



Criteria and Requirements for the Phase A Concept Study

Earth System Explorers Program

2023 Earth System Explorers (ESE)

~~Version 0~~

Revision A

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**ESE ANNOUNCEMENT OF OPPORTUNITY (NNH23ZDA0160)
CRITERIA AND REQUIREMENTS FOR THE
PHASE A CONCEPT STUDY**

INTRODUCTION

As the outcome of the 2023 Earth System Explorers (ESE) Announcement of Opportunity (NNH23ZDA0160, hereafter, the “AO”) Step-1 competition, NASA has selected four ESE investigations that the Agency will fund to perform Concept Studies in Step 2. 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 2023 ESE Program Library at <https://explorers.larc.nasa.gov/2023ESE/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. Proposers 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, 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 nine months after the Concept Study Kick-Off Meeting (see below). This CSR Criteria & Requirements (C&R) document provides 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:

	ESE AO Requirement Description	ESE AO Section	ESE AO Requirement	Concept Study Reference
1	Costing of Conjunction Assessment Risk Analysis	4.6.4	-	Requirement CS-115
2	Science Enhancement Option (SEO) or its cost, if proposed	5.1.6	14, 15	Requirement CS-29
3	NOAA Operational Enhancement Opportunity	5.1.8	16, 17	Requirement CS-94, Requirement CS-95
4	Demonstration of maximum channel bandwidth	5.2.7	37	Requirement CS-41
5	Discussion of critical event coverage capabilities	5.2.6	41	Requirement CS-41
6	Detailed plan for orbital debris and disposal <i>Note that an Orbital Collision Avoidance Plan (OCAP) must be completed by Preliminary Design Review (PDR).</i>	5.2.10	43, B-63 to B-66	Appendix L.9
7	Mission Operations Tools and Services: Non-AMMOS (Advanced Multi Mission Operations System) system use and description	5.2.11	44	Appendix L.25 Requirement CS-130
8	Cybersecurity: Ground system data flow diagram	5.2.13	46	Requirement CS-125
9	Naming of Project Manager (PM) and Project Systems Engineer (PSE)	5.3	54, 55	Requirement CS-56
10	Risk management approach	5.3.6	58, 59	Requirement CS-57, Requirement CS-58
11	Requirements for real year dollar costs	5.6.2	B-13, B-49, B-50	Requirement CS-77, Cost templates
12	Discussion of cost estimate error and uncertainty	5.6.3	76	Requirement CS-75
13	Data Management & Software Management Plan	J.7	B-60, B-61, B-62	Requirement CS-103, Requirement CS-104, Requirement CS-105, Appendix L.5

Table 1. Deferred Step 1 Items Required for Step 2

Electronic versions of CSRs and all required and optional files are due to the ESE Program Scientist, Thorsten Markus (email: Thorsten.markus@nasa.gov), via the NASA Box service by 4 p.m. Eastern time on **June 17, 2025** (~12+ months from Step-2 Kickoff date) (**Amended 3/17/2025**). Electronic submission requires the utilization of 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 CSRs through *Box*, investigation teams must provide an email list of no more than three (3) individuals requiring access to *Box* to submit proposals. This email list must be provided to the Program Scientist no less than seven calendar days before the CSRs are due. Individuals on the list will then receive an emailed invitation with a secure link to *Box* from NASA. Investigation teams are encouraged to submit a test file using the secure link to *Box* to ensure functionality prior to CSR submittal.

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 down-selection decision.

For each investigation selected in Step 1, the Earth System Explorers Program Office at the NASA Goddard Space Flight Center (GSFC) will issue a Request for Proposal (RFP) for Phase A and a Phase B Bridge option. The Phase B Bridge option will cover the first five months of Phase B. The option will be exercised for investigations down-selected for implementation. The organization will have 30 days to respond to the RFP with a detailed, certified proposal for Phase A and the Phase B Bridge.

The focus of the Phase B Bridge that will be exercised for the down-selected investigation(s) is:

1. Participation in the project kick-off meeting with the ESE Program Office;
2. Work performed with the ESE 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 five months of Phase B.

New contracts for all Study Teams will be negotiated during the Phase-B bridge and will cover the remaining lifecycle cost (Phase B – Phase F).

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 must be a self-contained document.

The CSR evaluation process will include Site Visits (either in person, virtual, or hybrid) by the evaluation team to each Concept Study Team's chosen site to hear oral briefings and, if needed, to receive updates and clarification of material in the CSRs. These Site Visits 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 Concept Study Team respond to these either prior to, during, or after the Site Visit. Any additional information provided to NASA by the Concept Study Team will be considered during the evaluation and treated as updates and clarifications to the CSR.

Concept Study 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 PI and their team, to ensure that they are accurate and that they will satisfy NASA requirements. Concept Study Teams are also responsible for assuring 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 two ESE investigations into the subsequent phases of mission development for flight and operations (*i.e.*, Phases B-F). The target date for this continuation decision (*i.e.*, “down-selection”) is Fall 2025.

Upon the down-selection decision, NASA will execute the Bridge Phase option and begin to provide Phase B funding for the project(s) that is(are) 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.

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 Sections 7.2.1 through 7.2.4 of the AO, apply fully to CSRs **if not amended in this document [Amended in Rev A]**. 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 small business subcontracting, will also be evaluated. In case of conflict between the AO and the C&R, the C&R requirements take precedence. New subfactors and details added to Step-1 AO factor definitions are highlighted using *blue italicized* text for the evaluation of the CSR. Items deleted from Step-1 AO factor definitions are highlighted using ~~struck through text~~ below.

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 (RFI).

Each CSR must be a self-contained document and must not refer to information contained in the Step-1 proposal. 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:

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

Scientific Merit of the Proposed Investigation (Form A)

The ESE 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 will convene a peer review panel to re-evaluate the scientific merit of the objectives 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).

Scientific Implementation Merit and Feasibility of the Proposed Investigation (Form B)

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 are highlighted below using blue italicized text for the evaluation of the CSR.

- 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, *including details on data collection strategy and plans*; 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 (OSDMP) ~~and~~ *including Data Analysis plan, Data Management Plan (DMP), Software Management Plan (SMP), and Open Science Plan (OSP)*. 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 and societal applications communities. 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 communities; *assessment of societal applications of the mission data, a plan to engage users to facilitate feedback on mission products pre-launch, and accelerate the use of mission products post-launch to inform decisions, and budget adequacy to implement these activities*; 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.

Details regarding the plan for Societal Applications are given in Section E.6

- Factor B-4. Science resiliency. This factor includes both developmental and operational resiliency. Developmental resiliency includes the approach to descope 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 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. **This factor is not applicable to this solicitation in Step 2. [Amended in RevA]**

Factor A-3 of the AO will also be re-evaluated as a factor for Scientific Implementation Merit and Feasibility; it has been renumbered as Factor B-7 below.

- Factor B-7. Likelihood of scientific success. This factor includes how well the anticipated measurements support the goals and objectives; the adequacy of the anticipated data to complete the investigation and meet the goals and objectives; and the appropriateness of the mission requirements for guiding development and ensuring scientific success.

Two new evaluation Factors B-8 and B-9 are not described in the AO, and therefore were not evaluated for Step-1 proposals. These new factors will be evaluated for the CSRs in addition to the factors specified in AO Section 7.2.3 (repeated or updated above as Factors B-1 through B-7).

- Factor B-8. *Maturity of proposed Level 1 science requirements and Level 2 project requirements. This factor includes assessment of whether the Level 1 science requirements are mature enough to guide the achievement of the objectives of the Baseline Mission and the Threshold Mission, and whether the Level 2 requirements are consistent with 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 the 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 to determine 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-9. *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.*

Details of evaluations of SEOs are given in Section E.6.

TMC Feasibility of the Proposed Mission Implementation (Form C)

All of the Technical, Management, and Cost (TMC) Feasibility 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.*

- 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*. 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, *as applicable*.
- 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 and *ground systems, operational scenarios and timelines for each mission phase, operations team roles and responsibilities*, and navigation/tracking/trajectory analysis), 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. 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 ~~those~~ *backup* plans to ensure success of the ~~investigation~~ *mission* when systems having a TRL less than 6 are proposed. The maturity and technical readiness of the spacecraft, ~~and~~ *and* ~~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.

Note that the risk management aspects of AO Factor C-4 have been removed from Factor C-4 and included here in a new evaluation Factor C-6. The text deleted from AO Factor C-4 is the basis for the new Factor C-6.

- 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 spaceflight experience of ~~any~~ *the PI, PM, PSE, and all other* named Key Management Team members; ~~the expected commitment, qualifications and experience of the Key Management Team members not named;~~ *and 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 mission, including contributions. ~~Also evaluated under this factor is the adequacy of the identified risks, 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 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, 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, along with the effect of the small business subcontracting plan including small disadvantaged businesses.*
- 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, *the methods and rationale used to develop the estimated cost*, the discussion of cost risks, the adequacy and allocation of cost reserves by phase, and the scope of work (*covering all elements of the mission, including contributions*). 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. If the project proposes any significant spending prior to KDP-C (Confirmation), the rationale/justification for this spending must also be detailed.*

Three new evaluation Factors C-6, C-7, and C-8 are not described in the AO and therefore were not evaluated for Step-1 proposals. These new factors will be evaluated for the CSRs in

addition to the factors given in AO Section 7.2.4 (repeated or updated above as Factors C-1 through C-5).

- *Factor C-6. Adequacy of the risk management plan.* The adequacy of the ~~identified~~ *proposed risks 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.*

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. The completeness of Phase B plans and the adequacy of the Phase B approach will be assessed. 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) will also be included in the factors above. Details of the SEO evaluations are given in Section E.6 and Section J.

The panel evaluating the ~~third evaluation criterion~~, TMC Feasibility of the Proposed Mission Implementation criterion will also provide comments to NASA regarding the bulleted items below. While these comments will not be considered in the evaluation, they may be considered during *down*-selection.

- The extent to which the proposed investigation provides career development opportunities to train the next generation of engineering and management leaders.
- Programmatic risk for which examples include but are not limited to stability and reliability of proposed partners and their contributions, the size and nature of contributions, environmental assessment approvals, and late/non-delivery of NASA-provided project elements.

Merit of the Small Business Subcontracting Plans and National Oceanic and Atmospheric Administration (NOAA) Operational Enhancement Opportunity (OEO)

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 Small Business Subcontracting Plans. 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.

Merit of the NOAA Operational Enhancement Opportunity. Shortly after ESE down-selection, NOAA intends to review the OEO concept, if proposed, and decide, with NASA support, whether to request a sole source Request for Proposal (RFP) for the OEO as a modification to the NASA ESE contract, subject to any legal requirements applicable to such a transaction. The evaluation criteria for the OEO sole source proposal will be established at the time of the request for a sole-source OEO proposal, as the criteria may vary depending on the nature of the OEO. NOAA and NASA reserve the right to accept or decline proposed OEO activities at any time during the mission. As these activities are optional and are not included within the baseline investigation, the science enabled by OEO activities is not considered part of the scientific merit of the proposed investigation nor can the OEO science be necessary to achieve the proposed ESE investigation objectives. These OEO concepts and activities will not be part of the body of the ESE CSR and will not be part of NASA's down-selection criteria for ESE.

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 will be evaluated as a separate factor 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.

At the Step-2 down-selection, the Selection Official may consider a wide range of programmatic factors in deciding whether to select any proposals and in selecting among top-rated proposals, 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 a 2023 ESE 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.

GENERAL REQUIREMENTS

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 proposer's discretion but see Requirement CS-4 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 (*i.e.*, no more than 15 characters per horizontal inch; six characters per horizontal centimeter). There is no minimum requirement for fonts used within figures and tables, but all text in figures and tables shall be legible; fonts smaller than 8-point are often illegible.

Requirement CS-4 The CSR shall conform to the page limits specified in the CSR Structure and Page Limits table. A page quota higher than that in the Step-1 proposal has been allotted to accommodate an expected greater maturity of detail.

- Two extra pages each 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);
- Five extra pages are allotted for all science enhancement options (SEOs), in the Science Implementation Section, if proposed;
- **Not applicable [Amended in Rev A]**; and
- Five extra pages are allotted for the Societal Applications.

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. Pages allocated for the proposed SEOs, OEOs, and Societal Applications 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 20 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-50 and Requirement CS-77), 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

Requirement CS-5 The CSR and all required and optional files shall be submitted electronically by the deadline specified in the INTRODUCTION section via the NASA *Box* service, which is FIPS 140-2 certified, with Advanced Encryption Standard (AES) 256-bit encryption at rest and in transit. CSR submitters will be provided with details regarding use of the NASA *Box* service before the CSR Submittal. To submit CSRs through *Box*, investigation teams 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 seven calendar days before the CSRs are due. Individuals on the list will then receive an emailed invitation with a secure link to *Box* from NASA. Investigation teams are encouraged to submit a test file using the secure link to *Box* to ensure functionality prior to CSR submittal.

Requirement CS-6 The CSR shall be unlocked, bookmarked, searchable Adobe Portable Document Format (PDF) file(s) composed of the main CSR, all tables, and all applicable CSR appendices (see Section L). A 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 balance of the CSR and appendices. 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 permitted.

Requirement CS-7 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-11)
- Trajectory file(s), if applicable (Requirement CS-36 and Requirement CS-37)
- Fact Sheet in PDF format (Requirement CS-16)
- Schedule in MS-Project format Requirement CS-51)
- Master Equipment List (MEL) in MS-Excel format (Requirement CS-117)
- Program and Project Management Standard References (Requirement CS-132)
- Cost Tables in MS-Excel format (Requirement CS-79 and Requirement CS-91)
- Any additional cost data to assist in validation, if applicable (See Section L.16 of this document)
- Optional NOAA OEO (Requirement CS-94 and Requirement CS-95), in format as specified in Requirement CS-1 through Requirement CS-6

Requirement CS-8 CSRs written in their entirety by non-government institutions are not mandated to follow CUI marking instructions. However, CSRs that are written fully or partially by government institutions are required to 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. 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-9 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 Investigation Summary Information):

“The information (data) contained in [insert page numbers or other identification] of this proposal 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.”

An example demonstrating the red-bordered box marking is shown in the CUI_Portion_Marking_Sample.pdf document in the Program Library.

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.

Requirement CS-10 Materials identified as subject to U.S. export laws and regulations, in accordance with Section 5.8.3 of the AO, shall be redacted into separate versions of files that are collected in a Redacted folder.

Requirement CS-11 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 the Concept Study Team is proposing to provide work should the mission be down-selected. Additionally, 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 shall be provided. A draft list of the participants as a Microsoft Excel spreadsheet document shall be provided to the point-of-contact (AO Section 6.1.5) three months prior to the due date of the CSR. Use the Microsoft Excel spreadsheet template that has been posted to 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-12 The Concept Study Team shall create a separate document that contains a table with all of the requirements (Requirement CS-1 through Requirement CS-133) 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 along with the CSR submission.

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

A. GRAPHIC COVER PAGE AND INVESTIGATION SUMMARY

Requirement CS-13 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-14 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; and
- The name and title of an official who is authorized to commit the proposing organization through the submission of the CSR;
- 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 (or none).

Requirement CS-15 The following Summary Information shall be included in this Section:

- Names and institutions of all participants in the investigation;
- The Enhanced PI-Managed Mission Cost of the investigation (\$FY2024);
- The proposed contributions and contributing organizations, and
- A summary of the investigation, not to exceed 300 words. The Proposal Summary shall not contain proprietary or confidential information that the submitters wish to protect from public disclosure.

B. FACT SHEET AND EXECUTIVE SUMMARY

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

- Science objectives (including the importance of the science to the program science goals);
- Mission overview;
- Instrument complement;
- Key spacecraft characteristics;
- Project management and participating organizations (including teaming arrangements and all named key personnel);
- Schedule summary;

- The proposed PIMMC in Real Year dollars (RY\$) and in Fiscal Year 2024 (FY24) dollars from cost tables based on Cost Table Templates 3a and 3b respectively; and
- The proposed Total Cost, including a breakdown of any contributed costs by contributing organization, in RY\$ and in FY24\$ from the table based on Cost Table Template 1.

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, and small business subcontracting plans.

C. CSR TABLE OF CONTENTS

Requirement CS-18 Every CSR shall contain a Table of Contents that parallels the outline provided in Sections D through Requirement CS-93 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) 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-15 through B-18 in Appendix B of the AO. If there are no changes from the Step-1 proposal, including no Form A 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 from the Step 1 Form A PMW clarification responses must be incorporated in the Science Investigation section (See Requirement CS-20).

Requirement CS-20 Any changes to the Baseline and Threshold Science Investigations defined in the Step-1 proposal shall be clearly identified and the rationale for the change(s) provided. Such changes to the science investigation shall be highlighted in bold or a color with column marking for easy identification. In addition, a change matrix shall be provided as an appendix (see Section L.17 of this document). The science change matrix shall contain, at a minimum:

- The original (proposed) science objectives
- Any new or deleted science objectives
- Any change made to the baseline investigation science objectives, or to the text of Section D that supports those objectives;
- Any change made to the threshold investigation science objectives, or to the text of Section D that supports those objectives;
- Any change made to the Science Traceability Matrix (STM), or to the text of Section D that supports the STM requirement flow-down;
- Rationale for the changes; and
- Locations within the CSR.

Corrections (*e.g.*, typos and errors) and nominal updates (*e.g.*, revised references, clarified sentences) to this section, that do not constitute a change to the proposed science investigation

(e.g., no change to science mission objectives, requirements, implementation details, measurements and data, etc.) are not required to be individually identified and tracked; however, a summary of such changes shall be provided.

Step 1 Form A PMW clarifications shall be incorporated appropriately throughout Section D of the CSR and identify that they were provided in Step-1 (i.e., not new changes in Step-2). This includes PMW clarifications that have changed or been superseded by Phase A study results. Rationale for why the clarification has been changed or superseded must be provided. The Step 1 Form A PMW clarifications must be identified using different methods from any new Step 2 Phase A changes. The proposer can color code text, highlight using a specific color, highlight in bold, column mark, or use any combination to identify the PMW clarification responses. An identification key must be provided. If the Step 1 Form A PMW clarification response affects any of the science objectives it must be included in the change matrix described above.

E. SCIENCE IMPLEMENTATION

E.1. Level 1 and Level 2 Requirements

The Level 1 requirements identify the mission, science, and programmatic requirements as well as constraints imposed on the project. Consistent with NPR 7120.5, both baseline and threshold requirements are to be described. Baseline Science Requirements are the mission performance requirements necessary to achieve the full science objectives of the investigation. Threshold Science Requirements are those mission performance requirements necessary to achieve the minimum science acceptable for the investment.

The Level 1 requirements (referred to as program level requirements in NPR 7120.5) and Level 2 requirements (project level requirements) specify requirements and constraints on science data collection, mission and spacecraft performance, prime mission lifetime, budget, schedule, access to space, and any other requirements or constraints that need to be controlled. The Level 2 requirements flow down from the Level 1 requirements. For example, Level 2 science requirements must describe the data products that would be needed to complete the Level 1 science requirements. The Level 1 requirements provide the criteria to be used to evaluate whether a project should be called for a termination review if it appears it might fail to meet its requirements.

Examples of Level 1 requirements can be found within the Program Level Requirements Appendix (PLRA) documents in the Program Library, and examples of Level 2 requirements can be found within the Mission Definition Requirements Agreement (MDRA) documents, along with presentation slides on Level 1 and Level 2 requirements given at the PI Masters Forums (<https://soma.larc.nasa.gov/pi-masters-forums/>).

Requirement CS-21 CSRs shall provide a set of proposed Level 1 requirements that will achieve the objectives of the Investigation. Both Baseline Science Requirements and Threshold Science Requirements shall be identified. The Level 1 science requirements shall be clearly traceable to the science objectives. The CSR shall provide Level 2 requirements to guide the design and development 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 mission science objectives. State each requirement in unambiguous, objective, quantifiable, and verifiable terms. Requirements shall not conflict with each other. 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, 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, 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:

- Mass; broken out at major subsystem level breakouts (*e.g.*, electronics, detectors, and optics);
- Viewing direction(s) in body coordinates;
- Pointing accuracy and stability requirements;
- Operational modes;
- Operational mode timeline;
- Data demand for each instrument operational mode;
- Onboard data processing and storage required from spacecraft;
- Power demand for each instrument operational mode including peak, average, and stand-by power;
- Instrument thermal control capability;
- Applicable instrument diagrams (*e.g.*, optical path); and
- Characteristics of relevant instrument components (*e.g.*, listing of size of optics) in the MEL.

E.4. Data Analysis and Data Sufficiency

Requirement CS-25 A Data Analysis Plan including approaches for data retrieval and algorithm development, validation, preliminary analysis, image processing, calibration and correction 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.

Requirement CS-26 This section shall demonstrate the degree to which the proposed instruments and mission can provide the necessary data to achieve science objectives, and demonstrate the sufficiency of the data (quality, quantity, *etc.*) gathered to complete the scientific investigation. The flow-down from science investigation goals to measurement objectives and instrument performance shall be stated clearly and supported by quantitative analysis.

Requirement CS-27 This section shall provide a discussion of all plans (schedules, costs, and deliverables) and their approach and commitment to delivering project data to the appropriate NASA data archives, and indicate such in the plans and schedules for Phase B. This discussion shall also provide assurance that all activities have been considered and included with separate allocation and budgeting of appropriate resources.

Additional requirements for OSDMP are discussed in section L.5.

E.5. Science Team

Requirement CS-28 This section shall identify each key member of the science team 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 science team members shall be explicitly defined, the necessity of that role shall be justified, and the funding source (NASA or contributed) for each science team member shall be noted. The role of each collaborator shall be described and justified. A summary table shall be included, with columns for:

1. Science team member name;
2. Their roles and responsibilities on the mission; and
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-85 to Requirement CS-91).

E.6. Plan for SEO

Requirement CS-29 If an SEO is proposed, this section shall define and describe plans for the proposed activities (see AO Section 5.1.6). 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. The SEO shall support the NASA Earth Science to Action Strategy, promoting integration of innovation, scientific discovery, and emerging user needs to accelerate the use of Earth science and enable solutions that generate the science-based decision support information needed by users. Additionally, a justification and a cost plan for SEO activities are required in Section J of this document.

E.7. Plan for Societal Applications

Per the AO, proposals are required to articulate, to the extent possible, potential innovative and practical applications of the mission data (aka, societal applications) and a plan to engage those users that would use mission data to inform their decisions and actions. Proposers are referred to the AO as well as the NASA SMD ESD *Directive on Project Applications Program* (2016) in the Program Library for further information. NASA recognizes that, in some science investigations, societal applications are not possible. In such cases, the proposer is required to explain and justify why there is no application dimension to the investigation.

Requirement CS-30 The proposal shall describe: (a) innovative and practical societal applications of the data that will be collected and disseminated; (b) how users will be engaged; (c) how the project will adapt to new societal applications opportunities that may emerge; (d) how the project will coordinate societal applications activities with NASA; and (e) a budget for the implementation of the activities listed above. Proposers should clearly differentiate between the societal applications activities that will be conducted as part of their investigation versus those that others might pursue using data collected by their investigation. If it is not possible to identify societal applications, the proposer shall justify why there is no application dimension to the investigation.

F. MISSION IMPLEMENTATION

F.1. General Requirements and Mission Traceability

Requirement CS-31 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-32 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, shall be provided 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), 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-33 Designs for all elements of the mission shall be described in sufficient detail to demonstrate that the mission 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, mission operations, and any additional elements. It shall also discuss environmental effects, such as radiation, temperature, and contamination, on the flight systems.

Requirement CS-34 **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.

- Launch or delivery readiness date;
- Launch window, and launch or delivery date flexibility;
- Mission duration;
- 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;

- Critical events, which includes LV separation telemetry;
- Telecomm link summary for all communication modes (based on requirements identified in Appendix L.18, *Communications Design Data*);
- Ground station(s) usage (*e.g.*, location(s) and transmitting and receiving communication parameters); and
- Space systems fault management approach and design.

Requirement CS-35 Launch Services and Launch Vehicle Compatibility: For AO-provided launch services, compatibility with the proposed launch vehicle shall be demonstrated by providing in the appropriate CSR section the 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 nonstandard 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.

ESE 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. ESE Phase A Concept Study teams should work with Hamilton Fernandez, Mission Manager, hamilton.fernandez@nasa.gov, for Launch Services Program support.

Requirement CS-36 Trajectory for non-Electric Propulsion: For any investigation that will perform Phase E operations beyond Geostationary Earth Orbit (GEO) to achieve its science orbit, the following information shall be provided in Appendix L.26 in the CSR. 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).

- Checkout Duration: The minimum duration allocated after launch before the primary propulsion system will be commanded to provide required delta-V.
- Initial Mass Assumptions: Provide the initial mass used for generation of the trajectories including propellant loading assumptions.
- 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.
- 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.

Any other trajectory specific information not called out above that would be relevant to reviewers attempting to validate the trajectory should also be included.

Requirement CS-37 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).

- Checkout Duration: The minimum duration allocated after launch before the primary propulsion system will be commanded to provide required delta-V.

- Initial Mass Assumptions: Provide the initial mass used for generation of the trajectories including propellant loading assumptions.
- 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.
- 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.
- Assumed Engine Duty Cycle: Provide the overall Duty Cycle for the EP engines and if applicable provide the duty cycle over each trajectory segment.
- 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.
- 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, should also be included.

Requirement CS-38 Flight System Capabilities: This section shall address the following flight system capabilities 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. Note that the heritage of the components and subsystems are to be discussed in Appendix L.12.

1. Spacecraft Parameters:

- Figure of the complete spacecraft/instrument system on the launch vehicle and in flight, with major components labeled and approximate overall dimensions.
- 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:

- Propulsion, including:
 - a) A list of all specific events of the proposed delta-V budget (including 3-sigma values for stochastic maneuvers);
 - b) For each propulsion mode type (monopropellant, bi-propellant, dual-mode, solar electric, etc.), engines and thrust levels, and specific impulse;
 - c) Propellant allocation (impulse vs. attitude control system); and
 - d) Propellant margins, including nominal (to meet delta-V requirement) and additional (to meet mass growth).
- Command and Data Handling, including:
 - a) Spacecraft housekeeping data rates for nominal and safing strategy;
 - b) Data storage unit size (Mbits); and

- c) Maximum storage record and playback rate.
- Power
 - Solar-powered missions:
 - a) Expected power requirement and margins for each operational mission phase;
 - b) Type of array structure (rigid, flexible, body mounted);
 - c) Solar array axes of rotation (vector projected in spacecraft coordinates);
 - d) Array size;
 - e) Solar cell type and efficiency;
 - f) Expected power generation at Beginning of Life and End of Life;
 - g) Worst case Sun incidence angle to solar panels for each mission phase;
 - h) Battery type and storage capacity;
 - i) Phased and worst-case battery Depth of Discharge (DOD); and
 - j) Spacecraft bus voltage.
- Attitude Determination and Control, including system pointing requirements and capabilities. Describe or define the following:
 - a) Each spacecraft operational mode, including the sensors and actuators used, control method, and safing and/or contingency modes;
 - b) Attitude determination methodology and estimate of accuracy, including identifying whether ground post-processing is required to meet science needs;
 - c) Agility requirements for slews or scanning;
 - d) Appendage pointing requirements, including articulation control methods and deployment accommodations;
 - e) Sensor selection and performance, including identifying mounting location and field-of-view (FOV);
 - f) Actuator selection and sizing, including identifying mounting location(s);
 - g) Translational maneuver (ΔV) control and accuracy;
 - h) Momentum management approach and mitigation of impacts on navigation accuracy, if applicable;
 - i) On-orbit calibrations, if required, including expected accuracy; and
 - j) Attitude control requirements for the spacecraft pointing control, pointing knowledge (at the instrument interface), pointing stability, or jitter.
- Thermal control, including:
 - a) Temperature requirements including allowable temperature ranges;
 - b) Temperature control approach (*i.e.*, passive vs. active);
 - c) Cooling loads; and
 - d) Special thermal design considerations (*e.g.*, cryogenic instrument requirements).
- Structures, including:
 - a) Requirements;
 - b) Governing load cases and margins;
 - c) Chosen materials; and
 - d) Their qualification testing.
- Flight software, including:

- a) 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;
- b) Provide the logical lines of code by Computer Software Configuration Item (CSCI) and the basis for these estimates;
- c) A description of the functionality for each CSCI;
- d) Code counts categorized as either New, Modified, Full Reuse, or Autogenerated;
- e) Development method (spiral, waterfall, agile, *etc.*);
- f) The development approach for any major new algorithms to be incorporated in the flight software; and
- g) The approach for interface management and plans for software verification and validation.

Requirement CS-39 Additional Mission Elements: This section shall address any other major mission elements (*e.g.*, lander, 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-40 Flight System Contingencies and Margins: This section shall summarize contingencies and margins of all key flight systems resources. It shall provide the proposer'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:

- Dry mass;
- Launch mass useable by the proposed mission;
- Propellants;
- Power (including energy storage);
- CPU utilization;
- Data (including storage and downlink volume);
- Attitude control; and
- Any other driving mission element requirements derived from the Key Driving Requirements.

See the table following Requirement B-33 of the AO for definitions of contingency and margin.

Requirement CS-41 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 investigation. Any additional elements that are applicable to explaining the mission operations and demonstrating their feasibility shall also be addressed. This section shall provide, at a minimum, the following items:

- Description of ground systems and facilities, including supporting ground software at the Mission Operations Center (MOC) and at the Science Operations Center (SOC) required for development, testing, and operations;

- Telecommunications, Tracking, and Navigation including:
 - a) Downlink information and data volume;
 - b) Uplink information;
 - c) For all transmit and receive modes, provide mode timeline, data rate(s), durations, and compliance with maximum channel bandwidth; and
 - d) Ground network utilization plan including ground stations, downlink parameters (frequencies, periods, capacities, margins, *etc.*), and retransmission capability;
- Description of approach for acquiring and returning critical event data, including clear identification of procurement and costing for supplemental resources (*e.g.*, mobile ground stations) if such are needed;
- Operations plan, including a *quantitative discussion* of nominal sequence planning and commanding showing the ability of the Mission Operations System (MOS) 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, team training, availability of spacecraft experts for operations, operations center development; and
- 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 events and spacecraft/payload events for key mission phases;
 - b) Timelines for each key mission phase; containing Spacecraft, Payload, and ground events and processing and identifying margin for each phase if available;
 - c) Data flow diagrams which clearly show the major operational facilities and key software components utilized for both the uplink and downlink processes;
 - 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;
 - e) An 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;
 - f) A plan for required maintenance and refresh of vendor supplied ground systems (hardware and software) during extended cruise operations;
 - g) 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; and
 - h) Interface between the Flight Operations Team and the Conjunction Assessment Risk Analysis (CARA) team at NASA Goddard Space Flight Center (GSFC).

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-42 This section shall provide a clear statement of NASA SCA_N networks (Deep Space Network [DSN], Near Space Network [NSN]) support requirements in tabular format, showing 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 in hours, number of passes each week, and the number of weeks for which this support is required.

Proposers should be advised that SCA_N intends to migrate away from use of Tracking and Data Relay Satellite Services (TDRSS) and is actively working to validate commercial alternatives. No new mission will be allowed using TDRSS. Missions that are considering proposing specialized services previously offered by TDRSS, such as demand access services, should work with SCA_N to understand the potential commercial service alternatives.

F.3. Development Approach

Investigation teams 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-43 This section shall describe the development plan. This description shall include the following items:

- 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;
- Identification of instrument-to-spacecraft interfaces;
- A description of how the interface management process will be developed and maintained;
- Discussion of fault management approach and design;
- Identification of any special or unique implementation/interfaces for supplemental resources that may have been added for critical event coverage;
- Roles and responsibilities for the interface management process as specified in NPR 7123.1;
- Essential trade studies completed in Phase A, including considered options and conclusions;
- Essential trade studies to be conducted in Phase B, including considered options and driving requirements;
- 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;
- Descriptions of when contracts are required, the acquisition strategy, including any incentive strategy;

- Management and closure of action items, hardware discrepancies, test anomalies, *etc.*; and
- Plan for handling any special processes.

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

- Roles and responsibilities for the software management process—as specified in NPR 7150.2—and product development responsibilities;
- A description of how the flight and ground software will be developed and maintained;
- Software assurance approach;
- 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;
- Descriptions of when contracts are required, the acquisition strategy, including any incentive strategy;
- Description of static analysis to be used during the software development and testing; and
- Software coding standard to be used for each of the software programming languages being used on the project.

Requirement CS-45 This section shall describe the plan for mission assurance. 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.

Requirement CS-46 The CSR shall indicate any expected deviation(s) from the recommended requirements in the *Earth System Explorers Program Mission Assurance Requirements (MAR)* – Class C and in Appendix D of NPR 8705.4. Tailoring below the ESE MAR shall not be proposed.

F.4. New Technologies/Advanced Engineering Developments

Requirement CS-47 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:

- Identification and justification of the TRL for each proposed system (Level 3 WBS instrument 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, in the Program Library);

- 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*);
- Rationale for the stated TRL value of an element that is an adaptation of an existing element of known TRL;
- 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.
- An estimate of the resources (staffing, cost, and schedule) required to complete the technology and/or advanced engineering development; and
- 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.

If no new technologies or advanced engineering development is required, system TRL 6 or above at the time of CSR submission shall be clearly demonstrated.

F.5. Assembly, Integration, Test, and Verification

Requirement CS-48 An illustration and discussion of the time-phased flow of the Integration and Test (I&T) Plan shall be presented. It shall include the key facilities, testbeds, and team members involved in the I&T Plan.

Requirement CS-49 The project's assembly, integration, test, and verification (AIT&V) approach shall be described in this section. 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 can't 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. The AIT&V description shall demonstrate the credibility of the overall AIT&V approach, as reflected by consistency between the described 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.

F.6. Schedule

Requirement CS-50 A project schedule foldout(s) covering all phases of the investigation shall be provided to at least WBS Level 3 for the spacecraft elements (one level below the spacecraft), and Level 4 for instruments (one level below each individual 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:

- Spacecraft development, integration and test, and major review dates;
- Activities for advancement to TRL 6, and other key engineering development activities;
- Instrument development and major review dates, including instrument-to-spacecraft/host integration and test;
- Ground systems development and major review dates (*e.g.*, mission operations and data analysis development schedule);
- Major deliverables (*e.g.*, Interface Control Documents (ICDs), simulators, engineering models, flight models, *etc.*);
- Launch vehicle integration and launch readiness or delivery readiness;
- Compliance with National Environmental Policy Act (NEPA) and Nuclear Flight Safety processes, if appropriate;
- Long-lead item specifications, development paths, and their impacts to schedule;
- Development schedule for Science Enhancement Options (SEOs), if any;
- Schedule critical paths identification, including any significant secondary critical paths; and
- Funded schedule reserve, with indications of appropriate reserves associated with major milestones and deliverables, including allocated critical path reserves; and
- **Not applicable [Amended in Rev A].**

Requirement CS-51 The project schedule shall be additionally provided in Microsoft Project format along with the CSR submission. Although the project schedule foldout(s) in Requirement CS-50 does not need to have been generated in Microsoft Project, the project schedule file provided along with the CSR submission shall address the items specified in Requirement CS-50 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 are expected to be fully linked to their predecessor and successor tasks, and the level of linkage detail should support the assignment of the critical path in the graphical foldout. 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 I shall be included in the file.

G. MANAGEMENT

Requirement CS-52 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, PM, PSE, and other Key Management Team members shall be described. The commitments and the roles and responsibilities of all institutional team members shall be described.

Requirement CS-53 This section shall demonstrate how the proposed management plans, decision-making processes, tools (including performance measurement and reporting), and organization structure 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 if any, 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. Include a clear description of the methods and frequency of planned communication within the project team.

Requirement CS-54 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-55 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, shall be described. 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.

Requirement CS-56 This section shall name all of the team members who will occupy the key project management positions identified in Requirement CS-55. It shall, in addition:

- 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;

- Provide any program/project management certifications held by or planned to be obtained by the PM; and
- Address the role(s), responsibilities, commitments by phase, and percentage of time devoted to the mission for the PI, PM, PSE, and all other named Key Management individuals, and shall provide reference points of contact, including address and phone number, for each of these individuals.

Requirement CS-57 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. The Earth System Explorers Mission Assurance Requirements document, available in the Program Library, will also apply. Note that the MAR requires a ~~draft Mission Assurance Implementation Plan (MAIP)~~ and Compliance Matrix to be submitted with the CSR (see Section L.22 of this document). **Study Teams are required to use the ESE MAR Compliance Matrix template (provided in the ESE Program Library) as the basis for developing the proposed draft compliance matrix document for the CSR.**

[Amended in Rev A] Plans for using standard risk management tools, including probability and impact charts, risk lists, mitigation plans and triggers shall be described. The role(s) in the risk management process of each of the key management personnel shall be discussed.

Requirement CS-58 This section shall describe the project risks and project resiliency considering these risks and shall include the items below.

- The top risks considered significant by the project team, especially technical risks and risks associated with contributed hardware (if any) and potential mitigation strategies and associated schedule impacts. Provide 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. 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). To determine the cumulative effect of risks on resources, each impact shall be paired with a probability. The cumulative effect of the products of probabilities and impacts shall not reduce the resource below that necessary to achieve baseline science. 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-76). If resources for these risks have been included in the basis of estimate, indicate so. Reserves held to account for risks not shown in the basis of estimate shall be identified as encumbered reserves.
- Any potential descopes, including savings of resources (mass, power, dollars, schedule, *etc.*) by implementing descopes, the decision milestone(s) for implementing descopes, and the scientific impact.
- The risk resulting from any international contributions to the proposed investigation and potential mitigation strategies.

Requirement CS-59 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-60 This section shall include a discussion of the management approaches for controlling cost growth.

Requirement CS-61 A summary of reserves in cost and schedule shall be identified by mission phase, project element, and year, and the rationale for each shall be discussed. The specific means by which integrated costs, schedule, and technical performance will be tracked and managed shall be defined. Specific reserves and the timing of their application shall be described. Management of the reserves and margins, including who in the management organization manages the reserves and when and how the reserves are released, shall be discussed. This shall include the strategy for maintaining reserves as a function of cost-to-completion. All funded schedule margins shall be identified. The relationship between the use of such reserves, margins, potential descope options, and their effect on cost, schedule, and performance shall be fully discussed. When considering potential descope options, consider the investigation as a total system including instrument(s), spacecraft, ground system, launch services, and operations.

Requirement CS-62 This section shall clearly delineate the Government-furnished property, services, facilities, *etc.* required to accomplish all phases of the project.

Requirement CS-63 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.

NASA NPR 7120.5 establishes the requirements by which NASA formulates and implements space flight programs and projects. This document emphasizes program and project management based on life cycles, Key Decision Points (KDPs), and evolving products during each life-cycle phase.

Requirement CS-64 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.

Tailoring to NASA requirements described in NPR 7120.5 may be proposed by missions at any risk classification. Proposers shall 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. Note that these adjustments reflect potential modifications to the baseline investigation, to be addressed after down-selection.

Requirement CS-65 CSRs 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 panel evaluating the TMC Feasibility evaluation criterion will provide comments to the Selection Official on the proposed tailoring of the requirements in NPR 7120.5 and their justifications. These comments will not be considered for the TMC Feasibility risk rating but may be considered in the down-selection decision.

Requirement CS-66 The NASA FAR Supplement (NFS) places Earned Value Management (EVM) requirements on NASA contracts in clauses NFS 1852.234-2 and NFS 1834.201, amended by Procurement Class Deviation PCD 15-05. The requirements apply to all cost or fixed-price incentive contracts for development or production work, with specific levels of validated compliance with the ANSI/EIA-748 guidelines required for contracts above \$20M (RY) and for those above \$100M (RY). Full NFS compliance is required for all contracts.

For projects with a Life Cycle Costs (LCC) greater than \$250M (RY), NPR 7120.5 requires ANSI/EIA-748-compliant EVM for all portions of the work, including NASA in-house and contracted portions of the project. For projects with a LCC less than \$250M (RY), NPR 7120.5 makes EVM optional but only for the NASA in-house portion of the work.

Requirement CS-67 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-68 This section shall describe plans to retire risk due to uncertainty associated with contributions by the end of Phase A. It shall address:

- 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, Requirement CS-96 through Requirement CS-99);
- 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
- Acknowledgement of the complexities and risks involved with contributions and plans to handle those complexities or risks. This includes the schedule risk for implementing 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, ESE projects are subject to the same requirements as all other NASA missions. 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-69 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-70 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-71 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-85). 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-86 through Requirement CS-89). See Section J for requirements for any SEO costs (Requirement CS-92). A discussion of the basis of estimate shall be provided, with a discussion of heritage and commonality with other programs (Requirement CS-74). Quantify and explain any cost savings that result from heritage. All costs, including all contributions made to the investigation, shall be included (Requirement CS-82). 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). This will include cost by NASA fiscal year to the lowest level of detail the project is working with, in Microsoft Excel format.

All cost tables referenced in this section are provided as templates in the Program Library.

Requirement CS-72 A WBS as defined in NPR 7120.5 and the *NASA Work Breakdown Structure (WBS) Handbook*, available in the Program Library, shall be provided and used to describe how all project costs are accounted in the cost proposal.

Requirement CS-73 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, establishment of an interface between the Flight Operations Team and the CARA 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 AO Sections 4 and 5.

Requirement CS-74 This section shall provide a Basis of Estimate (BoE) table that is clearly traceable to the WBS of the cost tables from 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 reserve level(s) shall be provided. The rationale for the proposed cost reserve levels shall be presented. Proposers shall include additional Basis of Estimate data to assist the validation of their cost estimates. Examples of useful BoE data for different cost estimating methodologies include:

- 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-75 This section shall include a discussion of sources of estimate error and uncertainty in the proposed cost.

Requirement CS-76 This section shall include a discussion of cost risks and mitigation strategies.

Requirement CS-77 This section shall provide two foldout cost tables, using the template of Cost Table Templates 3a and 3b in the Program Library. 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 FY2024 dollars (FY24\$). 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 table shall be the NASA standard WBS elements as defined in NPR 7120.5 and Appendix C and the *NASA WBS Handbook*. 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 table 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 mission phase. The tables include totals by WBS and by phase and life cycle in both RY\$ and Fiscal Year 2024 dollars (FY24\$). Investigation teams shall use their own forward pricing rates to translate between RY\$ and FY24\$. For organizations that are without approved forward pricing rates, the investigation teams may use the NASA inflation/deflation indices available in the Program Library to translate between RY\$ and FY24\$.

Requirement CS-78 The CSR 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-79 A table with the new obligation authority (NOA) required in RY\$ by fiscal year using the format of Cost Table Template 6 shall be provided. If the mission is selected for flight, SMD will use this information to prepare its budget request.

Requirement CS-80 For Phase B only, a time-phased cost breakdown for each WBS element, using the template of Cost Table Template 2, shall be completed. Use only the line items shown in Cost Table Template 2 that are relevant for each phase of the project. The purpose of this set of tables is to provide detailed insight into how the project allocates funding during each phase of work.

Requirement CS-81 The Concept Study Team 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-82 All contributions and direct/indirect costs associated with the work performed at NASA Centers shall be fully costed and accounted for in the CSR and summarized 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 this data is twofold: 1) to determine those costs that are included in the NASA SMD cost but are not funded out of the ESE 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 Appendix L.1, Requirement CS-96 through Requirement CS-99).

Definitions for cost element terms shown in the cost tables are provided in Appendix C.2 of the AO.

Requirement CS-83 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-84 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-85 This section shall provide a detailed cost proposal for performing the Phase B portion of the mission. 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:

- Contract Pricing Proposal. Complete cost and pricing data for Phase B shall be submitted after down-selection by down-selected teams (see Part III).
- Work Breakdown Structure. A WBS shall be provided for Phase B. The structure of the WBS should be consistent with the plans set forth in the Science Implementation, Mission Implementation, and Management sections of the Concept Study and the Statement of Work provided as an appendix to the Concept Study. 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).
- Cost Estimating Techniques. The process and techniques used to develop the Phase B cost proposal shall be described. For portions of the cost proposal 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 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. Include the assumptions used as the basis for the Phase B cost and identify those that are critical to the cost sensitivity in the investigation. If any "discounts" were assumed in the cost estimates for business practice initiatives or streamlined technical approaches, describe the basis for these discounts, how they have been incorporated in the cost estimate, and how they will be managed by the investigation team.
- Workforce Staffing Plan. A workforce staffing plan (including Civil Servants) that is consistent with the WBS shall be provided. This 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 month. Time commitments for the PI, PM, PSE, Co-Is, and other key personnel must be clearly shown.

- Phase B Time-Phased Cost Summary. A summary of the total Phase B costs consistent with the table created for Requirement CS-80 (Cost Table Template 2) shall be provided. The Phase B cost summary shall include all costs to NASA SMD by WBS, including all contributed costs. The Phase B cost summary shall be phased by month.
- Elements of Cost Breakdown. 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-80 (Cost Table Template 2) shall be provided. This information is in addition to that provided in Requirement CS-77 through Requirement CS-82 (Cost Table Templates 1 through 5). The cost proposal shall include, but is not limited to, the following cost elements:
 - a. Direct Labor.
 - 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. A summary of material and parts costs for each element of the WBS shall be provided.
 - c. Subcontracts. 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 shall be identified. Explain the adjustments, if any, and the indirect rates (or burdens) applied to the subcontractors' proposed or anticipated amounts. Describe fully the cost analysis or price analysis and the negotiations conducted regarding the proposed subcontracts.
 - d. Other Direct Costs.
 - 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.

- 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-86 This section shall provide a cost estimate for performing the Final Design and Fabrication/System Assembly, Integration and Test, and Launch (Phase C/D) of the mission. The Phase C/D cost estimates shall correlate with the plans set forth in the Concept Study. This Phase C/D cost estimates shall include the following elements:

1. Work Breakdown Structure. A WBS shall be provided for Phase C/D. The WBS shall be described to the subsystem level (*e.g.*, Attitude Control System, Propulsion System, 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 for the payload. All other WBS elements shall be at least to the major task level (*e.g.*, Project Management, Systems Engineering, GSE, *etc.*).
2. Cost Estimating Techniques. The process and techniques used to develop the Phase C/D cost estimate shall be described. 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 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 cost estimate derived parametrically, the cost-estimating model(s) and techniques used in the Phase E 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. Include the assumptions used as the basis for the Phase C/D cost and identify those that are critical to the cost sensitivity in the investigation. If any "discounts" were assumed in the cost estimates for business practice initiatives or streamlined technical approaches, describe and the basis for these discounts, how they have been incorporated in the cost estimate, and how they will be managed by the investigation team.

3. Workforce Staffing Plan. A workforce-staffing plan (including Civil Servants) that is consistent with the WBS shall be provided. This 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, PM, PSE, Co-Is, and other key personnel shall be clearly shown.
4. Phase C/D Time-Phased Cost Summary. A summary of the total Phase C/D costs consistent with Cost Table Template 2 format shall be provided. The Phase C/D cost summary shall include all costs to NASA SMD by WBS, along with all contributed costs. The Phase C/D cost summary shall be phased by fiscal year. Phase C/D extends 30 days beyond launch, so be sure to account for all costs for this period, including tracking support and mission operations.

Requirement CS-87 This section shall provide a cost estimate for performing the Operations and Sustainment Phase (Phase E) of the mission. The Phase E cost estimates shall correlate with the plans set forth in the Concept Study. The Phase E cost estimates shall include the following elements:

- Work Breakdown Structure. A WBS shall be provided for Phase E. The WBS should be consistent with the plans set forth in the Concept Study and the Statement of Work that is provided as an appendix.
- Cost Estimating Techniques. The process and techniques used to develop the Phase E cost estimate shall be described. 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 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 cost estimate derived parametrically, the cost-estimating model(s) and techniques used in the Phase E 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. Include the assumptions used as the basis for the Phase E cost and identify those that are critical to the cost sensitivity in the investigation. If any "discounts" were assumed in the cost estimates for business practice initiatives or streamlined technical approaches, describe the basis for these discounts, how they have been incorporated in the cost estimate, and how they will be managed by the investigation team.
- Workforce Staffing Plan. A workforce staffing plan (including Civil Servants) that is consistent with the WBS shall be provided. This workforce staffing plan shall include all team member organizations and shall cover all management, manufacturing, technical (scientific and engineering), and support staff. Phase E workforce staffing plan shall be phased by fiscal year. Time commitments for the PI, PM, PSE, Co-Is, and other key personnel shall be clearly shown.

- Phase E Time-Phased Cost Summary. A summary of the total Phase E costs consistent with Cost Table Template 2 format shall be provided. The Phase E cost summary shall include all costs to NASA SMD by WBS, along with all contributed costs. The Phase E cost summary shall be phased by fiscal year.

Requirement CS-88 This section shall provide a cost estimate for performing the Closeout Phase (Phase F) of the mission. The Phase F cost estimates shall correlate with the plans set forth in the Science Investigation, Science Implementation, Mission Implementation, and Management sections. This Phase F cost estimate shall include the following elements:

- Work Breakdown Structure. A WBS shall be provided for Phase F. The WBS should be consistent with the plans set forth in the Science Implementation, Mission Implementation, and Management sections and the Statement of Work that is provided as an appendix.
- Cost Estimating Techniques. The process and techniques used to develop the Phase F cost estimate shall be described. 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 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 cost estimate derived parametrically, the cost-estimating model(s) and techniques used in the Phase F 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. 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. If any "discounts" were assumed in the cost estimates for business practice initiatives or streamlined technical approaches, describe the basis for these discounts, how they have been incorporated in the cost estimate, and how they will be managed by the investigation team.
- Workforce Staffing Plan. A workforce staffing plan (including Civil Servants) that is consistent with the WBS shall be provided. This 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, PM, PSE, Co-Is, and other key personnel shall be clearly shown.
- Phase F Time-Phased Cost Summary. A summary of the total Phase F costs consistent with Cost Table Template 2 shall be provided. The Phase F cost summary shall include all costs to NASA SMD by WBS, along with all contributed costs. The Phase F cost summary shall be phased by fiscal year.

Requirement CS-89 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; Near Space Network (NSN), Deep Space Network (DSN) and other 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.

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

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-90 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-91 Cost tables from Cost Table Templates 1, 2, 3a, 3b, 4a, 4b, 5, 6, and 7 shall be provided as additional files along with the CSR 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 RY\$
- Cost Table Template 3b: Total mission cost profile by mission phase, fiscal year, and WBS in FY\$
- Cost Table Template 4a: Co-I funding profile by mission phase in RY\$ and FY\$
- Cost Table Template 4b: Collaborator funding profile by mission phase in RY\$ and FY\$
- Cost Table Template 5: NASA civil service costs by fiscal year in RY\$
- Cost Table Template 6: New Obligation Authority Budget in RY\$
- Cost Table Template 7: Funding profile for any SEO activities by fiscal year in RY\$

J. JUSTIFICATION AND COST PROPOSAL FOR ANY SCIENCE ENHANCEMENT OPTION(S)

SEO activities, discussed in AO Section 5.1.6, include guest investigator programs, general observer programs, 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 AO Cost Cap 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-92 For any proposed SEO activity, this section shall provide sufficient data and justifications to enable evaluation of not only the science value of the concept, but also its feasibility. This section shall also provide a cost estimate for performing the SEO activity. 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, expanded by WBS as applicable, at the bottom of the cost tables in Requirement CS-77 (Cost Table Templates 3a and 3b). Include a discussion of the estimating techniques used to develop the cost estimates.

K. OTHER FACTORS

Requirement CS-93 A Small Business Subcontracting Plan, covering Phases B through F, shall be provided as an appendix; see Appendix L.15, Requirement CS-121.

Requirement CS-94 If NOAA OEO activities are proposed, the submission shall define and describe the proposed activities and their costs per the guidance in the AO (5.1.8 NOAA *Operational Enhancement Opportunity*) and shall be in the form of additional file(s) to be submitted with the CSR.

Requirement CS-95 If NOAA OEO activities are proposed, they shall be clearly separable from the Baseline Science Investigation and Threshold Science Investigation. The OEO shall be submitted via the NASA Box service, as a separate pdf document (no greater than five pages) along with the CSR. Proposers shall indicate that they consent to the release of the supplementary information to NOAA.

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-96 Letters of commitment signed by an institutional official authorized to commit the resources of the respective institutions or organizations shall be provided from:

- 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
- All major or critical participants in the mission regardless of source of funding.

Requirement CS-97 Personal letters of commitment signed by the individual shall be provided from every critical Proposal Team member as defined in Section A.1 of AO Appendix B. 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. For personal letters of commitment, an email sent from the individual Proposal Team member to the PI stating the member's commitment will be sufficient to satisfy the signature requirement for personal letters of commitment.

See AO Section 5.8.1 for detailed definitions of the terms above. 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-98 If the use of NASA-provided communication and/or navigation services is proposed, this appendix shall include an associated letter of commitment. Requirements for the content of the letters of commitment may be found in AO Section 5.7.2 and Section 5.8.1.

Requirement CS-99 This appendix shall include letters of commitment from non-U.S. individuals and/or institutions that are team members or contributors to 2023 ESE investigations. 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. Such commitments shall be submitted no later than the Site Visit.

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.

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 CSR. 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 the 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 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-100 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:

- A description of each project;
- Its relevance to the subject of the CSR;
- The proposed performance and the actual performance;
- The planned delivery schedule of data to the appropriate data archive and the actual delivery schedule of data to the appropriate data archive;
- The proposed cost and actual cost;
- The proposed schedule and actual schedule;
- An explanation of any differences between proposed performance, cost and schedule and what was actually achieved; and
- 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 item will have a negative effect on the overall assessment, 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-101 This section shall include resumes or curriculum vitae for the PI, DPI (if one), PM, PSE, any other named Key Management Team members identified in the Management section, and all Co-Is 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, PM, and PSE. Resumes or curriculum 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-102 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.

L.5. Open Science and Data Management Plan

Requirement CS-103 A schedule-based end-to-end Open Science and Data Management Plan (OSDMP), 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, management and release of software, and the archiving of all science products shall be described. The Open Science and Data Management Plan shall be in compliance with requirements and the guidelines in the *NASA Plan for Increasing Access to the Results of Scientific Research*, the latest version of SPD-41: *Scientific Information Policies* document, available in the Program Library, and the scientific information policies of the ESE Program. A justification shall be provided for any scientific information not made openly available. The plan shall:

- Include approaches for data retrieval, validation, preliminary analysis, image processing, calibration, correction, and archiving;
- 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;
- 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;
- 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
- Demonstrate allocation of sufficient resources (cost, schedule, workforce, computational) for archiving as well as for preliminary analysis of the data by the Project Investigation 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-104 The OSDMP shall include a Data Management Plan (DMP). The DMP shall describe how data will be made openly accessible and archived to enable the accessibility and reproducibility of the scientific information. The DMP shall identify the appropriate NASA data repository and the machine-readable formats, metadata to be provided, and standards to be used. It shall include an estimate of the raw data volume and the data latency by product for submission of raw and reduced data, to the data archive, in physical units accessible to the science community.

Requirement CS-105 The OSDMP shall include a Software Management Plan (SMP). The SMP shall describe the software and tools to be developed (including their current status), 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-106 If the investigation requires NASA High-End Computing (HEC) resources, the CSR shall state the: 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. Submission of a letter of support is not required. 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.

Requirement CS-107 The OSDMP shall include an Open Science Plan (OSP). The OSP shall include a description of how publications, including peer reviewed papers, conference presentations, and technical documents, are made publicly available. The OSP may describe how public meetings will be held. **[Amended in Rev A]** The OSP shall describe approaches to opening access to publications, team meetings, and any other activities going beyond those required by SPD-41.

L.6. Incentive Plan(s)

Requirement CS-108 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-109 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:

- A brief summary of the mission and the foreign partner’s role in it;
- A list of NASA’s responsibilities within the partnership; and
- 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-110 If the investigation includes international participation, either through involvement of non-U.S. nationals and/or involvement of non-U.S. entities, this section 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.*, 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 whether the license has been applied for or, if not, the projected timing of the application and any implications for the schedule.

Requirement CS-111 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-112 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. 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 $\pm$ 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(s) or instrument(s) 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-113 As applicable for Earth and Moon orbiters, this appendix shall describe how the project will comply with NASA requirements in NASA-STD-8719.14 to limit the generation of orbital debris and dispose of hardware.

Requirement CS-114 This section shall discuss briefly how the mission meets the NPR 8715.6 and NASA-STD-8719.14 orbit debris requirements applicable to its proposed orbit. Both NPR 8715.6 and NASA-STD 8719.14 are available in the Program Library. For LEO missions, this section shall briefly 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
- Develop an Initial Orbital Debris Assessment Report (ODAR) and assess whether an End-of-Mission Plan (EOMP) is required.

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.

NASA has established conjunction assessment risk analysis requirements in NASA Interim Directive (NID) 7120.132* for Earth-orbiting missions up through GEO and NPR 8715.6, Chapter 3 for missions in other orbits, which will apply to investigations selected through this AO. For Earth-orbiting missions, the Conjunction Assessment Risk Analysis (CARA) team at the NASA GSFC is funded directly by NASA Headquarters (HQ) to perform the actual analysis and risk assessment; the costs for these services need not be included in the PIMMC. However, an investigation to which these requirements are applicable will have to budget costs under the PIMMC to establish a working interface between the Flight Operations Team and the CARA team in the Concept Study Report. (See AO Section 4.6.4)

*Note: NASA Interim Directive (NID) 7120.132 and NPR 8715.6 have been superseded by NPR 8079.1 on June 27, 2023. For this CSR evaluation, NID 7120.132 and NPR 8715.6 are still in effect. The official guidance in NPR 8079.1 will be imposed for down-selected missions.

Requirement CS-115 This section shall discuss briefly how the mission meets the NID 7120.132 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; and
- Plans and cadence for maneuver notifications to CARA and for pursuing close approach mitigations as needed.

L.10. 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).

Requirement CS-116 For NASA Center CSRs, this section shall include any descriptions, justifications, representations, indications, statements, and/or explanations that are required by the regulations.

L.11. Master Equipment List

Requirement CS-117 This appendix shall include a Master Equipment List (MEL) in a spreadsheet format with no document formatting summarizing all major components of each flight element subsystem and each instrument element component to support validation of proposed mass estimates, power estimates, contingencies, design heritage, and cost. Fully contributed instruments should include enough subsystem detail to support validation of instrument design. A Microsoft Excel template for this MEL is included as Table B5 of the AO, and available in the Program Library.

The breakouts should be traceable to block diagrams and heritage claims provided in other parts of the proposal. 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 onto which the chip(s) will be integrated, and how much heritage will be used in the design.

Requirement CS-118 The MEL shall be provided in Microsoft Excel format along with the CSR submission.

L.12. Heritage

Requirement CS-119 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:

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

CSRs 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.13. Classified Materials

See Section 5.8.4 of the AO for options and associated requirements.

L.14. Not Applicable [Amended in Rev A]

This appendix does not apply to this solicitation in Step 2. [Amended in Rev A]

Requirement CS-120 Not applicable. [Amended in Rev A]

L.15. Small Business Subcontracting Plan

Requirement CS-121 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 SDBs 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 along with the CSR 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-122 If the Phase A effort results in changes from any science objective proposed in Step 1, this appendix shall provide a table with the following columns: the original objective, the new or revised objective, rationale for the change, and the section/paragraph in the CSR where the change occurs.

L.18. Communications Design Data

Requirement CS-123 Provide data and detailed link analyses for all communication modes, adequate to assess the design of the communications concept. This shall include a communications block diagram (showing all components) and 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: Transmitter RF Output Power, Transmitter Antenna Gain, Transmitter Off-Boresight Pointing Loss, Transmitter Circuit Loss, Carrier Frequency,

Transmitter-Receiver Range, Receiver Antenna Gain, Receiver Off-Boresight Pointing Loss, Receiver Circuit Loss, Receiver Bandwidth, Receiver System Temperature, Hot Body Noise Temperature, Data Modulation Index, Ranging Modulation Index, Data Rate, Forward Error Correcting Code including code rate, block size (if applicable), constraint length (if applicable), Carrier Modulation Index, Carrier Link Margin, and 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

Previously identified threats and vulnerabilities to space systems have indicated that the command uplink to robotic spacecraft needs to be better protected. On February 1, 2019, the NASA Associate Administrator issued a letter directing that all newly started or newly solicited robotic spacecraft protect their command uplink through the use of encryption that is compliant with Level 1 of the Federal Information Processing Standard (FIPS) 140-2. For more information regarding Space Systems Protection requirements that will be imposed after down-selection, see the NASA-STD-1006.pdf, available in the Program Library.

Space Systems Protection Requirement 1 (SSPR 1) in NASA-STD-1006 states, "Programs/projects shall protect the command stack with encryption that meets or exceeds the Federal Information Processing Standard (FIPS) 140, Security Requirements for Cryptographic Modules, Level 1." This requirement may be tailored to accommodate the nature of the mission and the following tailoring is suggested for use by applicable missions:

- Hosted instruments only require protection of the instrument command stack;
- Hosted instruments are only responsible for protection of the command stack until the host spacecraft operations center receives commands;
- Deep space missions (operations more than two million kilometers from Earth) may choose to limit controls applied to the space link if certain controls (*e.g.*, encryption and authentication) pose significant burden to operability or mission success, and if the threat to the space link is low; and
- Category 3/Class C or Class D missions may authenticate without encryption if they have no propulsion.

Proposers are encouraged to offer appropriate tailoring to SSPR 1, but an assessment of the additional impact of the tailoring not being accepted by NASA must be provided.

Additionally, the letter from the Associate Administrator required that the command uplink, position, navigation, and timing subsystems recognize and survive interference. Finally, information pertaining to the command uplink, including command dictionaries, must be protected—at least to the level of Controlled Unclassified Information (CUI).

The ESE project must comply with NASA-STD-1006 as discussed in Section 5.2.12 of the AO.

Requirement CS-124 The CSR shall provide the detailed plans addressing:

- The protection of uplink commands using approaches compliant with FIPS 140-2 Level 1;

- The ability of command uplink, position, navigation, and timing subsystems to recognize and survive interference;
- The protection of command uplink information at no less than the CUI level; and
- Demonstrating that adequate resources (including, but not limited to, cost, schedule, technical accommodation, *etc.*) have been allocated to comply with NASA-STD-1006 *including* generating a Project Protection Plan (PPP) by PDR and addressing associated Candidate Protection Strategies (CPSs). See AO Section 4.6.4 for background information.

Questions concerning the Project Protection Plan may be addressed to: Jerry Esper (Telephone: 240-267-9628, email: 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-125 The CSR 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 tracking stations).

Requirement CS-126 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 (Telephone: 240-267-9628, email: jerry.s.esper@nasa.gov).

L.21. Draft Mission Definition Requirements Agreement

Requirement CS-127 A draft Mission Definition Requirements Agreement (MDRA) shall be provided. MDRA's 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-128 This section shall provide a ~~draft Mission Assurance Implementation Plan (MAIP) and~~ Compliance Matrix for the *Earth System Explorers Mission Assurance Requirements* document in the Program Library. See the document for details. **An ESE MAR-approved compliance matrix template is provided for required use (Requirement CS-57). [Amended in Rev A]**

L.23. Launch Service Interface Requirements Document

See Requirement CS-35 for launch service and launch vehicle compatibility required information.

L.24. Impacts of Alternate LRD

Requirement CS-129 This section shall describe the impact of switching to the alternate LRD. The discussion is requested to inform programmatic considerations and will not be evaluated. Topics covered should include science, cost, schedule, launch vehicle, and any other significant benefits or detriments. Proposers are encouraged to make the assumptions needed to minimize the impact to the mission should the alternate launch date be chosen by NASA; such assumptions should be noted in the discussion.

L.25. Justification for the use of non-AMMOS MOS/GDS Tools

Requirement CS-130 If a ground/operations system solution other than the AMMOS or mission-unique adaptations to the AMMOS is proposed, it shall be described in this appendix. Describe the justification for using Mission Operation 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.26. Trajectory Data

See Requirement CS-36 and Requirement CS-37 providing trajectory data.

L.27. Acronyms and Abbreviations List

Requirement CS-131 This appendix shall provide a list of abbreviations and acronyms.

L.28. References and Management Standards List

CSRs 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 proposal must be included within the proposal itself.

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

Requirement CS-132 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 as additional files to be submitted with the CSR.

Requirement CS-133 If one or more references include ITAR/EAR material, the references shall be made available to NASA in a properly marked form as additional file(s) to be submitted with the CSR.

L.29. Trades Associated with a Reduction in Center Engineering, Safety, and Operations (CESO) Burden Rates [Amended in RevA]

CSRs being developed as part of the ESE Step-2 competition must use the \$52K (in FY2024 dollars) CESO burden rate per “equivalent head”, as stated in the ESE AO (ESE AO Section 5.6.6). An updated CESO burden rate of \$26K (in FY2026 dollars) will be applied to the down-selected ESE investigations, as applicable.

Requirement CS-134 This section shall address how the reduced burden rate would have affected key trades performed during Phase A as well as describing any potential benefits to the project from the reduced burden rate. This section shall not exceed two pages. [Amended in Rev A]

PART III – OTHER FACTORS REQUIRED AFTER DOWN-SELECT

Education Program Plan, and Communications and Outreach

Among NASA’s strategic goals is to communicate the results of its efforts to the American public and to enhance the science and technical education of the next generation of Americans. However, Education Program plans are not needed at this time. NASA may impose Education Program requirements during or subsequent to the Phase A Concept Study phase and will negotiate any additional funding necessary to meet these requirements.

A Communications Program (previously referred as Public Outreach) must be developed during Phase B of the project. The plan must include topline messaging, target audiences, and media processes linked to reaching target audiences, associated detailed costs, milestones, and metrics and timelines, and reporting requirements. Mission-related communications will be negotiated and funded directly through a NASA Center and are not within the PIMMC.

Conjunction Assessment Risk Analysis

NASA has established conjunction assessment risk analysis requirements in NID 7120.132 for Earth-orbiting missions up through GEO and NPR 8715.6, Chapter 3 for missions in other orbits, which will apply to investigations selected through this AO. Two organizations—the Conjunction Assessment Risk Analysis (CARA) team at NASA Goddard Space Flight Center for Earth-orbiting missions and the MArS (and Moon) Deepspace Collision Avoidance Process (MADCAP) team at the Jet Propulsion Laboratory for Moon and Mars missions—are funded directly by NASA HQ and the Multi-Mission Ground Systems and Services (MGSS) program, respectively, to perform the actual analysis and risk assessment; the costs for these services need not be included in the mission PIMMC. However, an investigation to which these requirements are applicable will have to establish a working interface between the Flight Operations Team and the CARA or MADCAP team. This interface will be used to routinely share orbital ephemerides data and covariance data, any maneuvering plans, and to perform any maneuver planning activities required for collision avoidance once on orbit. See “Appendix D. Best Practices for NASA Missions” in OCE-51, NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook in the Program Library for more detail. Estimates of how many maneuver planning events may be required in a particular orbit regime may be requested from the CARA program.

While provision of a draft will be deferred to early Phase B, an Orbital Collision Avoidance Plan (OCAP) must be completed by PDR following the guidance in NID 7120.132 as part of final mission design and orbit selection. The conjunction assessment operations process and associated interface between the mission and CARA or MADCAP team must be agreed-to and documented in a Conjunction Assessment Operations Interface Agreement (CAOIA) by ORR.

For additional information regarding CARA, including potential input on orbit and trajectory trade studies, proposers may contact Alinda Mashiku (Telephone: 301-286-6248, email:

alinda.k.mashiku@nasa.gov). For information regarding MADCAP, please contact David Berry (Telephone: 818 354 0764; email: david.s.berry@jpl.nasa.gov).

To the extent that these requirements go beyond what is required in NPR 7120.5E, the additional costs associated with them will be outside the AO Cost Cap.

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 instructions 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 FAR Table 15-2 (Instructions for Submitting Cost/Price Proposals When Certified Cost or Pricing Data Are Required). 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.

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
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

CPSCandidate Protection Strategy
 C&RCriteria and Requirements
 CS.....Citizen Science
 CSCI.....Computer Software Configuration Item
 CTSCornell Technical Services
 DAACDistributed Active Archive Center
 DLADeclination of Launch Asymptote
 DMP.....Data Management Plan
 DOD.....Department of Defense
 DOEDepartment of Energy
 DOR.....Differential One-way Ranging
 DPI.....Deputy Principal Investigator
 DRDDelivery Readiness Date
 DSN.....Deep Space Network
 DTNDelay/Disruption Tolerant Networking
 EAEnvironmental Assessment
 EAR.....Export Administration Regulations
 EASSS.....Evaluations, Assessments, Studies, Services, and Support
 EBPOC.....Electronic Business Point of Contact
 EIRPEffective 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
 ESE.....Earth System Explorers
 ETU.....Engineering Test Unit
 EVEarth 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

FPGAField-Programmable Gate Array

FSRFunded Schedule Reserve

FTEFull Time Equivalent

FYFiscal Year

G&A.....General and Administrative

GAO.....Government Accountability Office

GBOGround-Based Observatory

GDS.....Ground Data System

GEOGeosynchronous Orbit

GFEGovernment Furnished Equipment

GFSGovernment Furnished Service

GSE.....Ground Support Equipment

GSFC.....Goddard Space Flight Center

N/A.....**Not Applicable [Amended in RevA]**

HBZ.....HUB Business Zone

HPD.....Heliophysics Programs Division

HQ.....Headquarters

HSPDHomeland Security Presidential Directive

HUBZone.....Historically Underutilized Business Zone

IAT.....Integration, Assembly, and Test

ICD.....Interface Control Document

N/A.....**Not Applicable [Amended in RevA]**

IRD.....Interface Requirements Document

ISAS.....Institute of Space and Astronautical Science

I&T.....Integration and Test

ITARInternational Traffic in Arms Regulations

IV&VIndependent Verification and Validation

JPLJet Propulsion Laboratory

JSC.....Johnson Space Center

KDP.....Key Decision Point

LaRCLangley Research Center

LEGS.....Lunar Exploration Ground System

LRD.....Launch Readiness Date

LSP.....Launch Service Provider

LSPISLaunch Service Provider Information Summary

LVLaunch Vehicle

MAMission Assurance

MADCAPMars (and Moon) Deep-space Collision Avoidance Process

~~MAIP.....Mission Assurance Implementation Plan~~

MCOMission Commitment Office

MCR.....Mission Concept Review

MDAAMission Directorate Associated Administrator

MDRA.....Mission Design Requirements Agreement

MELMaster Equipment List

MEV.....Maximum Expected Value

MGSS.....Multi-mission Ground Systems and Services

MMRTGMultiple Mission Radioisotope Thermoelectric Generator

MOCMission Operations Center

MOCSMission Operations and Communications Services

MO&DAMission Operations and Data Analysis

MOS.....Mission Operations Services

MOUMemorandum of Understanding

MPVMaximum Possible Value

MRPP.....Mission Resilience and Protection Program

MTM.....Mission Traceability Matrix

NASA.....National Aeronautics and Space Administration

NASA-STD.....NASA-Standard

NEPANational Environmental Policy Act

NFSNASA FAR Supplement

NFSNuclear Flight Safety

NIDNASA Interim Directive

NISNNASA Integrated Services Network

NLSNASA Launch Services

NOAA.....National Oceanic and Atmospheric Administration
 NODISNASA Online Directives Information System
 NOINotice of Intent
 NPD.....NASA Policy Directive
 NPR.....NASA Procedural Requirements
 NRANASA Research Announcement
 NRCNational Research Council
 NRESSNASA Research and Education Support Services
 NRPNASA Routine Payload
 NSFNational Science Foundation
 NSN.....Near Space Network
 NSPIRES.....NASA Solicitation and Proposal Integrated Review and Evaluation System
 NSSNASA Safety Standard
 OCAPOrbital Collision Avoidance Plan
 OCE.....Office of the Chief Engineer
 OCFOOffice of the Chief Financial Officer
 OCI.....Organizational Conflict of Interest
 ODAROrbital Debris Assessment Report
 N/A.....**Not Applicable [Amended in RevA]**
 OEOOperational Enhancement Opportunity
 N/A.....**Not Applicable [Amended in RevA]**
 ORROperations Readiness Review
 OSMAOffice of Safety and Mission Assurance
 OSSOffice of Space Science
 OSTP.....Office of Science and Technology Policy
 PDFPortable Data Format
 PDR.....Preliminary Design Review
 PEA.....Program Element Appendix
 PI.....Principal Investigator
 PICProcurement Information Circular
 PIMMCPrincipal Investigator-Managed Mission Cost
 PLRAProject 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

SMD.....Science Mission Directorate
 SMP.....Software Management Plan
 SNSpace Network
 S/NSignal to Noise
 SOC.....Science Operations Center
 SOMA.....Science Office of Mission Assessments
 SOW.....Statement of Work
 SPASecondary Payload Adapter
 SPASE.....Space Physics Archive Search and Extract
 SPDSMD Policy Document
 SPGStrategic Planning Guidance
 SRR.....System Requirements Review
 SSMSSafety, 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
 STMScience Traceability Matrix
 TATechnical Authority
 TAATechnical Assistance Agreement
 TDOTechnology Demonstration Opportunity
 TMC.....Technical, Management, and Cost
 TPMTechnical Performance Metric
 TRLTechnology Readiness Level
 UARCUniversity 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
 WYEWork Year Equivalent

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REVISIONS

Revision	Date	Notes
A	03/17/2025	Concurred by SMD 3/17/2025 Modified CSR due date; Removed MAIP requirement and associated language from document; Added requirement regarding use of the ESE MAR Compliance Matrix template; Removed Factor B-6, Appendix L.14, and Requirement CS-120; Added Appendix L.29 and Requirement CS-134; Modified language in Requirements CS-4, CS-50, CS-57, CS-107, CS-120, CS-128, Appendix L.22, and Acronym list.

Revisions/additions are in bold and/or *italicized* text and deletions are struck through. Both will be noted with an amendment date.

National Aeronautics and Space Administration

