responsibilities shall be discussed. The organization chart shall clearly indicate how the project team is structured. The internal operations and lines of authority with delegations, together with internal interfaces shall be described. Relationships with NASA, major subcontractors, and associated investigators shall be discussed. The primary team members reporting relationship within the project shall be provided. The mission unique roles and responsibilities, as specifically applicable to the proposed investigation, of the PI, DPI, PM, PSE, and other Key Management Team members shall be described. The commitments and the roles and responsibilities of all institutional team members, including team members responsible for SC (as applicable), shall be described.

Requirement CS-54. This section shall demonstrate how the proposed management plans, decision-making processes, tools (including performance measurement and reporting), and organization will be applied to manage and control the project during development and operation. The decision-making processes that the team will use shall be described, focusing particularly on the roles of the PI, DPI, PM, PSE, and the balance of the Key Management Team in those processes. In particular, the management processes as they apply to the relationships among organizations and key personnel shall be described, including systems engineering and integration; requirements development; configuration management; schedule management; team member coordination and communication; progress reporting (both internal and to NASA); performance measurement; and resource management. This discussion shall include all phases of the mission, including preliminary analysis, technical definition, design and development, and operations phases, as well as products and results expected from each phase. The section shall include a clear description of the methods and frequency of planned communication within the project team. If applicable, the section shall describe how the team will be organized for the manufacture, test, and calibration of multiple flight units.

Requirement CS-55. This section shall summarize the relevant institutional experience and refer to supporting detail included in Appendix L.2, *Relevant Experience and Past Performance*. If experience for a partner organization is not equivalent to, or better than, the requirements for the proposed mission, explain how confidence can be gained that the mission can be accomplished within cost and schedule constraints.

Requirement CS-56. This section shall describe each key position, including its roles and responsibilities, how each key position fits into the organization, and the basic qualifications required for each key position. A discussion of the unique or proprietary capabilities that each partner organization brings to the team, along with a description of the availability of personnel at each partner organization to meet staffing needs, shall be included. The contractual and financial relationships between team partners shall be described. Where multiple builds are proposed, this section shall address the relevant experience as well as the staffing, facilities and GSE capabilities of the implementing institutions commensurate with the needs of the multiple-build production.

Requirement CS-57. This section shall name all of the team members who will occupy the key project management positions identified in Requirement CS-56. It shall, in addition:

1. Describe the previous work experience of each of these key individuals, including the outcomes and complexity of the work they did, and it shall explain the relevance of these experiences to the responsibilities of the key project management positions they will occupy;
2. Provide any program/project management certifications held by or planned to be obtained by the PM;
3. Address the role(s), responsibilities, commitments by phase, and percentage of time devoted to the mission for the PI, DPI, PM, PSE, and all other named key management individuals; and
4. Provide reference points of contact, including address and phone number, for each of these individuals.

Requirement CS-58. This section shall describe plans for risk management, both in the overall mission design and in the individual systems and subsystems. NASA's required risk management procedures are provided in NPR 8000.4, *Agency Risk Management Procedural Requirements*, available in the Program Library. SPD-39, *SMD Standard Mission Assurance Requirements for Payload Classification D* will also apply. Note a draft Mission Assurance Implementation Plan (MAIP) and Compliance Matrix to be submitted with the CSR (see Section L.22 of this document). This section shall describe plans for using standard risk management tools, including probability and impact charts, risk lists, mitigation plans and triggers. The role(s) in the risk management process of each of the key management personnel shall be discussed.

Requirement CS-59. This section shall describe the project risks and project resiliency considering these risks and shall include the items below.

1. The top risks considered significant by the project team, especially technical risks and risks associated with:
   a. technology or advanced engineering developments discussed in Section F.4;
   b. contributed hardware (if any);
   c. international contributions (if any);
   d. multiple-unit build production (if applicable), *etc*.
2. Potential mitigation strategies and associated schedule impacts.
3. Quantitative risk assessments, where the probability and impact of occurrence are independently and numerically specified prior to mitigation; specification of probability and impact after mitigation is encouraged but not required.
   a. Where appropriate, an impact may be specified in terms of any resource that is quantified in the CSR. Furthermore, individual quantitative risk assessments may address multiple resources, as well as temporal increments (*e.g.*, mitigation followed by post-mitigation).
   b. In order to determine the cumulative effect of risks on resources, each impact shall be paired with a probability.
   c. The cumulative effect of the products of probabilities and impacts shall not reduce the resource below that necessary to achieve baseline science.
4. In the case of cost, the products of pre-mitigation probabilities and impacts shall be included as encumbered cost reserves or explicitly identified in the basis of estimate, including cost validations. If cost risks are in this list, they shall be discussed in Section I (see Requirement CS-83) of the CSR.

Requirement CS-60. If the proposed risk management approach includes potential descoping of mission capabilities, this section shall include the following. When considering potential descope options, consider the investigation as a total system including instrument(s), spacecraft, ground system, access to space services, and operations.

1. a discussion of the approach to such descopes, including savings of resources (mass, power, dollars, schedule, *etc*.) by implementing descopes;
2. the decision milestone(s) for implementing descopes; and
3. the scientific impact of individual, as well as combined, descopes.

Requirement CS-61. If the CSR contains proposed contributions or cooperative arrangements, this section shall describe the technical and management interfaces in any proposed cooperative arrangements, explicitly demonstrating that the contributions are within the contributors' scientific and technical capabilities, and contingency plans for coping with potential failures of the proposed cooperative arrangements.

Requirement CS-62. This section shall include a discussion of the management approaches for controlling growth in the project cost during development and operations. This discussion shall be focused on issues that the project could reasonably foresee and the response to which would be within the project's control.

Requirement CS-63. This section shall provide a summary of reserves in cost and schedule by mission phase, project element, and year, and shall discuss the rationale for each. The discussion shall include the following.

1. The specific means by which integrated costs, schedule, and technical performance will be tracked and managed;
2. Specific cost and schedule reserves and the timing of their application;
3. Management of the cost and schedule reserves, including who in the management organization manages the reserves and when and how the reserves are released, including the strategy for maintaining reserves as a function of cost-to-completion;
4. Identification of all funded schedule reserves; and
5. The relationship between the use of cost reserves and funded schedule reserves, potential descope options, and their effect on cost, schedule, and performance. When considering potential descope options, consider the investigation as a total system including instrument(s), spacecraft, ground system, launch services, and operations.

Requirement CS-64. This section shall clearly delineate the Government-furnished property, services, facilities, *etc.* required to accomplish all phases of the project.

Requirement CS-65. This section shall list the major project reviews expected to be conducted during the project's life cycle consistent with NPR 7120.5 and the approximate time frame in the Project Schedule for each review.

Tailoring to NASA requirements described in NPR 7120.5 may be proposed by missions at any risk classification. Proposers must identify any tailorable requirements that are proposed to be adjusted, provide a rationale for each adjustment, and describe the cost, schedule, and/or other benefits that would be realized should one or more of the adjustments be accepted by NASA. NASA SMD has defined an implementation policy to manage Category 3/Class D projects. SPD-48: *NASA Science Mission Directorate (SMD) Category3/Class-D Projects Implementation Policy* describes the approach that has been approved by SMD leadership to guide the implementation of Class D investigations. SPD-48 includes a pre-approved package of tailoring of requirements. SPD-48 may be found in the Program Library. Note that these adjustments reflect potential modifications to the baseline investigation, to be addressed after down-selection.

Requirement CS-66. This section shall describe any deviations from the prescribed requirements in NPR 7120.5, NPR 7123.1, or other NASA procedural requirements that will require a waiver during formulation.

Requirement CS-67. This section shall identify any adjustment to tailorable NASA requirements described in NPR 7120.5 for consideration by NASA after

down-selection, provide a rationale for each adjustment, and describe the cost, schedule, and/or other benefits that would be realized should one or more of the adjustments be accepted by NASA. The CSR shall provide this information for proposed adjustments to requirements not specifically identified in the SPD-39 as already being tailored. Tailoring below the SPD-39 requirements is not allowed.

The panel evaluating the third evaluation criterion, *TMC Feasibility of the Proposed Investigation Implementation*, will provide comments to the Selection Official on the proposed tailoring of the requirements and their justifications. These comments will not be considered for the TMC Feasibility of the Proposed Investigation Implementation risk rating but may be considered in the down-selection decision.

Requirement CS-68. This section shall describe plans and capabilities for application of Earned Value Management (EVM) consistent with Section 5.3.7 of the AO.

Requirement CS-69. This section shall clearly describe the approach to reporting progress to the Government, and indicate the progress reviews the Government is invited to attend to provide independent oversight. The process, including the individual or organization responsible, for reporting integrated cost, schedule, and technical performance shall be discussed. A description of the information to be presented shall be included.

Requirement CS-70. This section shall describe plans to retire risk due to uncertainty associated with contributions. It shall address:

1. Commitments for contributions from implementing organizations and/or other funding agencies. Letters of commitment from all organizations involved in a contribution, particularly including the implementing organization (*e.g.*, laboratory or institute) and, if external funding is required, the funding agency (*e.g.*, national space agency), shall be provided as an appendix (see Section L.1 of this document);
2. Mitigation plans, where possible, for the failure of funding and/or contributions to be provided when that funding and/or contributions are outside the control of the PI. Mitigation may include, but is certainly not limited to, descoping the contributed items and holding reserves to develop the contribution directly. Note that reserves held for this purpose should be weighted by likelihood and are considered encumbered. When no mitigation is possible, this shall be explicitly acknowledged, and the stability and reliability of proposed partners, as well as the appropriateness of any proposed contribution, should be addressed; and
3. Acknowledgement of the complexities and risks involved with contributions and plans to handle those complexities or risks. This includes the schedule risk for implementing any required technical assistance agreements and international agreements. An adequate and realistic schedule shall be allocated for having international

agreements executed. NASA will not begin working on any international agreements until after the down-selection decision is made.

H. PRELIMINARY DESIGN AND TECHNOLOGY COMPLETION (PHASE B) PLAN

Once entering Phase B, Astrophysics SMEX projects are subject to the same requirements as all other NASA projects. Note that the CSR only satisfies some of the KDP-B deliverable requirements, and that the balance will have to be developed early in Phase B (consistent with Section 2.2.7.1 in NPR 7120.5: "In a two-step AO process, projects are down-selected following evaluation of concept study reports and the down-selection serves as KDP B. Following this selection, the process becomes conventional with the exception that products normally required at KDP B that require Mission Directorate input or approval will be finished as early in Phase B as feasible.").

Requirement CS-71. This section shall address plans and products for the Preliminary Design and Technology Completion Phase (Phase B). It shall identify the key mission tradeoffs to be performed and options to be investigated during Phase B that could lead to reductions in risk of implementation, including those issues, technologies, and decisions points critical to mission success. This section shall also describe and provide the rationale for any anticipated long-lead acquisitions.

Requirement CS-72. The Phase B Plan shall include a detailed schedule and shall define the products to be delivered and the schedule for their delivery. The schedule shall include the PDR and delivery dates of the following required products:

- A detailed descope plan including the criteria, impact, and savings of descope options;
- A complete set of baseline Level 1 requirements, including mission success criteria; and
- The baseline project plan.

Requirement CS-73. If more than one contractual arrangement is needed for the completion of Phase B, a separate Statement of Work (SOW) and budget breakout shall be provided for each organization. Subsequent phases will be added to the contract after each phase has been approved through the confirmation review process.

I. COST AND COST ESTIMATING METHODOLOGY

The CSR cost proposal shall provide information on the anticipated costs for all mission phases. A detailed cost proposal is required for Phase B (Requirement CS-91, Requirement CS-92, Appendix L.4). Cost estimates are also required for the follow-on phases (*i.e.*, Phases C/D, and E/F), including a description of the estimating techniques used to develop the cost (Requirement CS-93 through Requirement CS-95). See Section J for requirements for any SEO costs

(Requirement CS-98). A discussion of the basis of estimate must be provided, with a discussion of heritage and commonality with other programs (Requirement CS-79 through Requirement CS-83), and an explanation of any cost savings that result from heritage. All costs, including all contributions made to the investigation, shall be included (Requirement CS-89). Specific information that would better enable NASA to validate costs (*e.g.*, WBS Level 3 data) may be provided as an appendix (Appendix L.16) accompanied by files in the augmented submission. This can include cost by NASA fiscal year to the lowest level of detail the project is working with, in Microsoft Excel format.

Template for all cost tables referenced in this section are provided in the Program Library.

Requirement CS-74. This section shall provide a WBS as defined in NPR 7120.5 and the NASA *Work Breakdown Structure* (*WBS*) *Handbook* and use it to describe how all project costs are accounted in the cost proposal. The structure of the WBS should be consistent with the plans set forth in the Science Implementation, Mission Implementation, and Management sections of the CSR and the SOW(s) provided as an appendix to the CSR. The WBS shall be described to the subsystem level (*e.g.*, Attitude Control System, Propulsion, Structure and Mechanisms) for the spacecraft, to at least the instrument level for simple instruments, and to the major component level for more complicated instruments. All other WBS elements shall be at least to the major task level (*e.g.*, Project Management, Systems Engineering, GSE).

Requirement CS-75. This section shall include the estimated cost of the proposed investigation. The estimated cost shall encompass all proposed activities, including all applicable mission phases, mission unique or special launch services (*e.g.*, load isolation systems, unique mechanical/electrical interfaces, payload processing facilities, commodities, post-encapsulation access requirements, supplemental propulsion systems, deployable telemetry tracking assets, and GN2 purge), flight systems, ground systems, establishment of an interface between the Flight Operations Team and the CARA or MADCAP team, ground systems, ground network fees, contributions, any other AO-specific activities (*e.g.*, SC), and all cost reserves. Cost for ground network fees, data archive, and other mission-unique elements shall be clearly described. These costs shall be consistent with the policies and requirements in Sections 4 and 5 of the AO.

Requirement CS-76. This section shall show that the PIMMC has not increased over the Step-1 PIMMC by more than 20%.

Requirement CS-77. This section shall summarize the estimated costs to be incurred in Phases A through F, including: Concept and Technology Development (Phase A), Preliminary Design and Technology Completion (Phase B); Final Design and Fabrication (Phase C); System Assembly, Integration and Test, and Launch, extending through in-orbit checkout, usually launch plus 30 days (Phase D); Operations and Sustainment (Phase E); Closeout (Phase F);

LV, upper stages, or launch services; ground system costs beyond what is provided by the AO; access to space services beyond those provided by the AO; and cost of activities associated with social or educational benefits (if not incorporated in any of Phases A through F). The Cost Table Template 1 shall be used to summarize these costs. The total mission cost estimate shall be consistent with the Work Breakdown Structure. Detailed plans for any aspects of the mission not discussed elsewhere in the CSR shall be discussed here. The funding profile shall be optimized for the mission. Contributions not included in the NASA SMD cost shall be clearly identified as separate line items.

Requirement CS-78. This section shall state the fraction of PIMMC incurred prior to KDP C (Confirmation) and justify inclusion of cost elements that are beyond the scope of the Formulation phase (see AO Section 4.1.1).

Requirement CS-79. This section shall provide a Basis of Estimate (BOE) that is clearly traceable to the WBS of the *Cost Table Templates 3a and 3b*, including a description of the methodologies and assumptions used to develop the proposed cost estimate. The cost estimating methodology discussion in this section shall provide an overview of the cost estimate development process. Additional cost estimates or other validation efforts shall be described, the results presented, and any significant discrepancies discussed. A description of cost reserves that provides insight into the adequacy and robustness of the proposed unencumbered cost reserves level(s) shall be provided. The rationale for the proposed cost reserve levels shall be presented. The section shall include additional quantified BOE data to assist the validation of the cost estimates. The following is a non-exhaustive list of examples of useful BOE data for different cost estimating methodologies.

- Example for system and subsystem estimates based on analogy. Include the original heritage cost and rationale for any adjustments used to obtain the current proposed element costs.
- Example for system and subsystem estimates based on a parametric model. Provide the name and version of the model, general heritage assumptions and other key inputs used that can help explain the cost estimate.
- Example for bottom-up system and subsystem estimates. Provide information on what portion of the WBS element is labor vs material. For the labor, provide a FTEs and/or WYEs breakout by year with average labor rates. For material provide a summary list of the significant hardware quotes used in the estimate, the date of the quote, and the importance of the quoted hardware to investigation success.

Requirement CS-80. If applicable, the BOE description shall document the multiple build costing methodology including the approach used to calculate recurring unit costs.

Requirement CS-81. If the proposed PIMMC is greater than $120M (FY25$) and a reimbursement for contractor EVM difference is requested consistent with Section 5.3.7 of the AO, then this section shall justify that amount by providing a basis of estimate for the difference in cost between implementation of validated EVM and application of the performance measurement basic best practices referenced in the *Guidance and Expectations for Small Category 3, Risk Classification D (Cat3/ClassD) Space Flight Projects with Life-Cycle Cost Under $150M* document. The reimbursement amount can be shown as an increase to the Adjusted AO Cost Cap. If the estimated difference exceeds $1.5M (FY25$), include the remainder within the PIMMC.

Requirement CS-82. This section shall include a discussion of sources of estimate error and uncertainty in the proposed cost.

Requirement CS-83. This section shall include a discussion of cost risks and mitigation strategies.

Requirement CS-84. This section shall provide two foldout cost tables, using the template of *Cost Table Templates 3a and 3b*. The tables shall identify the proposed cost required in each project phase and in each Fiscal Year; the costs shall be respectively in Real Year dollars (RY$) and in FY 2025 dollars (FY25$). The top portion of the tables shall contain cost data relevant to the PIMMC. The lower portion shall contain cost data for contributions and enhanced mission costs. The rows in the tables shall be the NASA standard WBS elements as defined in NPR 7120.5 and in the *NASA WBS Handbook* consistent with the WBS defined per Requirement CS-74. The costs for most elements shall be provided at least to WBS Level 3. It is requested that instruments be shown to WBS Level 4 where the data is available. The costs of individual instruments and any unique flight system elements such as coordinating science ground stations, or nonstandard facilities, shall be explicitly shown. The columns in the tables shall be grouped and subtotaled by project phase and shall be labeled with the appropriate Fiscal Years. Years that span more than one project phase shall be split into two columns by project phase. The tables include totals by WBS and by phase and life cycle in both RY$ and Fiscal Year 2025 dollars (FY25$). The Study Team shall use their own forward pricing rates to translate between RY$ and FY25$. For organizations that are without approved forward pricing rates, the Study Team may use the NASA inflation/deflation indices available in the Program Library to translate between RY$ and FY25$.

Requirement CS-85. The latest inflation index provided in the tables found in the Program Library shall be used to calculate all real-year dollar amounts if an industry forward pricing rate is not available. Note that the official inflation index table from Step 1 may have been updated. If something

other than the provided inflation index is used, the rates used shall be documented.

Requirement CS-86. All costs shall include all burdens and profit/fee in real-year dollars by fiscal year, assuming the inflation rates used by NASA in the Program Library, or specifically documented industry forward pricing rates.

Requirement CS-87. This section shall identify each reserve amount to the lowest level consistent with the proposed reserve management strategy. For example, if each subsystem manager will have spending authority over a reserve for the subsystem, each such amount shall be identified separately. If more convenient, the reserve details may be shown in a separate table, with totals reported using each of *Cost Table Templates 3a and 3b*.

Requirement CS-88. This section shall show costs (NASA SMD and contributed) associated with each Co-I and collaborator using *Cost Table Templates 4a and 4b* respectively; all Co-Is and collaborators shall be identified in the applicable table.

Requirement CS-89. This section shall fully cost and account for all contributions and direct/indirect costs associated with the work performed at NASA Centers, and summarize these costs in one page using the template provided in *Cost Table Template 5*. NASA Center costs shall include Civil Servant services, as well as the cost for the use of Government facilities and equipment on a full-cost accounting basis.

The purpose of the data in Requirement CS-89 is twofold:

1. to determine those costs that are included in the NASA SMD cost but are not funded out of the Explorers program, and
2. to determine Civil Servant contributions that are not included in the NASA SMD cost.

Teams should work with their respective NASA Centers to develop estimates for these costs. Contributions by NASA Centers should be documented by a Letter of Commitment, provided as an appendix (see Section L.1).

Requirement CS-90. The augmented submission shall include a table with the funding required in RY$ by fiscal year using the format of *Cost Table Template 6*. If the mission is selected for flight, SMD will use this information to prepare its budget request.

Requirement CS-91. For Phase B only, the augmented submission shall include a time-phased cost breakdown for each WBS element, using the template of *Cost Table Template 2*. The submission shall use only the line items shown in *Cost Table Template 2* that are relevant for Phase B.

Requirement CS-92. This section shall provide a detailed cost proposal for performing the Phase B portion of the project. The Phase B cost proposal shall correlate

with the plans set forth in the concept study. This Phase B cost proposal shall include the following elements:

1. Contract Pricing Proposal. Complete cost and pricing data for Phase B shall be submitted after down-selection by the down-selected team (see Appendix L.4 and Part III).
2. Work Breakdown Structure. This section shall show how the WBS of Requirement CS-74 applies to Phase B.
3. Proposal Pricing Technique. This section shall describe the process and techniques used to develop the cost proposal for Phase B. For portions of the cost proposal developed with a grass-roots methodology, the bases from which the estimates were derived and details on how the estimates were extrapolated from the bases shall be provided. For portions of the cost proposal derived from vendor quotes/historical actuals/catalogue prices/*etc.*, sufficient information shall be provided to understand the fidelity of the values. For portions of the cost proposal derived from analogies, the value of and the methodology for extrapolating the analogy shall be described. For portions of the cost proposal derived parametrically, the cost-estimating model(s) and techniques used in the Phase B cost estimate shall be provided. The heritage of the models and/or techniques applied to this estimate, including any differences between missions contained in the model's database and key attributes of the proposed mission shall be described. The section shall include the assumptions used as the basis for the Phase B cost and identify those that are critical to cost sensitivity in the investigation. If any "discounts" were assumed in the cost estimates for business practice initiatives or streamlined technical approaches, the section shall describe how these have been incorporated in the cost estimate and how they will be managed by the project team.
4. Workforce Staffing Plan. This section shall provide a Phase B workforce staffing plan (including Civil Servants) that is consistent with the WBS. This plan shall include all team member organizations and shall cover all management, manufacturing, technical (scientific and engineering), and support staff. The Phase B workforce staffing plan shall be phased by month. Time commitments for the PI, DPI, PM, PSE, Co-Is, and other key personnel shall be clearly shown.
5. Phase B Time-Phased Cost Summary. This section shall provide a summary of the total Phase B costs consistent with the table created for Requirement CS-91 (Cost Table Template 2). The Phase B cost summary shall include all costs to NASA SMD by WBS, as well as all contributed costs. The Phase B cost summary shall be phased by month.
6. Elements of Cost Breakdown. This section shall provide cost or pricing data as defined in FAR 15.401 and supporting evidence stating the basis for the estimated costs by the WBS levels used in the table created for Requirement CS-91 (Cost Table Template 2). This

information is in addition to that provided in Requirement CS-74 through Requirement CS-91 and shall include, but is not limited to, the following cost elements:

a. Direct Labor to include:
   i. the basis of labor-hour estimates for each of the labor classifications;
   ii. the number of productive work-hours per month;
   iii. a schedule of the direct labor rates used in the proposal, with a discussion of the basis for developing the proposed direct labor rates for the team member organizations involved; the forward-pricing method (including midpoint, escalation factors, anticipated impact of future union contracts, *etc.*); and elements included in the rates, such as overtime, shift differential, incentives, and allowances;
   iv. if available, evidence of Government approval of direct labor rates for proposal purposes for each labor classification for the proposed performance period; and
   v. if Civil Servant labor is to be used in support of the Phase B study, but is not to be charged directly to the investigation, this labor shall be considered as a contribution by a domestic partner, subject to the same restrictions as other contributions by domestic or foreign partners, and a discussion of the source of funding for the Civil Servant contributions shall be provided.
b. Direct Material, to include a summary of material and parts costs for each element of the WBS.
c. Subcontracts, to identify each effort (task, item, *etc.*, by WBS element) to be subcontracted, and list the selected or potential subcontractors, locations, amount budgeted/proposed, and types of contracts; to explain the adjustments, if any, and the indirect rates (or burdens) applied to the subcontractors' proposed or anticipated amounts; and to describe fully the cost analysis or price analysis and the negotiations conducted regarding the proposed subcontracts.
d. Other Direct Costs, to include:
   i. a summary of travel and relocation costs, including the number of trips, their durations, and their purposes;
   ii. a summary of all unique computer related costs;
   iii. specific task areas of problems that require consultant services, including the quoted daily rate, the estimated number of days, associated costs (*e.g.*, travel) if any, and a statement of whether the consultant has been compensated at the quoted rate for similar services performed with Government contracts; and
   iv. any other direct costs included in the proposal for Phase B, provided in a manner similar to that described above.

e. Indirect Costs, to include:
   i. all indirect expense rates for the team member organizations (in the context of the AO, indirect expense rates include labor overhead, material overhead, general and administrative [G&A] expenses, and any other cost proposed as an allocation to the proposed direct costs);
   ii. a schedule of off-site burden rates, including a copy of the company policy regarding off-site vs. on-site effort, if applicable;
   iii. evidence of Government approval of any/all projected indirect rates for the proposed period of performance, including the status of rate negotiations with the cognizant Government agency, and a comparative listing of approved bidding rates and negotiated actual rates for the past five fiscal years; and
   iv. fee arrangements for the major team partners.

Requirement CS-93. This section shall provide a cost estimate for performing the Final Design and Fabrication/System Assembly, Integration and Test, and Launch (Phase C/D) portion of the mission. The Phase C/D cost estimates shall correlate with the plans set forth in the concept study. The Phase C/D cost estimate shall include the following elements:

1. Work Breakdown Structure. This section shall show how the WBS of Requirement CS-74 applies to Phase C/D.
2. Cost Estimating Techniques. This section shall describe the process and techniques used to develop the Phase C/D cost estimate. For portions of the cost estimate developed using a grass-roots methodology, the bases from which the estimates were derived and details on how the estimates were extrapolated from the bases shall be provided. For portions of the cost estimate derived from vendor quotes/historical actuals/catalogue prices/*etc.*, sufficient information shall be provided in order to understand the fidelity of the values. For portions of the cost estimate derived from analogies, the value of and the methodology for extrapolating the analogy shall be described. For portions of the Phase C/D cost estimate derived parametrically, the section shall describe the cost-estimating model(s) and techniques. The heritage of the models and/or techniques applied to this estimate, including any differences between projects contained in the model's database and key attributes of the proposed project, shall be described. The section shall include the assumptions used as the basis for the Phase C/D cost and identify those that are critical to the cost sensitivity. The section shall identify any "discounts" assumed in the cost estimates for business practice initiatives or streamlined technical approaches and the basis for these discounts. The section shall describe how the discounts have been incorporated in the cost estimate and how they will be managed by the project team.
3. Workforce Staffing Plan. This section shall provide a Phase C/D workforce-staffing plan (including Civil Servants) that is consistent

with the WBS. This workforce-staffing plan shall include all team member organizations and shall cover all management, manufacturing, technical (scientific and engineering), and support staff. The Phase C/D workforce-staffing plan shall be phased by fiscal year. Time commitments for the PI, DPI, PM, PSE, Co-Is, and other key personnel shall be clearly shown.

4. Phase C/D Time-Phased Cost Summary. This section shall provide a summary of the total Phase C/D costs consistent with *Cost Table Template 2*. The Phase C/D cost summary shall include all costs to NASA SMD by WBS, as well as all contributed costs. The Phase C/D cost summary shall be phased by fiscal year. Phase C/D extends 30 days beyond launch, including tracking support and mission operations.

Requirement CS-94. This section shall provide a cost estimate for performing the Operations and Sustainment Phase (Phase E) of the mission. The Phase E cost estimate shall correlate with the plans set forth in the concept study. The Phase E cost estimate shall include the following elements:

1. Work Breakdown Structure. This section shall show how the WBS of Requirement CS-74 applies to Phase E.
2. Cost Estimating Techniques. This section shall describe the process and techniques used to develop the Phase E cost estimate. For portions of the cost estimate developed using a grass-roots methodology, the bases from which the estimates were derived and details on how the estimates were extrapolated from the bases shall be provided. For portions of the cost estimate derived from vendor quotes/historical actuals/catalogue prices/*etc.*, sufficient information shall be provided in order to understand the fidelity of the values. For portions of the cost estimate derived from analogies, the value of and the methodology for extrapolating the analogy shall be described. For portions of the Phase E cost estimate derived parametrically, the section shall describe the cost-estimating model(s) and techniques. The heritage of the models and/or techniques applied to this estimate, including any differences between projects contained in the model's database and key attributes of the proposed project, shall be described. The section shall include the assumptions used as the basis for the Phase E cost and identify those that are critical to the cost sensitivity. The section shall identify any "discounts" assumed in the cost estimates for business practice initiatives or streamlined technical approaches and the basis for these discounts. The section shall describe how these discounts have been incorporated in the cost estimate and how they will be managed by the project team.
3. Workforce Staffing Plan. This section shall provide a Phase E workforce staffing plan (including Civil Servants) that is consistent with the WBS. This workforce staffing plan shall include all team member organizations and shall cover all management, manufacturing, technical (scientific and engineering), and support staff. The Phase E

workforce staffing plan shall be phased by fiscal year. Time commitments for the PI, DPI, PM, PSE, Co-Is, and other key personnel shall be clearly shown.

4. Phase E Time-Phased Cost Summary. This section shall provide a summary of the total Phase E costs consistent with Cost Table Template 2. The Phase E cost summary shall include all costs to NASA SMD by WBS, as well as all contributed costs. The Phase E cost summary shall be phased by fiscal year.

Requirement CS-95. This section shall provide a cost estimate for performing the Closeout Phase (Phase F) of the mission. The Phase F cost estimate shall correlate with the plans set forth in the concept study. The Phase F cost estimate shall include the following elements:

1. Work Breakdown Structure. This section shall show how the WBS of Requirement CS-74 applies to Phase F.
2. Cost Estimating Techniques. This section shall describe the process and techniques used to develop the Phase F cost estimate and provide a description of the cost estimating model(s) and techniques. The heritage of the models applied to this estimate including any differences between projects contained in the model's database and key attributes of the proposed project shall be discussed. The section shall include the assumptions used as the basis for the Phase F cost and identify those that are critical to the cost sensitivity in the investigation. The section shall identify any "discounts" assumed in the cost estimates for business practice initiatives or streamlined technical approaches and the basis for these discounts. The section shall describe how these have been incorporated in the cost estimate and will be managed by the project team.
3. Workforce Staffing Plan. This section shall provide a workforce staffing plan (including Civil Servants) that is consistent with the WBS. This Phase F workforce staffing plan shall include all team member organizations and shall cover all management, manufacturing, technical (scientific and engineering), and support staff. The workforce staffing plan shall be phased by fiscal year. Time commitments for the PI, DPI, PM, PSE, Co-Is, and other key personnel shall be clearly shown.
4. Phase F Time-Phased Cost Summary. This section shall provide a summary of the total Phase F costs consistent with *Cost Table Template 2*. The Phase F cost summary shall include all costs to NASA SMD by WBS, as well as all contributed costs. The Phase F cost summary shall be phased by fiscal year.

Note that the Phases C/D, E, and F time-phased cost summaries for Requirement CS-93, Requirement CS-94, and Requirement CS-95 above may be combined into a single table in Cost Table Template 2 format.

Immediately following the continuation decision (i.e., down-selection), the contractor will be requested to submit a formal cost proposal based upon the Federal Acquisition Regulation (FAR) Part 15. The instruction and format for submission of this formal cost proposal are found in FAR Part 15.403-5 and Table 15.2. The definitive contract will include an option provision for Phases B, C/D, E, and F with a not-to-exceed amount for each phase.

Requirement CS-96. The cost elements proposed in the formal proposal for contract award shall be traceable to the cost proposal provided in the CSR. Any changes in cost from the CSR shall be described in detail.

Requirement CS-97. Completed versions of *Cost Table Templates 1, 2, 3a, 3b, 4a, 4b, 5, 6, and 7* shall be provided as additional files along with the augmented submission. Microsoft Excel format templates of tables are available for download in a consolidated workbook from the Program Library.

- Cost Table Template 1: Total mission cost funding profile by organization
- Cost Table Template 2: Time-phased cost breakdown by WBS and major cost category
- Cost Table Template 3a: Total mission cost profile by mission phase, fiscal year, and WBS in real year dollars
- Cost Table Template 3b: Total mission cost profile by mission phase, fiscal year, and WBS in fiscal year dollars
- Cost Table Template 4a: Co-I funding profile by mission phase in real year dollars
- Cost Table Template 4b: Co-I funding profile by mission phase in fiscal year dollars
- Cost Table Template 5: NASA civil service costs by fiscal year in real year dollars
- Cost Table Template 6: Optional SC Incentive and SEO costs by fiscal year in real year dollars
- Cost Table Template 7: Funding profile for any SEO activities by fiscal year in real year dollars

J. JUSTIFICATION AND COST PROPOSAL FOR ANY SCIENCE ENHANCEMENT OPTION

SEO activities, discussed in AO Section 5.1.8, include extended missions and archival data analysis programs. The selections from the Step-1 proposals were made primarily on the merit of the baseline proposed science; no prejudice or commitment to any attendant proposed SEO activity was made at selection. It is incumbent upon investigation teams, therefore, to fully discuss these project additions in the CSR.

Funding for SEO activities is outside of the PIMMC, and will therefore result in a separate decision by NASA as to whether to accept or reject these proposed expansions to the Baseline Science Investigation. Therefore, the CSR must provide sufficient clarity to allow contractual execution if NASA elects to fund any SEO activities.

All definitions, guidelines and constraints outlined in the AO and applicable to SEOs are still valid for the concept study. There are no page count limits for narrative descriptions, rationale, and data for these enhancements, but conciseness and brevity are encouraged.

Requirement CS-98. If SEO activities are proposed, this section shall provide sufficient information (including all applicable TRLs at CSR submittal) and justification to enable evaluation of the science value, viability, and cost of the concept.

Requirement CS-99. This section shall provide a cost estimate for performing any SEO activities. In completing the Cost section, the guidelines for Phases B through D apply. For each SEO proposed, complete a one-page summary of costs using the format shown in the *Cost Table Template 7*. Also, include the total amount in the SEO line item at the bottom of the cost table in Requirement CS-84 (*Cost Table Templates 3a and 3b*). Include a discussion of the estimating techniques used to develop the cost estimates.

K. OPTIONAL STUDENT COLLABORATION

NASA is providing an Student Collaboration (SC) incentive of 1% of the PIMMC. If the SC cost to NASA is less than the SC incentive, then the proposed SC cost to NASA will be outside of the PIMMC. If the total SC cost exceeds the SC incentive, then the balance of the NASA cost of the SC must be funded within the PIMMC. If the SC costs NASA less than the SC incentive, the project will not receive the balance of the funds up to the full incentive amount. SC resources, as an addition to a mission's implementation, are not available to solve project cost overrun issues. Contributions to the SC are permitted.

If a SC is proposed to be launching on a separate spacecraft, it would be the responsibility of the project within their allotted SC funding to provide the launch. If eligible, projects may apply to NASA's CubeSat Launch Initaitve (CSLI), but NASA does not guarantee that they will be accepted. If a SC is not accepted by CSLI or another provider, NASA does not commit to finding it another launch opportunity.

Requirement CS-100. If a SC is proposed, this section shall describe a detailed plan. This plan shall include:

1. A summary description of the planned SC;
2. A development schedule for the SC, including decision points for determining readiness for flight;
3. A demonstration of how the SC will be incorporated into the mission investigation on a non-impact basis;
4. A plan for recruiting student participants;
5. A plan for the mentoring and oversight of students to maximize the opportunity for teaching, learning, and success in contributing to the mission; and
6. An appropriate plan for evaluation.

Requirement CS-101. If a SC is proposed, this section shall demonstrate that the proposed SC is clearly separable from the proposed Baseline and Threshold Science Missions; will not increase the mission development risk; and will not impact the science investigation in the event that the SC is not funded, fails during flight operations, or encounters technical, schedule, or cost problems during development.

Requirement CS-102. If a SC is proposed, this section shall identify the funding set aside for the SC, and any contributions to the SC. This funding may be outside the PI-Managed Mission Cost up to the Student Collaboration incentive, and any SC costs beyond the Student Collaboration incentive, unless contributed, shall be within the PI-Managed Mission Cost.

L. CSR APPENDICES

The following additional information is required to be supplied with the CSR. This information is to be provided in the form of appendices to the CSR, and, as such, will not be counted within the specified page limit.

L.1. *Letters of Commitment*

Requirement CS-103. This appendix shall provide letters of commitment signed by officials authorized to commit the resources of the respective institutions or organizations from:

1. all organizations offering contributions of goods and/or services (including Co-Is and collaborator services, both U.S. and non-U.S.) on a no-exchange-of-funds basis, including all non-U.S. organizations providing hardware or software to the investigation; and
2. all major or critical participants in the mission regardless of source of funding.

See AO Section 5.8.1 for the definition of major partners and for the required elements in an institutional letter of commitment. Critical participants are those participants (organizations and individuals) who are assigned tasks considered by the PI to be critical to the success of the mission, including those who provide unique required services. All other participants are non-critical. Note that participants may be members of multiple headings, in which case, provide a letter of commitment for each applicable heading. A complete letter of commitment from a vendor will include the specifics of the quote.

Requirement CS-104. If the use of NASA-provided communication and/or navigation services is proposed, this appendix shall include an associated letter of commitment from the network provider.

Requirement CS-105. This appendix shall provide personal letters of commitment signed by the individual from every Concept Study Team member as defined in Section 5.8.2 of the AO. Personal letters of commitment shall indicate the Concept

Study Team member's commitment to the proposed investigation and specifically to the role, responsibilities, and participating organization proposed for them.

An email sent from the individual Concept Study Team member to the PI stating the member's commitment will be sufficient to satisfy the signature requirement for personal letters of commitment.

Requirement CS-106. This appendix shall include letters of commitment from non-U.S. individuals and/or institutions that are team members or contributors to the investigation. These letters of commitment shall provide evidence that the non-U.S. institution and/or government will commit the appropriate technical, personnel, and funding resources to the proposed investigation if selected by NASA.

The required elements in a letter of commitment are: (i) a precise description of what is being contributed by the partner and what assumptions are being made about NASA's role; and (ii) the strongest possible statement of whether the contribution will be funded, or what further decisions must be made before the funding is committed by the partner. An authorized officer or representative of the partner institution or government must sign the respective letter of commitment. If the institution providing the funding is not the same as the institution providing the contributed item, then a letter is required from both institutions.

Letters of commitment provided for the Step-1 proposal can be reused if the description of the commitment is unchanged and if the letter of commitment meets the requirements for letters of commitment for the Concept Study Report.

L.2. *Relevant Experience and Past Performance*

In evaluating the CSR, NASA will consider the past performance of the major partner organizations. The evaluation of past performance will not be arithmetic; instead, the information deemed to be most relevant and significant will receive the greatest consideration. Relevant experience will be viewed as the demonstrated accomplishment of work, which is comparable or related to the objectives of the proposed investigation and/or the scope of the proposed project. This includes space-based instrument development and investigations and associated development processes including engineering processes, management processes, operations, data analysis and delivery of data to appropriate data archives. NASA will review the past performance information provided by the proposer. In addition, NASA may review the major team partners' past performance on other NASA and/or non-NASA projects or contracts that provide insight into those institutions' past performance on airborne or space-based instrument or spacecraft development and investigations and associated development processes including engineering processes, management process, operations, data analysis and delivery of data to the appropriate data archive. In conducting the evaluation, NASA reserves the right to use all information available.

Requirement CS-107. This appendix shall describe relevant experience and past performance by the major team partners (organizations) in meeting the requirements of projects similar to the subject of the CSR. This may include space-based instrument development and investigations. The discussion of relevant experience and past performance shall include:

1. a description of each project;
2. its relevance to the subject of the CSR;
3. the proposed performance and the actual performance;
4. the planned delivery schedule of data to the appropriate data archive and the actual delivery schedule of data to the appropriate data archive;
5. the proposed cost and actual cost;
6. the proposed schedule and actual schedule;
7. an explanation of any differences between proposed performance, cost, and schedule and what was actually achieved; and
8. points of contact for the past project's customer. If the customer for the past project was the United States Government, then the contract number shall be included along with current technical point(s) of contact and phone number(s).

For projects that are not yet complete, the current projected performance, cost, and schedule shall be used in place of actual values. Projects that ended more than 5 years ago need not be included.

Investigation teams are cautioned that omissions or an inaccurate or inadequate response to this evaluation item will have a negative effect on the overall evaluation, and while NASA may consider data from other sources, the burden of providing relevant references that NASA can readily contact rests with the investigation team.

L.3. *Resumes*

Requirement CS-108. This appendix shall include resumes or curricula vitae for the PI, DPI, PM, PSE, any other named Key Management Team members identified in the Management section, and all Co-Is and Collaborators identified in the Science section. Specifically, each resume shall cite the individual's experience that is pertinent to the role and responsibilities that they will assume in the proposed investigation. Project management experience shall be included in the resumes of the PI, DPI, PM, and PSE. Resumes or curricula vitae shall be no longer than three pages for the PI and one page for each additional participant. Resumes shall be organized alphabetically after that of the PI, by surname. Photographs shall not be included in any of the resumes.

L.4. *Phase B Contract Implementation Data*

Provision of draft SOWs may be deferred to the date of each Concept Study Team's Site Visit.

Requirement CS-109. This appendix shall provide draft SOWs for all potential contracts with NASA. SOWs shall be provided for each contract phase (*i.e.*, Phases B through F) and shall clearly define all proposed deliverables (including science data) for each option, potential requirements for Government facilities and/or Government services, and a proposed schedule for the entire mission.

Requirement CS-110. (deferred until after down-selection, see Part III) This appendix shall provide cost and pricing data for Phase B that meet the requirements of the FAR Part 15 Table 15-2. These cost and pricing data are necessary and required to implement the contract. Complete cost or pricing data shall be included with the CSR for each organization participating in Phase B, and must be signed by each organization's authorized representative. This requirement may be satisfied with one form, provided that all institutions involved in Phase B are included and have provided the appropriate signatures. These data are in addition to the data provided in *Cost Tables Templates 1-7* for evaluation purposes, and allocate project costs per the cost categories defined in Table 15-2, but still align at the highest levels with the evaluation data. Also see Section I of PART II above for additional guidance.

See Phase B Contract Implementation Data section in Part III of this document for Phase B contracting activities following down-selection.

L.5. *Data Management and Software Management Plans*

Requirement CS-111. This appendix shall include a schedule-based end-to-end draft of the Data Management Plan (DMP). The plan shall be in compliance with the requirements and the guidelines in the *NASA Plan for Increasing Access to the Results of Scientific Research*, with the applicable version of SPD-41 and with the *Astrophysics Scientific Information Management Policy*, or a justification shall be provided that this is not necessary given the nature of the work proposed. The draft plan shall:

1. Include approaches for data retrieval, validation, preliminary analysis, image processing, calibration, correction, and archiving;
2. Identify science products (*e.g.*, flight data, ancillary or calibration data, theoretical calculations, higher order analytical or data products, laboratory data, *etc.*), including a list of the specific data products, and the individual team members responsible for the data products;
3. Identify the calibration and measurement algorithm document, including a list of the individual team members responsible for the document;
4. Identify the appropriate NASA data archive and the formats and standards to be used. If a NASA archive is not identified, discuss how the mission will satisfy NASA's obligation to preserve data for future researchers;

5. Include an estimate of the raw data volume and a schedule – including the data latency by product – for the submission of raw and reduced data to the data archive, in physical units accessible to the science community, as well as required calibration information; and
6. Demonstrate allocation of sufficient resources (cost, schedule, workforce, computational) for archiving as well as for preliminary analysis of the data by the Project Investigation Science Team, publication of the results in refereed scientific journals, as well as for the development of any new algorithms, software, or other tools.

Requirement CS-112. This appendix shall include a draft of the Software Management Plan (SMP). The SMP shall describe the software and tools to be developed (including the timeline for software and tools release and the current status of their development), the software and tool documentation, the planned license for the software, the open version control platform planned for use, the management for testing and management, and the individual team members responsible for the software and tools.

Requirement CS-113. If the investigation requires NASA High-End Computing (HEC) resources, this section shall state:

1. requirements, by year, for computing in the "standard billing units" (SBUs);
2. data storage need in Terabytes, by year;
3. explanation of the need to use this capability.

The Study Team does not need to submit a letter of commitment for use of NASA HEC resources. The general HEC webpage is at https://hec.gsfc.nasa.gov/index.html, and SBU Conversion Factors may be found at https://www.hec.nasa.gov/user/policies/sbus.html. Costs associated with HEC utilization will not count against the PIMMC.

L.6. *Incentive Plan(s)*

Requirement CS-114. If applicable, this appendix shall provide draft incentive plans. Incentive plans shall outline contractual incentive features for all major team members. Incentive plans shall include both performance and cost incentives, as appropriate.

L.7. *Technical Content of any International Agreement(s)*

Requirement CS-115. Draft language for the technical content of any International Agreement(s) is required for all non-U.S. partners in the investigation. Sample agreements are available in the Program Library. The draft language shall include:

1. a brief summary of the mission and the foreign partner's role in it;
2. a list of NASA's responsibilities within the partnership; and

3. a list of the non-U.S. partner's responsibilities within the partnership. Note that NASA prefers to establish agreements with foreign Government funding agencies, and not with the institution that will be funded to perform the work.

L.8. *International Participation Plans (Update from Proposal)*

Requirement CS-116. If the investigation includes international participation, either through involvement of non-U.S. nationals and/or involvement of non-U.S. entities, this appendix shall describe any updates to plans for compliance with U.S. export laws and regulations; *e.g.*, 22 CFR 120-130, *et seq.* and 15 CFR 730-774, *et seq.*, that were provided in the Step-1 proposal (see Appendix B, Section J.5 in the AO). The discussion shall describe in detail the proposed international participation and shall include, but not be limited to, whether or not the international participation may require the proposer to obtain the prior approval of the Department of State or the Department of Commerce via a technical assistance agreement or an export license or whether a license exemption/exception may apply. If prior approvals via licenses are necessary, the CSR shall include a discussion about whether the license has been applied for or, if not, the projected timing of the application and any implications for the schedule.

Requirement CS-117. If a CSR includes international participation, this appendix shall include the following statement, "If selected for flight, U.S. export laws and regulations; *e.g.*, 22 CFR 120 130, *et seq.* and 15 CFR 730 774, *et seq.*, as applicable to the scenario surrounding the particular international participation, will be followed."

Requirement CS-118. Foreign nationals requiring access to NASA facilities and information systems will be required to comply with Homeland Security Presidential Directive HSPD-12 (see http://www.dhs.gov/homeland-security-presidential-directive-12), where applicable. This appendix shall also discuss the impact, if any, on the investigation and the proposed international participation of compliance with HSPD-12. If no impact is anticipated, this shall be explicitly stated.

L.9. *Planetary Protection Plan*

Requirement CS-119. If applicable, this appendix shall describe the plan for compliance with the planetary protection requirements described in Section 5.1.6 of the AO. At minimum, it shall address:

1. the anticipated planetary protection Category of the mission under NASA directives;
2. the proposed mission operational accommodations to comply with the anticipated requirements, including organizational responsibilities;

3. the proposed steps to be taken for the preparation of flyby, orbital, and/or landed portions of the spacecraft to comply with any requirements for overall microbiological cleanliness and recontamination prevention prior to launch;
4. steps intended to be taken for planetary protection compliance; and
5. the implementing organization and any partner responsible for implementing those steps.

L.10. *Requirements Related to Orbital Debris, Collision Avoidance, and End-of-Mission*

This appendix is required only for missions conducting significant operations or ending their mission life in Low Earth Orbit (LEO) (< 2000 km perigee), near Geosynchronous Orbit (GEO) (GEO ± 300 km), at the Moon (lunar orbiters, impactors, or landers) or near Lagrange points.

Per NPR 8715.6, *NASA Procedural Requirements for Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environments*, orbital debris is defined as any object placed in space by humans that remains in orbit, and no longer serves any useful function. Objects range from spacecraft to spent launch vehicle stages to components, and also include materials, fragments, or other objects which are intentionally or inadvertently cast off or generated.

Every selected investigation team must conduct a formal assessment during Phase A of the orbital debris the spacecraft or instrument will create upon mission termination.

For missions traveling beyond Earth orbit, plans for conducting these assessments are required at the end of Phase A only for missions where the mission approach (either during nominal operations, in the event of an anomaly, or at the end of mission) indicates that the likelihood of generating orbital debris in the locations described above is high during nominal operations.

Requirement CS-120. This appendix shall discuss briefly how the mission meets the NPR 8715.6 and NASA-STD-8719.14 orbit debris requirements applicable to its proposed orbit.

Requirement CS-121. For LEO missions, this appendix shall discuss the lifetime of the mission and whether it meets the 25-year post-mission requirement. An orbital lifetime analysis addressing all assumptions and inputs contributing to the analysis shall be provided and describe, at a minimum:

- Vehicle mass;
- Drag area or Cross-sectional area;
- Initial orbit used for the analysis;
- Solar and atmospheric conditions assumptions (*i.e.*, models or parameters);
- Methodology: analytical tool, table lookup, reference plot; and
- Key elements of an Initial Orbital Debris Assessment Report (ODAR) and an assessment of whether an End-of-Mission Plan (EOMP) is required.

Requirement CS-122. This appendix shall provide a brief description, including any cost deltas, of the impact on the investigation if the 25-year post-mission orbital lifetime requirement is changed to 5 years. This description shall assume that the requirement change is implemented at PDR. The evaluators may submit comments to the Selection Official on appendix material that addresses this requirement.

NASA-STD 8719.14 indicates "an 'Initial ODAR' is required for each project to assist NASA management in considering potential orbital debris issues during concept development (Phase A) and development of preliminary requirements, specifications, and designs (Phase B) to estimate and minimize potential cost impacts." As such, an Initial ODAR may be submitted in response to this section. However, given that the Office of Safety and Mission Assurance (OSMA) will not interface with projects until Phase B, the Step-2 Evaluation Panel will perform the reviews referenced in NASA-STD 8719.14. While Initial ODAR Section 2 (Orbital Debris Limitation Summary) indicates that "Further analyses are not needed at this time", questions that require analysis or raise concerns regarding the design of the mission (*e.g.*, objects significantly greater than the 1 kg threshold in question (i) for Full Spacecraft Development, or constellations of spacecraft), may elicit follow-ups from the Step-2 Evaluation Panel.

Requirement CS-123. For non-LEO missions, this appendix shall include a discussion of how end-of-mission requirements will be met.

Requirement CS-124. If the plan is to dispose of the satellite at the end of mission, this appendix shall provide the parameters of the disposal orbit, the delta-v allocation for disposal, and any other relevant assumptions.

NASA has established conjunction assessment risk analysis requirements in NPR 8079.1. Two organizations—the Conjunction Assessment Risk Analysis (CARA) team at NASA Goddard Space Flight Center for Earth-orbiting missions and the Multi-mission Automated Deepspace Conjunction Assessment Process (MADCAP) team at the Jet Propulsion Laboratory for NASA spacecraft not orbiting the Earth —are funded directly by NASA HQ to perform the actual analysis and risk assessment; the costs for these services need not be included in the PI-Managed Mission Cost. However, an investigation to which these requirements are applicable have to budget costs under the PI-Managed Mission Cost to establish a working interface between the Flight Operations Team and the CARA or MADCAP team (See AO Section 4.6.4).

Requirement CS-125. This appendix shall discuss briefly how the mission meets the NPR 8079.1 conjunction assessment and collision avoidance requirements applicable to its proposed orbit. The discussion shall include, at a minimum:

- Schedule and plans for development of an Orbital Collision Avoidance Plan (OCAP) and Conjunction Assessment Operations Implementation Agreement (CAOIA);
- Plans and cadence for production of spacecraft ephemerides and their delivery to CARA or MADCAP; and
- Plans and cadence for maneuver notifications to CARA or MADCAP and for pursuing close approach mitigations as needed.

For additional information regarding CARA, including potential input on orbit and trajectory trade studies, Study Teams may contact Ms. Alinda Mashiku (Telephone: 301-286-6248, email: alinda.k.mashiku@nasa.gov). For information regarding MADCAP, please contact Mr. David Berry (Telephone: 818-354-0764; email: david.s.berry@jpl.nasa.gov)

L.11. *Compliance with Procurement Regulations by NASA PI Proposals*

This appendix is required only for CSRs submitted by NASA PIs or NASA Centers (excluding JPL). CSRs submitted by NASA Centers must comply with regulations governing proposals submitted by NASA PIs (NFS 1872.306).

For a NASA Center CSR, this appendix shall include any descriptions, justifications, representations, indications, statements, and/or explanations that are required by the regulations.

L.12. *Master Equipment List*

Requirement CS-126. The augmented submission shall include a Master Equipment List (MEL) in a spreadsheet format summarizing all major components of each flight element subsystem and each instrument element component. Fully contributed instruments should include enough subsystem detail to support validation of instrument design. A Microsoft Excel template of the MEL is available for download in the Program Library.

The MEL will support validation of proposed mass estimates, power estimates, contingencies, design heritage, and cost.

The breakouts should be traceable to block diagrams and heritage claims provided in other parts of the CSR. For each major component, current best estimates (CBE) and contingency for mass and power, number of flight units required, and some description of the heritage basis must be provided. Power values should represent nominal steady state operational power requirements. Information to be provided includes identification of planned spares, identification of engineering models and prototypes with their fidelities, required deliveries for simulators and testing, contingency allocations for individual components, and other component description/characteristics.

Certain items should include additional details sufficient to assess functionality and/or cost, to identify and separate individual elements. List each electronic board separately, identify the functionality of each board (either in the MEL or in the Mission Implementation section), and provide the board clock speed. If proposing Field Programmable Gate Arrays (FPGAs) or Application Specific Integrated Circuits (ASICs), or Radio Frequency Integrated Circuits (RFICs), list the design size (in the appropriate sizing parameter such as logic cells, logic elements), the board the chip(s) will be integrated onto, and how much heritage will be used in the design.

Requirement CS-127. This appendix shall include a PDF copy of the Microsoft Excel MEL.

L.13. *Heritage*

Requirement CS-128. This appendix shall discuss each element of any heritage from which the proposed investigation derives substantial benefit, including heritage from spacecraft subsystems, instruments, ground systems, flight and ground software, test set ups, simulations, analyses, *etc*. This discussion shall be at an appropriate level of granularity (*e.g.*, component, assembly, subsystem) to clearly separate the heritage element from other elements of the design. The discussion of each element shall include:

1. A concise description of the design heritage claimed;
2. A description of changes required to accommodate project-unique applications and needs;
3. Anticipated benefits to the proposed investigation;
4. A brief rationale supporting how the benefits of heritage will be achieved; and
5. For any proposed elements with substantial design heritage, a comparison of the cost of the heritage items to the proposed cost.

The discussion shall substantiate all heritage claims, including descriptions of changes required to accommodate project-unique applications and needs. Where enhancements to heritage elements are proposed or heritage is from a different application, sufficient descriptions must be provided to independently assess the current level of maturity.

The evaluation team will use a scale with three levels (full, partial, or none) as illustrated in Table 3 below.

	Full heritage	Partial heritage	No heritage
Design	Identical	Minimal modifications	Major modifications
Manufacture	Identical	Limited update of parts and processes necessary	Many updates of parts or processes necessary
Software	Identical	Identical functionality with limited update of software modules (<50%)	Major modifications (≥50%)
Provider	Identical provider and development team	Different however with substantial involvement of original team	Different and minimal or no involvement of original team
Use	Identical	Same interfaces and similar use within a novel overall context	Significantly different from original
Operating Environment	Identical	Within margins of original	Significantly different from original
Referenced Prior Use	In operation	Built and successfully ground tested	Not yet successfully ground tested

Table 3. Heritage Assessment

L.14. *Classified Materials*

See Section 5.7.4 of the AO for options and associated requirements. The Step-1 page limit does not apply.

L.15. *Small Business Subcontracting Plan*

Requirement CS-129. This appendix shall provide a small business subcontracting plan covering Phases B through F, including the proposed goals and targets and the quality and level of work that will be performed by various categories of small business concerns, as described in Section 5.5.1 of the AO, with the exception of separately identifying and being evaluated on participation targets of Small Disadvantaged Business (SDB) concerns in North American Industry Classification System (NAICS) codes determined by the Department of Commerce to be underrepresented industry sectors. Its effect on the technical, management, and cost feasibility of the investigation shall be described.

This plan will be negotiated prior to any Phase B contract award.

L.16. *Additional Cost Data to Assist Validation (Optional)*

In addition to the specific cost table data requested in the Cost Proposal (Section I), investigation teams may also provide any additional costing information/data that they feel will assist NASA to validate the project's proposed costs. Vendor quotes, cost estimates, rationale for design heritage cost savings, are all examples of data that can be included here. Input and output files for any publicly available cost model may be included with the augmented submission, if accompanied by discussion in this appendix.

The information provided may also include cost by NASA fiscal year to the lowest level of detail the project is working with, in Microsoft Excel format.

L.17. *Science Change Matrix*

Requirement CS-130. This appendix shall document all modifications made to the Science Investigation (Section D) since the original Step-1 submission in a table with the following columns:

1. the section/paragraph in the CSR where the modification occurs,
2. whether the modification represents a change to a science objective or related performance,
3. description of the change, and
4. rationale for the change.

Science Change Matrix Example, available in the Program Library, provides an example format for Appendix L.18 (under "Entries in Science Change Matrix"). This format documents Section D changes and provides rationale for those changes.

L.18. *Communications Design Data*

Requirement CS-131. This appendix shall provide data and detailed link analyses for all communication modes, adequate to assess the design of the communications concept. This shall include:

1. A communications block diagram (showing all components);
2. A discussion of compliance with the applicable maximum channel bandwidth limits;
3. Link budget design control tables for all radio communications links (data and carrier) showing relevant spacecraft and earth station parameters and assumptions for the highest data rate and the emergency link at the maximum distance and throughput at which each particular link could be used. In particular the following parameters shall be provided:
    a. Transmitter RF Output Power,
    b. Transmitter Antenna Gain,
    c. Transmitter Off-Boresight Pointing Loss,
    d. Transmitter Circuit Loss,

e. Carrier Frequency,
f. Transmitter-Receiver Range,
g. Receiver Antenna Gain,
h. Receiver Off-Boresight Pointing Loss,
i. Receiver Circuit Loss,
j. Receiver Bandwidth,
k. Receiver System Temperature,
l. Hot Body Noise Temperature,
m. Data Modulation Index,
n. Ranging Modulation Index (if used),
o. Data Rates, including bit rate and symbol rate,
p. Forward Error Correcting Code including code rate, block size (if applicable), constraint length (if applicable),
q. Carrier Modulation Index,
r. Carrier Link Margin, and
s. Data Link Margin.

For more information on these requirements, including table format, see NASA's *Mission Operations and Communication Services*, available in the Program Library.

L.19. *Project Protection Plan*

The CSR must address the Project Protection Plan, including compliance with NASA-STD-1006 as discussed in Section 5.2.12 of the AO.

Requirement CS-132. This appendix shall provide the detailed plans addressing the protection of uplink commands using approaches compliant with FIPS 140 Level 1.

Requirement CS-133. This appendix shall provide the detailed plans addressing the ability of command uplink, position, navigation, and timing subsystems to recognize and survive interference.

Requirement CS-134. This appendix shall provide the detailed plans addressing the protection of command uplink information at no less than the CUI level.

Requirement CS-135. This appendix shall provide the detailed plans addressing the development of a Project Protection Plan (PPP) by PDR, including Candidate Protection Strategies (CPSs).

The Program Library includes a template *Project Protection Plan.*

Questions concerning the Project Protection Plan may be addressed to: Jerry Esper, SMD Program Executive for Systems Security, E-mail: jerry.s.esper@nasa.gov.

L.20. *Cybersecurity*

With the rise in cyberattacks on all computer systems, NASA needs to be proactive in protecting all flight and ground assets. To protect mission IT assets, NASA requires projects to develop a System Security Plan (SSP) using the NIST 800-53 controls as a basis. The requirement to follow NIST 800-53 flows from NPR 2810.1. The SSP begins with a description of the mission, including all end-to-end data flows, and uses NIST 800-series documents to develop the content of the SSP.

Requirement CS-136. This appendix shall provide a ground system data flow diagram showing end-to-end flows of all mission data, including any flows to facilities outside the control of the mission itself (such as ground stations).

Requirement CS-137. This appendix shall demonstrate that adequate resources (including, but not limited to, cost, schedule, technical accommodation, *etc*.) have been allocated to develop and implement a System Security Plan consistent with NIST 800-53.

Questions concerning Cyber Security may be addressed to: Jerry Esper, SMD Program Executive for Systems Security, E-mail: jerry.s.esper@nasa.gov.

L.21. *Draft Mission Definition Requirements Agreement*

Requirement CS-138. This appendix shall provide a draft Mission Definition Requirements Agreement (MDRA). MDRAs define Level 2 requirements for the baseline mission, encompassing the programmatic, science and instrument, mission implementation and spacecraft, and ground data requirements.

An example MDRA is provided in the Program Library.

L.22. *Draft MAIP and MAR Compliance Matrix*

Requirement CS-139. This section shall provide a draft Mission Assurance Implementation Plan (MAIP) and Compliance Matrix for the SPD-39: *SMD Standard Mission Assurance Requirements for Payload Classification D* document in the Program Library. See the document for details.

Requirement CS-140. The draft MAIP shall describe the approach to the selection of Electrical, Electronic, Electromechanical, and Electro-Optical (EEEE) parts, covering all major vendors and suppliers.

Appendix C of SPD-39 provides a template of the compliance matrix.

Requirement CS-141. For every item marked “Yes” in the draft Compliance Matrix to SPD-39, the comment column shall indicate how compliance will be achieved.

Requirement CS-142. For every item not marked "Yes" in the draft Compliance Matrix to SPD-39, the comment column shall explain the reason for the deviation from full compliance and the approach to meeting the intent of the requirement. The comment shall discuss any resulting risk to investigation success.

L.23. *Justification for the use of non-AMMOS MOS/GDS Tools*

Requirement CS-143. This section shall describe the justification for using Mission Operation System or Ground Data System (MOS/GDS) tools other than those available from the Advanced Multi-Mission Operating System (AMMOS). For each non-AMMOS tool, this section shall contain:

1. A list of requirements that the equivalent AMMOS tool does not meet for the proposed flight project; and
2. The proposed non-AMMOS tool that satisfies the listed requirements.

If an AMMOS tool will meet the flight project requirements, this section must outline the reasons for not using that tool (*e.g.*, cost of mission-specific adaptations to the AMMOS tool, extensive heritage of use of the non-AMMOS tool by the mission operator).

L.24. *Acronyms and Abbreviations List*

Requirement CS-144. This appendix shall provide a list of abbreviations and acronyms.

L.25. *References and Management Standards List*

The CSR may additionally provide, in this appendix, a list of other reference documents and materials used in the concept study. The documents and materials themselves cannot be submitted unless they are within the CSR's page limit. Investigation teams are encouraged to include an active URL for those documents available through the Internet. If the URL is password protected, provide the password in the CSR. This may not include references to audio or video materials. However, CSRs must be self-contained: any data or other information intended as part of a CSR must be included within the CSR itself.

In addition, if the CSR proposes to use internal program and project management standards, then this section must provide those standards.

Requirement CS-145. This section shall provide a list of any internal program and project management standards to be used in the proposed development (*e.g.*, GEVS, "GOLD Rules"). To the extent practicable, the referenced documents shall be included with the augmented submission.

Requirement CS-146. If one or more references includes ITAR/EAR material, the references shall be made available to NASA in a properly marked form If one or more references via the augmented submission process.

PART III – OTHER FACTORS REQUIRED AFTER DOWN-SELECTION

Phase B Contract Implementation Data

Immediately following the continuation decision (*i.e.*, down-selection), successful teams will be requested to submit a formal cost proposal based upon the Federal Acquisition Regulation (FAR) Part 15. The instruction and format for submission of this formal cost proposal are found in FAR Part 15.403-5 and Table 15.2. Teams will be required to provide cost and pricing data for Phase B that are necessary and required to implement the contract for Phase B. Complete cost and pricing data will be required for each organization participating in Phase B. These data should allocate project costs per the cost categories defined in Table 15-2. See Section I of PART II for additional guidance.

PART IV – ABBREVIATIONS AND ACRONYMS

AA.....Associate Administrator
AES.....Advanced Encryption Standard
AIT&V.....Assembly, Integration, Test and Verification
AMMOS .....Advanced Multi-Mission Operations System
AM&O.....Agency Management and Operations
AO.....Announcement of Opportunity
AOR.....Authorized Organizational Representative
APD.....Astrophysics Programs Division
APPEL .....NASA Academy of Program, Project, and Systems Engineering Leadership
ASIC .....Application-Specific Integrated Circuits
ASRC.....Arctic Slope Regional Corporation
BIS .....Bureau of Industry and Security
BOE.....Basis of Estimate
BOL.....Beginning of Life
BOM .....Beginning of Mission
CADRe.....Cost Analysis Data Requirement
CAOIA.....Conjunction Assessment Operations Interface Agreement
CARA .....Conjunction Assessment Risk Analysis
CBE.....Current Best Estimate
CCR.....Central Contractor Registry
CD-ROM.....Compact Disc-Read Only Memory
CDR .....Critical Design Review
CEQ.....Council on Environmental Quality
CESO .....Center Engineering, Safety, and Operations
CFR.....Code of Federal Regulations
CMAD.....Calibration Measurements and Algorithms Document
CM&O .....Center Management and Operations
C&N.....Communication and Navigation
Co-I .....Co-Investigator
CPS .....Candidate Protection Strategy
C&R .....Criteria and Requirements
CSCI.....Computer Software Configuration Item
CTS .....Cornell Technical Services
DAAC .....Distributed Active Archive Center
DLA .....Declination of Launch Asymptote
DMP.....Data Management Plan
DOD.....Department of Defense

DOE .....Department of Energy
DOR .....Differential One-way Ranging
DPI .....Deputy Principal Investigator
DRD .....Delivery Readiness Date
DSN.....Deep Space Network
DTN .....Delay/Disruption Tolerant Networking
EA .....Environmental Assessment
EAR.....Export Administration Regulations
EASSS.....Evaluations, Assessments, Studies, Services, and Support
EBPOC.....Electronic Business Point of Contact
EIRP .....Effective Isotropic Radiated Power
EIS.....Environmental Impact Statement
EM.....Engineering Model
EOL.....End of Life
EOM.....End of Mission
EOSDIS.....Earth Observing System Data and Information System
ETU.....Engineering Test Unit
EV .....Earth Venture
EVM.....Earned Value Management
ESA .....European Space Agency
FAQ.....Frequently Asked Questions
FAR.....Federal Acquisition Regulation
FASAB.....Federal Accounting Standards Advisory Board
FFRDC.....Federally Funded Research and Development Center
FONSI.....Finding of No Significant Impact
FOV.....Field Of View
FPGA .....Field-Programmable Gate Array
FSR .....Funded Schedule Reserve
FTE .....Full Time Equivalent
FY .....Fiscal Year
G&A.....General and Administrative
GAO.....Government Accountability Office
GBO .....Ground-Based Observatory
GDS.....Ground Data System
GEO .....Geosynchronous Orbit
GFE.....Government Furnished Equipment
GFS .....Government Furnished Service
GSE.....Ground Support Equipment
GSFC.....Goddard Space Flight Center

HBCU .....Historically Black Colleges and Universities
HBZ.....HUB Business Zone
HQ.....Headquarters
HSPD .....Homeland Security Presidential Directive
HUBZone.....Historically Underutilized Business Zone
IAT.....Integration, Assembly, and Test
ICD.....Interface Control Document
IRD.....Interface Requirements Document
ISAS.....Institute of Space and Astronautical Science
I&T.....Integration and Test
ITAR .....International Traffic in Arms Regulations
IV&V .....Independent Verification and Validation
JPL .....Jet Propulsion Laboratory
JSC.....Johnson Space Center
KDP.....Key Decision Point
LaRC.....Langley Research Center
LEGS.....Lunar Exploration Ground System
LRD.....Launch Readiness Date
LSP.....Launch Service Provider
LSPIS.....Launch Service Provider Information Summary
LV .....Launch Vehicle
MA.....Mission Assurance
MADCAP .....Multi-mission Automated Deepspace Conjunction Assesssment Process
MAIP.....Mission Assurance Implementation Plan
MCO .....Mission Commitment Office
MCR.....Mission Concept Review
MDAA .....Mission Directorate Associated Administrator
MDRA.....Mission Design Requirements Agreement
MEL .....Master Equipment List
MEV.....Maximum Expected Value
MGSS.....Multi-mission Ground Systems and Services
MMRTG .....Multiple Mission Radioisotope Thermoelectric Generator
MOC .....Mission Operations Center
MOCS .....Mission Operations and Communications Services
MO&DA .....Mission Operations and Data Analysis
MOS.....Mission Operations Services
MOU .....Memorandum of Understanding
MPV.....Maximum Possible Value
MRPP.....Mission Resilience and Protection Program

MTM.....Mission Traceability Matrix
NASA.....National Aeronautics and Space Administration
NASA-STD....NASA-Standard
NEPA.....National Environmental Policy Act
NFS .....NASA FAR Supplement
NFS .....Nuclear Flight Safety
NID .....NASA Interim Directive
NISN .....NASA Integrated Services Network
NLS.....NASA Launch Services
NODIS .....NASA Online Directives Information System
NOI .....Notice of Intent
NPD.....NASA Policy Directive
NPR.....NASA Procedural Requirements
NRA .....NASA Research Announcement
NRC .....National Research Council
NRESS .....NASA Research and Education Support Services
NRP.....NASA Routine Payload
NSF .....National Science Foundation
NSN.....Near Space Network
NSPIRES.....NASA Solicitation and Proposal Integrated Review and Evaluation System
NSS .....NASA Safety Standard
OCAP.....Orbital Collision Avoidance Plan
OCE.....Office of the Chief Engineer
OCFO.....Office of the Chief Financial Officer
OCI.....Organizational Conflict of Interest
ODAR.....Orbital Debris Assessment Report
OMI.....Other Minority Institution
ORR .....Operations Readiness Review
OSMA.....Office of Safety and Mission Assurance
OSS .....Office of Space Science
OSTP.....Office of Science and Technology Policy
PDF .....Portable Data Format
PDR.....Preliminary Design Review
PEA.....Program Element Appendix
PI.....Principal Investigator
PIC .....Procurement Information Circular
PIMMC .....Principal Investigator-Managed Mission Cost
PLRA .....Project Level Requirements Agreement
PM.....Project Manager

PMC .....Program Management Council
PMW .....Potential Major Weakness
PNT .....Position, Navigation, and Timing
POC.....Point of Contact
PPP.....Project Protection Plan
PS .....Project Scientist
PSD .....Program Specific Data
PSE.....Project Systems Engineer
REC.....Record of Environmental Consideration
RF.....Radio Frequency
RFP .....Request for Proposal
RHU .....Radioisotope Heater Unit
ROD .....Record of Decision
ROM .....Rough Order-of-Magnitude
ROSES .....Research Opportunities in Space and Earth Sciences
RPS .....Radioisotope Power System
R&R .....Recruitment and Retention
RTG.....Radioisotope Thermoelectric Generator
RUG .....Rideshare User's Guide
RY .....Real Year
SALMON.....Stand Alone Missions of Opportunity Notice
SAM.....System for Award Management
SB.....Small Business
SC.....Student Collaboration
SCaN .....Space Communications and Navigation
SCG.....Security Classification Guide
SDB.....Small Disadvantaged Business
SDVOSB.....Service-Disabled Veteran Owned Small Business
SE.....System Engineer(ing)
SEO .....Science Enhancement Option
SI.....International System of Units
S&MA.....Safety and Mission Assurance
SME .....Subject Matter Expert
SMEX .....Small Explorer
SMD.....Science Mission Directorate
SMP.....Software Management Plan
SN .....Space Network
S/N .....Signal to Noise
SOC.....Science Operations Center

SOMA.....Science Office of Mission Assessments
SOW.....Statement of Work
SPA .....Secondary Payload Adapter
SPASE.....Space Physics Archive Search and Extract
SPD .....SMD Policy Document
SPG .....Strategic Planning Guidance
SRR.....System Requirements Review
SSMS .....Safety, Security, and Mission Services
SSP.....System Security Plan
STDT.....Science and Technology Definition Team
STEM.....Science, Technology, Engineering and Math
STI.....Scientific and Technical Information
STM .....Science Traceability Matrix
STP.....Solar Terrestrial Probe
TA .....Technical Authority
TAA .....Technical Assistance Agreement
TDO .....Technology Demonstration Opportunity
TMC.....Technical, Management, and Cost
TPM .....Technical Performance Metric
TRL .....Technology Readiness Level
UARC .....University Affiliated Research Center
URL.....Uniform Resource Locator
U.S. .....United States
U.S.C.....United States Code
VADR.....Venture-Class Acquisition of Dedicated and Rideshare
VOSB.....Veteran Owned Small Business
WBS.....Work Breakdown Structure
WOSB.....Women Owned Small Business
WYE .....Work Year Equivalent