The 2026 Senior Review of the Heliophysics System Observatory Missions in Extended Operations

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1. Executive Summary

The 2026 Heliophysics Senior Review of missions in extended operations within the Heliophysics System Observatory (HSO) was conducted between March and June 2026 and covers extended mission operations in the period of FY2027 – FY2029. The 2026 Senior Review assessed the participating missions against a common set of criteria covering scientific and data merits, contribution to the HSO and national priorities, technical and programmatic implementation, and the balance of the Heliophysics mission portfolio. The 2026 Senior Review comprised two separate reviews held in parallel: the Full Senior Review and the Simplified Senior Review. The Full Senior Review evaluated the success of the previous extended mission science investigation (or the success of the prime mission science investigation for those missions proposing to their first Senior Review) and the merits of the proposed future science investigation, the accessibility and usability of data produced by each mission, synergy with and benefit to the HSO and national priorities, the health of the mission, and plans for continued mission management and operations. The Simplified Senior Review evaluated the merits of mission data and mission performance for those missions that were previously designated as HSO Infrastructure.

The following missions were invited to submit proposals to the Full Senior Review: Interface Region Imaging Spectrograph (IRIS), Magnetospheric Multiscale (MMS), Parker Solar Probe, and Time History of Events and Macroscale Interactions During Substorms – Acceleration, Reconnection, Turbulence and Electrodynamics of Moon's Interaction with the Sun (THEMIS – ARTEMIS). MMS and Parker Solar Probe are categorized as missions of strategic significance with proposals for continued funding of extended operations and scientific research investigations via project funds. IRIS and THEMIS – ARTEMIS are categorized as Transition Science missions with proposals for continued funding of extended operations and a gradual reduction of mission funding for scientific research investigations to zero over the period from FY2027 – FY2029. The following missions were invited to submit proposals to the Simplified Senior Review: Global-scale Observations of the Limb and Disk (GOLD), Hinode, Solar Dynamics Observatory (SDO), Solar-Terrestrial Relations Observatory (STEREO), Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED), and Wind. These missions are categorized as Foundational Science missions with no mission-funded scientific research investigations.

The Call for Proposals was released on March 9, 2026, and proposals were due on May 8, 2026. The Senior Review Panel met and received presentations from each of the participating missions from June 8 – June 12, 2026. The process for the 2026 Senior Review differed from previous Senior Reviews. Participating missions were asked to submit presentation proposals in lieu of full proposals, and the panel consisted entirely of NASA civil servants not directly associated with the missions under review. The panel included key Heliophysics Division (HPD) personnel and subject matter experts from across the Heliophysics disciplines, as well as members from non-Heliophysics science disciplines and experts in mission management and flight operations.

The panel assessed the content of each mission proposal against a common set of evaluation criteria. The ratings for each evaluation criterion were weighted to provide an overall rating for each proposal. These overall ratings are summarized in Table 1 and Table 2.

The major findings of the panel are summarized as follows:

- Missions in extended operations continue to make valuable observations that benefit the HSO and that missions in extended operations continue to provide data products that are widely used by the Heliophysics science community. The proposals demonstrated improved synergy between missions in the HSO, directly addressing a major concern of the 2023 Senior Review.
- The missions in the Full Senior Review demonstrated excellent progress towards accomplishing the science proposed at the last Senior Review or during their prime operations. The missions in the Full Senior Review also proposed compelling science investigations for their extended missions that are consistent with Decadal Survey findings, and supportive of HPD priorities.
- Some proposed mission budgets did not demonstrate a convincing approach to identifying and prioritizing operational efficiencies. Instead, a common approach was to propose cuts to science operations that would dramatically reduce capabilities but then seek to restore those capabilities with over-guide requests.

Table 1: Overall proposal ratings for the Full Senior Review.

Mission	**Overall Rating**
IRIS	Very Good
MMS	Good/Fair
Parker Solar Probe	Very Good
THEMIS – ARTEMIS	Excellent/Very Good

Table 2: Overall proposal ratings for the Simplified Senior Review.

Mission	**Overall Rating**
GOLD	Very Good/Good
Hinode	Very Good/Good
SDO	Good
STEREO	Excellent
TIMED	Excellent/Very Good
Wind	Excellent/Very Good

2. Introduction

NASA's Science Mission Directorate (SMD) conducts reviews of its operating missions on a 3-year cycle per Title 51 U. S. Code §30504, as modified by the NASA Transition Authorization Act of 2017 (P.L. 115-10), to maximize the scientific return from these missions within finite resources which reads, in part:

(1) The Administrator shall carry out triennial reviews within each of the Science divisions to assess the cost and benefits of extending the date of the termination of data collection for those missions that exceed their planned missions' lifetime.

(2) In conducting an assessment under paragraph (1), the Administrator shall consider whether and how extending missions impacts the start of future missions.

The 2026 Heliophysics Division (HPD) Senior Review assessed the missions in extended operations (those that have completed their prime science mission) within the Heliophysics System Observatory (HSO), using a common set of criteria covering scientific and data merits, contribution to the HSO and national priorities, technical implementation, and the balance of the portfolio. The 2026 Senior Review comprised two separate reviews held in parallel: the Full Senior Review and the Simplified Senior Review. The Full Senior Review evaluated the success of the previous extended mission science investigation (or the success of the prime mission science investigation, for those missions proposing to their first Senior Review) and the merits of the proposed science investigation, the accessibility and usability of data produced by each mission, synergy with and benefit to the HSO and national priorities, the health of the mission, and plans for continued mission management and operations. The Simplified Senior Review evaluated the merits of mission data and mission performance for those missions that were previously designated as HSO Infrastructure.

The 2026 Senior Review covers extended mission operations in the period of FY2027 – FY2029. HPD will use the findings from this review to prioritize the operating missions, define an implementation strategy, and give programmatic direction and budgetary guidelines to the missions concerned for the next 3 fiscal years (FY2027, FY2028, and FY2029). HPD will also use budget information submitted to the Senior Review to plan for support of extended mission operations in later years (FY2030 – FY 2032).

The 2026 Senior Review incorporated lessons learned and recommendations from previous Senior Reviews. Specifically, the 2023 Heliophysics Senior Review Report found that all the HSO extended missions contribute valuable observations, and they continue to make discoveries and significant progress while addressing their compelling science investigations. The report also noted that "individual extended mission proposals lacked system-level coherence and perpetuated closed communities". The report recommended that "HPD develop a strategy and implementation plans for a more coordinated HSO mission portfolio" and made several recommendations to strengthen broader community participation in HSO missions and improve adherence to open science policies and directives. The 2026 Senior Review seeks to maximize the scientific return from HSO missions in extended operations, while minimizing the administrative burden on mission teams, reviewers, and HPD staff. The 2026 Senior Review promotes open participation in HSO mission science by the whole Heliophysics community, with a deliberate focus on innovation and cross-disciplinary research to ensure that the best science and most valuable data are funded.

Missions proposing to the 2026 Senior Review compete for an allocation from a pool of funds composed primarily of the budgets from all Heliophysics missions in extended operations. HPD strives to maintain a scientifically well-balanced portfolio consisting of both new and continuing missions within the finite resources available. Given the dynamic and constrained budgetary environment within which HPD operates, missions participating in the 2026 Senior Review were expected to significantly reduce costs and find efficiencies for operations in their proposals. It is understood that such cost reductions and efficiencies may lead to higher operational risk and/or increased risk of data collection degradation.

3. Senior Review Process

3.1. Proposal Categories

Full Senior Review

The Full Senior Review assesses operating missions within the HSO for scientific and data merit, mission performance, and portfolio balance. Strategic science missions (see Section 3.2), Explorers, and Missions of Opportunity that have successfully completed their prime mission and currently include a mission-funded science investigation were invited to propose to the Full Senior Review. The Full Senior Review assessed the following 4 missions: Interface Region Imaging Spectrograph (IRIS), Magnetospheric Multiscale (MMS), Parker Solar Probe, and Time History of Events and Macroscale Interactions During Substorms – Acceleration, Reconnection, Turbulence and Electrodynamics of Moon's Interaction with the Sun (THEMIS – ARTEMIS).

Missions undergoing a Full Senior Review were assessed on factors similar to those used in previous Senior Reviews, including but not limited to success of the previous mission science investigation, merits of the proposed science investigation, contribution to the HSO and national priorities, the health of the mission, and plans for continued mission management and operations. Assessment of mission management and operations included the management and reporting of funding, the suitability of the mission operating model to maximize its contribution to the HSO and be a responsible actor in space, and succession planning to develop future mission leaders.

Simplified Senior Review

The Simplified Senior Review focused on the merits of mission data and mission performance for missions that were previously designated as HSO Infrastructure and are proposing to continue extended operations as HSO Foundational Science missions (see Section 3.2). The Simplified Senior Review is intended to reduce the burden on projects to provide a full reevaluation of the mission goals and objectives with each cycle. Instead, this approach focuses on a programmatic review of the accessibility, usability, uniqueness and usefulness of data produced by each mission, synergy with and benefit to the HSO and national priorities, the health of the mission, and plans for continued mission management and operations. The Simplified Senior Review assessed the following 6 missions: Global-scale Observations of the Limb and Disk (GOLD), Hinode, Solar Dynamics Observatory (SDO), Solar-Terrestrial Relations Observatory (STEREO), Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED), and Wind.

3.2. Mission Categories

Strategic Science Missions

Strategic science missions are those missions for which SMD and/or HPD directs the science goals based on highest Decadal Survey priorities. Currently, MMS and Parker Solar Probe are categorized as missions of strategic significance. These missions will be considered for extended operations with continued funding of scientific research via project funds on a case-by-case basis. This ensures that HPD continues to be supportive of national priorities and initiatives that have been recommended by the Decadal Survey and addressed by these missions.

Transition Science Missions

HPD is introducing a new category of missions in the 2026 Senior Review called Transition Science missions. These are Explorers and Missions of Opportunity that have completed their prime mission and currently receive funding for a mission science investigation. The transition phase is a three-year period over which the mission-funded science investigation will be gradually reduced to zero while HPD ramps up support for competitively funded research using mission data. This phase is designed to allow time for mission science team members and other researchers to propose and be awarded funds via competitive funding avenues before funds through the mission are ramped down to zero. The goal of this new paradigm is to enable full and open participation in mission science by the whole Heliophysics community, thus ensuring that the most relevant research ideas are funded based on data determined by the community to be of greatest value. IRIS and THEMIS – ARTEMIS are categorized as Transition Science missions for the 2026 Senior Review.

After the transition phase is completed, Transition Science missions will be invited to propose to the next Simplified Senior Review for continuation as HSO Foundational Science missions. HSO Foundational Science missions receive funding for project management, mission operations and data activities. By continuing to fund core leadership functions throughout the life of the project via project funds, key team personnel and institutional knowledge will be maintained while securing mission science for the benefit of the wider Heliophysics community.

HSO Foundational Science Missions

HPD is introducing a new category of missions called HSO Foundational Science missions in place of HSO Infrastructure. HSO Foundational Science missions will provide long-term observations and measurements of physical phenomena or regions of space that are foundational to the advancement of Heliophysics science knowledge and understanding. They will also ensure continuity of unique observations and measurements that meet NASA objectives and national priorities such as space weather and support of exploration initiatives. HSO Foundational Science missions will receive funding for project management, mission operations and data activities. By continuing to fund core leadership functions throughout the life of the project via project funds, key team personnel and institutional knowledge will be maintained while securing mission science for the benefit of the wider Heliophysics community. While these missions will not receive funding for mission science investigations, they will be a critical component of the HSO fleet of science missions. HSO Foundational Science missions will be expected to work closely with the Heliophysics Digital Resource Library (HDRL) to ensure that scientifically useful data products are made accessible to the community in a timely manner that is consistent with NASA's open science policy.

3.3. Proposal Format

Missions participating in the 2026 Senior Review were invited to submit a presentation proposal in PowerPoint format to either the Full Senior Review or the Simplified Senior Review, along with supporting documentation including updated Project Data Management Plans (PDMPs) and Calibration and Measurement Algorithm Documents (CMADs). Missions that were invited to propose to the Full Senior Review were given the option to propose instead to the Simplified Senior Review for continued operations as an HSO Foundational Science mission, although no missions chose to exercise this option. Requirements for the presentation proposals described in the Call for Proposals included:

- Status of the science investigation approved at the previous Senior Review, or the prime mission science objectives, for those missions proposing for their first extended mission;
- Description of the proposed extended mission science goals and objectives;
- Plan to ramp down the mission-funded science investigation during the proposed extended mission;
- Discussion of the mission contributions to the HSO and national priorities including space weather and human space exploration;
- Current mission status, including the health of the spacecraft, instruments, and ground systems.
- Plans for proposed extended mission operations, including operation of the spacecraft and instruments, any supporting facilities, and delivery of high-quality science data products to the designated NASA archive;
- Updates to the mission Management Plan, including any proposed changes to key personnel;
- Updates to the mission Data and Code Management Plan, including updates to the PDMP and CMAD, and a description of how the mission data products are integrated with the appropriate NASA data archive.

Mission budget proposals were submitted as Excel spreadsheets using a template provided with the Call for Proposals. Mission budget proposals for the 2026 Senior Review cover a six-year planning window from FY2027 to FY2032, for consistency with the concurrent FY2028 Planning, Programming, Budgeting, and Execution (PPBE) process for missions not included in the Senior Review.

Proposals were submitted via the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES) and via the NASA Box content management system. The Box system was used for submission of files in native PowerPoint and Excel formats because NSPIRES only supports submission of proposals as Portable Document Format (PDF) files.

3.4. Senior Review Panel

The 2026 Senior Review Panel assessed the scientific and technical merits of the extended mission described in each proposal. The panel reviewed the following artifacts in conducting their assessment:

- Presentation proposals from the missions, including the submitted PowerPoint slides and oral presentations to the panel;

- Supporting documentation provided with the mission proposals, including updated Project Data Management Plans (PDMPs) and Calibration and Measurement Algorithm Documents (CMADs);
- Explorers and Heliophysics Project Division (EHPD) and Space Science Mission Operations (SSMO) report describing the management of missions in the HSO; and
- Heliophysics Digital Resource Library (HDRL) overview of the science data products provided by each mission and how the missions interact with the repository.

Panelists were NASA civil servants not directly associated with the missions under review, to ensure an objective evaluation of the extended mission portfolio. The panel included key HPD personnel such as the Operating Mission Program Executive(s) and Program Scientist, and subject matter experts from across the Heliophysics disciplines. The panel also included members from non-Heliophysics science disciplines within SMD (Astrophysics, Earth Science, and Planetary Science Divisions), as well as from NASA's Human Spaceflight Mission Directorate (HSMD), Human Health and Performance Directorate, Space Radiation, and experts in mission management and flight operations. A list of panel members is provided in Section 6. The panel was supported by mission management from the Explorers, Solar Terrestrial Probes and Living With a Star Program Office at NASA's Goddard Space Flight Center (GSFC). Logistical and technical support for the panel activities were provided under the NASA Research and Education Support Services (NRESS) contract. All proposals were made available to the full panel via the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES). Each proposal was assigned one primary and two secondary reviewers from the panel, and these panelists submitted preliminary individual evaluations based on the presentation proposals and supporting documentation via NSPIRES prior to the mission oral presentations to the panel. NRESS staff compiled these preliminary evaluations for each proposal and made them available to the full panel via a secure implementation of Google Drive as a starting point for discussions during the panel meeting described below.

Table 3: Schedule of Key Events for the 2026 Senior Review.

Event	Date
Draft Call for Proposals Issued	February 27, 2026
Pre-Proposal Briefing to Mission Teams	March 5, 2026
Final Call for Proposals Issued	March 9, 2026
Senior Review Proposals Due	May 8, 2026
Mission Presentations to Senior Review Panel	June 8 – 12, 2026
Draft Senior Review Recommendations to HPD	June 2026
Senior Review Panel Report to HPD	August 2026
HPD Letters of Direction to Missions	September 2026
Publication of Senior Review Panel Report	September 2026

The schedule of key events for the Senior Review is shown in Table 3. The panel held a virtual orientation kickoff meeting on May 26, 2026, to discuss the Senior Review process and the evaluation criteria. The panel convened in a hybrid mode to evaluate the proposals from June 8 – June 12, 2026. The in-person component of this meeting was held at the NRESS offices in Arlington, VA. Two panelists participated remotely for the full duration of the meeting, and one panelist participated remotely for the first two days.

The first day of the panel meeting began with an overview of the Senior Review process, schedule, evaluation criteria, and evaluation forms by the HPD Operating Missions Program Scientist, followed by a joint presentation from EHPD and SSMO leadership describing how the missions in the HSO are managed at NASA GSFC, and a presentation from HDRL project scientist describing how HDRL and its component facilities work with the missions to deliver data to the science community and to serve as the final active archive for mission data products. Over the following two days, each mission delivered an oral presentation to the panel based on their submitted presentation proposal. Each mission was given the same amount of time for their presentation (1 hour for the Full Senior Review, and 45 minutes for the Simplified Senior Review), and for a question-and-answer session with the panelists. Following the presentations and panel discussions, the primary and secondary reviewers drafted panel evaluations including strengths and weaknesses for each proposal using the evaluation criteria described in Section 3.5. These draft panel evaluations were provided to the full panel via Google Drive. During the remainder of the week, the panel finalized these evaluations and rated each proposal as described in Section 3.5. The HPD Operating Missions Program Executive and Program Scientist presented the panel evaluation findings and proposal ratings to HPD leadership on June 16, 2026.

3.5. Evaluation Criteria

The panel assessed the content of each mission proposal against the following criteria:

Criterion A: Scientific Success in Previous Mission Investigation (Full Senior Review Only)

- **Factor A-1:** Success of previous science investigation. (Achievement of Science Objectives in the previous extended mission period, for missions returning to their second or later Senior Review; or achievement of prime mission Science Objectives, for missions proposing for their first extended mission.)
- **Factor A-2:** Performance in addressing any findings in the previous Senior Review. (The panel had access to the previous Senior Review report for each mission, and other information from that review as needed.) This factor was only assessed for missions returning to the Senior Review.

Criterion B: Overall Evaluation of the Proposed Science Investigation (Full Senior Review Only)

- **Factor B-1:** Scientific merit and impact of the proposed in-guide science investigation.
- **Factor B-2:** Implementation merit of the proposed in-guide science investigation, including the plan for transition to competed research funding where applicable.
- **Factor B-3:** Relevance of the proposed in-guide science investigation to HPD's scientific goals as defined in the Division's Strategic Objectives and the 2024 Heliophysics Decadal Survey.
- **Factor B-4:** Cost reasonableness of the proposed in-guide science investigation.

Criterion C: Contribution to the Heliophysics System Observatory and National Priorities

- **Factor C-1:** Merit of the proposed data and code management plan.
- **Factor C-2:** Quality of the archival mission science data products and associated documentation.
- **Factor C-3:** Synergy with and benefit to the HSO, and contributions of mission data to meeting national priorities. This factor applies only to the proposed observations and

observations or investigations begun or completed during the past three years, to the extent to which those past observations or investigations provide context for future plans.

Criterion D: Technical Implementation

- **Factor D-1:** Health of the mission and suitability of the mission operating model to maximize its contribution to the HSO. For this factor, the mission includes the spacecraft, instruments, and project-managed ground systems.
- **Factor D-2:** Cost reasonableness of the mission's operations model. This factor includes the ability to continue healthy operations within the in-guide budget, and any proposed measures to increase efficiency and/or reduce costs during the extension period.
- **Factor D-3:** Sufficiency of the mission's plans to be a responsible actor in space, including compliance with orbital debris requirements and reasonable or reduced reliance on centralized services such as the Space Communications and Navigation (SCaN) program and spectrum allocation.
- **Factor D-4:** Sufficiency of the mission management plan, including the leadership succession plan.

Criterion E: Under-guide and Over-guide Requests (Informational Only)

- **Factor E-1:** Scientific merit and impact of any proposed under-guide or over-guide science investigation.
- **Factor E-2:** Implementation merit of any proposed under-guide or over-guide science investigation.
- **Factor E-3:** Merit and impact of any proposed under-guide or over-guide for data activities.
- **Factor E-4:** Merit and impact of any proposed under-guide or over-guide for mission operations.
- **Factor E-5:** Merit and impact of any proposed under-guide or over-guide for mission management, including the leadership succession plan.

Criteria A – D were rated and weighted to provide an overall proposal rating. For proposals to the Full Senior Review, the criteria were weighted as follows: Criterion A, 25%; Criterion B, 30%; Criterion C, 20%; Criterion D, 25%. For proposals to the Simplified Senior Review, only Criteria C and D were considered, and both criteria were equally weighted. Criterion E is informational and was not rated. It does not contribute to the overall proposal rating. The factors within each evaluation criterion were weighted equally in determining the rating for that criterion.

Each evaluation criterion was rated on a five-point scale based on the number and significance of the strengths and weaknesses identified by the panel, as described in Table 4. The final rating for each evaluation criterion is the median of the individual panelists' ratings. Intermediate ratings (for example, Excellent/Very Good) are allowed to provide finer granularity in the overall ratings weighted across all evaluation criteria.

Table 4: Five-point rating scale used for each evaluation criterion.

Adjectival rating (Numerical Score)	**Basis for rating**
Excellent (5)	A thorough and compelling proposal of exceptional merit that fully responds to the objectives of the Call for Proposals as documented by numerous or significant strengths and with no major weaknesses.
Very Good (4)	A competent proposal of high merit that fully responds to the objectives of the Call for Proposals, whose strengths fully out-balance any weaknesses and none of those weaknesses constitute fatal flaws.
Good (3)	A competent proposal that represents a credible response to the Call for Proposals, whose strengths and weaknesses essentially balance each other.
Fair (2)	A proposal that provides a nominal response to the Call for Proposals and whose weaknesses outweigh any strengths.
Poor (1)	A seriously flawed proposal having one or more major weaknesses that constitute fatal flaws.

4. Senior Review Findings

4.1. General Findings

The panel found that missions in extended operations continue to make valuable observations that benefit the HSO and that missions in extended operations continue to provide data products that are widely used by the Heliophysics science community. Several missions also make significant contributions to other national priorities including improved space weather predictions. Overall, the proposals demonstrated improved synergy between missions in the HSO, and numerous examples of scientific discoveries enabled by multi-mission coordinated observations were presented. The missions in the Full Senior Review demonstrated excellent progress towards accomplishing the science proposed at the last Senior Review, and in the case of Parker Solar Probe, exceeded their prime mission science objectives. The missions in the Full Senior Review also proposed compelling science investigations for their extended missions. However, in at least one case, the most compelling proposed science would not be accomplished during the next extended mission and would require an additional extension to accomplish this science.

A common theme was a lack of adequate justification for over-guide budget requests, particularly in the later years from FY2030 – FY2032. The panel noted a tendency to design those budgets to maintain earlier FY levels. Some proposals included cuts to science operations that would dramatically cut capabilities under their guideline budgets but then sought to restore those capabilities with over-guide requests. The panel found this strategy not credible and recommends prioritizing operational efficiencies over sacrificing capabilities without adequate justification.

4.2. Proposal Evaluations Summary

The individual criterion ratings and the overall ratings for each proposal in the Full Senior Review are shown in Table 5. The individual criterion ratings and the overall ratings for each proposal in the Simplified Senior Review are shown in Table 6. The detailed panel evaluations that led to these ratings are in Section 6.

Table 5: Proposal ratings by criterion and overall ratings for the Full Senior Review. Note that IRIS and THEMIS – ARTEMIS were directed to propose a plan to ramp down the project-funded science investigation to be a foundational science mission at the next Senior Review.

Mission	Criterion A (Previous Science)	Criterion B (Proposed Science)	Criterion C (Contribution to HSO)	Criterion D (Technical)	Overall
IRIS	Excellent	Good	Excellent	Very Good	Very Good
MMS	Good	Fair	Very Good	Fair	Good/Fair
Parker Solar Probe	Excellent	Very Good	Excellent	Good	Very Good
THEMIS – ARTEMIS	Excellent	Very Good	Excellent	Very Good	Excellent/ Very Good

Table 6: Proposal ratings by criterion and overall ratings for the Simplified Senior Review.

Mission	**Criterion C (Contribution to HSO)**	**Criterion D (Technical)**	**Overall**
GOLD	Very Good	Good	Very Good/Good
Hinode	Excellent	Fair	Very Good/Good
SDO	Very Good	Fair	Good
STEREO	Excellent	Excellent	Excellent
TIMED	Very Good	Excellent	Excellent/Very Good
Wind	Excellent	Very Good	Excellent/Very Good

5. Individual Proposal Evaluations

5.1. Full Senior Review Evaluations

Interface Region Imaging Spectrograph (IRIS)

Proposal Summary

The Interface Region Imaging Spectrograph, IRIS, is the highest resolution observatory to provide seamless coverage of spectra and images from the photosphere into the corona. It provides a unique combination of near and far-UV spectra and images at subarcsecond resolution and high cadence that allow the tracing of mass and energy through the critical interface between the solar surface and the corona or solar wind. The proposed mission extension will exploit the new insights gained from previous observations, inversions, and numerical models to focus on three new science objectives: (1) an investigation into the drivers of the first ionization potential (FIP) effects, (2) study the bursty nature of reconnection in solar flares, and (3) recover the thermodynamics and the radiative loss from energetic events such as nanojets, nanoflares, Ellerman bombs, and flares.

The IRIS mission has operated in a polar sun-synchronous orbit since launch in 2013. Mission operations are done through the Mission Operations Center (MOC) at the NASA Ames Research Center (ARC) with activities including downlinks/uplinks, unmanned ground processing of telemetry, housekeeping, maintenance of spacecraft, and instrument monitoring. Additionally, ESA pays 8 X-band passes/day in Svalbard, Norway. In the extended mission, IRIS plans to increase automation of routine commanding operations, monitoring, and housekeeping, and to reduce the number of operators for cost savings.

IRIS science operations take place at the Lockheed Martin Solar and Astrophysics Lab (LMSAL) Science Operations Center (SOC), in Palo Alto, CA, with additional functions provided by from the Smithsonian Astrophysics Observatory (SAO), Montana State University (MSU), and the Leland Stanford Jr. University (LSJU). Science operations activities include science planning, science targeting and observing programs, coordination with other space-based and ground-based observatories, calibration, testing of new observing programs, monitoring and maintenance of onboard mechanisms and instruments. IRIS plans to continue observation coordination with HSO missions such as Solar Orbiter, Parker Solar Probe, PUNCH, SDO and Hinode, as well as new missions coming online such as MUSE and EUVST. IRIS plans on cost reductions for science operations from FY28 onwards, including reduced operations during eclipse season and increasingly automated science planning. Following the launch of MUSE, the IRIS science plan is expected to be managed by the MUSE science plan through an automated translation script.

Data activities include processing of IRIS data to L0, L1, L2, ancillary data (SDO-IRIS, Hinode-IRIS) and quicklook movies, data annotation to feed into Heliophysics Events Knowledgebase (HEK), movie of the week, data calibration, data archiving at LMSAL, data validation including ensuring validity and stability of data quality/calibration, maintenance of documentation and web pages. IRIS plans on cost reductions on data activities from FY28 onwards by increasingly reducing priority in producing ancillary data, reducing manual data annotation, and reducing the frequency of data calibration and validation.

Mission management functions largely come out of LMSAL, including the principal investigator, project manager, science lead, science operations lead, and data calibration manager. The mission scientist works out of GSFC and the mission ops manager out of ARC. Deputies have been appointed that have taken on many tasks during recent years and will take on more tasks and responsibility as senior leadership personnel transitions to MUSE following launch in 2027.

Overall Evaluation/Rationale

Significant progress has been made on each of the four science objectives from the previous Senior Review. In particular, IRIS has greatly accelerated the process of obtaining chromospheric diagnostics from spectral data by expanding the IRIS^{2+} database. The proposed new science investigations are highly relevant to HPD scientific goals and strategic objectives and have potential for high impact. IRIS data products are of high importance for studying highly dynamic and energetic processes on the Sun across multiple layers of the solar atmosphere. IRIS will provide key complementary data that enhance the science investigations for ongoing and future HSO missions. The mission remains in excellent health with a nominal orbit, power, battery, attitude control, and no degradation to the instruments. However, a major weakness was found in that the proposed science objectives could be done with existing data and therefore do not serve as a justification for extending the mission. The major strengths outweigh the single major weakness; therefore, the proposal is rated Very Good.

Excellent	Excellent/ Very Good	Very Good	Very Good/ Good	Good	Good/ Fair	Fair	Fair/ Poor	Poor
		X						

Criterion A: Scientific Success in Previous Investigation

Major Strengths

(A-1): IRIS has greatly accelerated the process of obtaining chromospheric diagnostics from spectral data by expanding the IRIS^{2+} database. The IRIS Team has actively leveraged machine-learning approaches to accelerate scientific progress and develop innovative diagnostic tools. The spectral line database increased from 40k to 135k representative profiles covering 14 lines, allowing a fast inversion that provides both the thermodynamic and radiative loss in minutes. The new SDO2IRIS^{2+} visual transformer translates SDO images into chromospheric thermodynamic quantities based on IRIS^{2+} inversions, which provides insights beyond the relatively small IRIS field of view. These tools enable the scientific community to use IRIS data efficiently to understand chromospheric diagnostics.

(A-1): Significant progress has been made on each of the four science objectives from the previous Senior Review. This includes advances in chromospheric diagnostics, understanding of chromospheric heating and flare dynamics, and inferring non-thermal electrons during nanoflares. The accomplishments for each Science Objective are clearly presented and supported with specific scientific results, new data products and capabilities, model-observation comparisons, and relevant publications. A total of 26 publications were cited, containing developments on the previous science objectives, many in high-impact journals. Progress in understanding chromospheric heating included the development of new capabilities, such as PIROCK – a greatly accelerated numerical method for the Ebysus multi-fluid code – to study drivers of the FIP effect in the partially ionized chromosphere. Observations of the optically thin O I line provide strict constraints on theoretical models of the chromosphere, and the refinement of models to explain the widths of Mg II h & k provide a sensitive signature of chromospheric dynamics and structure. Discoveries in the field of flare dynamics, such as evidence for slip-running reconnection and bursty reconnection, have opened new questions that will drive future flare dynamics investigations. Finally, IRIS has put constraints on heating and non-thermal particle properties of small heating events (nanoflares), otherwise largely unobservable with coronal observatories.

Minor Strengths

(A2): IRIS has responded satisfactorily to the two minor weaknesses called out in the 2023 Senior Review.

Major Weaknesses

None.

Minor Weaknesses

None.

Criterion A Rating

Excellent	Very Good	Good	Fair	Poor
X				

Criterion B: Evaluation of the Proposed Science Investigation

Major Strengths

(B-1, B-3): The proposed science investigations are highly relevant to HPD scientific goals and strategic objectives and have potential for high impact. Improved $IRIS^{2+}$ inversion schemes will be applied to recover thermodynamics and radiative loss from energetic events, probing fundamental physical processes in the chromosphere and the role of the transition region in system coupling. Investigation into the chromospheric footprint of the coronal first-ionizing potential (FIP) will place tight constraints on FIP models, improving understanding of the connection between the chromosphere, corona, and slow solar wind. Finally, high-cadence observations of quasi-periodic pulsations in solar flares will provide new insights into the physical processes at work in energetic events. These new science objectives are comprehensive and well aligned with the 2024 Decadal Survey and SMD Science Plan 2025. The team has clearly articulated strong scientific justification for each objective, supported by recent relevant findings, and has outlined plans for coordinated observations using both space- and ground-based observatories. The plan outlines specific tasks associated with each new science objective, to be completed through the finalization of modeling efforts, data analysis, publication preparation, documentation, and updates to the supporting databases.

Minor Strengths

(B-4): The cost of the proposed science investigation appears feasible and appropriate for the scope of the planned work.

(B-2): The IRIS team's transition plan for evolving science developments into competitively funded research (ROSES) is compelling and well-structured.

Major Weaknesses

(B-2): The proposed science objectives could be done with existing data and therefore do not serve as a justification for extending the mission. The science objective addressing the FIP effect is largely a correlation study and modeling effort to explain spectral features that can be done with existing full-disk mosaics and data from various well-observed solar scenes. The remaining science objectives rely on coordinated observations of energetic events and can be done with existing observations. It was stated that these analyses would benefit from new observations, but that claim lacked compelling justification.

Minor Weaknesses

The proposal did not break out costs of the three proposed science goals, making it difficult to estimate the return on investment.

Criterion B Rating

Excellent	Very Good	Good	Fair	Poor
		X		

<u>Criterion C: Contribution to the Heliophysics System Observatory and National Priorities</u>

Major Strengths

(C-2): The proposed data products are of high importance for studying highly dynamic and energetic processes on the Sun across multiple layers of the solar atmosphere. There is extensive documentation and data resources available to the community, including the IRIS Data Analysis Guide, the Python Data Analysis Guide, quick-look and analysis codes hosted in GitHub and GitLab repositories for Python-based tools, and SolarSoft resources for IDL-based tools. Data are annotated and searchable with a web interface with over 142,000 queries and nearly a million data downloads to date. These resources, together with accessible observational datasets and modeling products, ensure a strong foundation for significant scientific return from the mission.

(C-3): IRIS will provide key complementary data that enhance the science investigations for ongoing and future HSO missions. IRIS's unique role in the HSO includes providing critical high-resolution observations of the interface region between the photosphere and corona not available elsewhere. IRIS plans to coordinate intensively with Solar Orbiter, Parker Solar Probe, PUNCH, SDO, SUIT/Aditya, Proba-3, NUSTAR, and Hinode, as well as sounding rocket and ground-based observatories. It will continue to extend a demonstrated track record of coordinated observations comprising >75% of its observing time. The mission will provide complementary data that will enhance the science investigations for future missions Solar-C/EUVST and MUSE, the latter mission eventually driving the IRIS science planning. A strong partnership has been established and continues to grow with HSO missions and ground-based observatories.

Minor Strengths

(C-1): The proposed data and code management plan is comprehensive and mature, including all necessary descriptions for calibration and the measurement algorithm, along with necessary references to published literature on calibration and technical documentation.

Major Weaknesses

None.

Minor Weaknesses

None.

Criterion C Rating

Excellent	Very Good	Good	Fair	Poor
X				

<u>**Criterion D: Technical Implementation**</u>

Major Strengths

(D-1): IRIS remains in excellent health with a nominal orbit, power, battery, attitude control, and no degradation to the instruments. IRIS has no on-board propulsion, no consumables, and no changes to orbit, spacecraft or mission parameters are planned. Reaction wheels are healthy with quarterly reversal of wheel spin direction implemented to prolong lifetime by ensuring lubrication. Star tracker performance nominal after 2019 software update improved hot pixels. The mission is expected to continue to deliver high-quality observations.

Minor Strengths

(D-2): IRIS has a reasonable management plan that includes increased efficiencies to reduce cost.

(D-3): IRIS is compliant with orbital debris requirements and requires minimal low-risk actions to execute the decommissioning process.

(D-4): IRIS has a sufficient succession plan. Leadership responsibilities are planned to be redistributed among currently appointed deputies when senior leadership transitions to MUSE in 2027 and the mission science transitions to completed research.

Major Weaknesses

None.

Minor Weaknesses

(D-2): Mission operations costs are not well justified. The proposal lacked sufficient details on data calibration frequency, whether additional automation can be applied, or whether all data products produced are high priority.

Criterion D Rating

Excellent	Very Good	Good	Fair	Poor
	X			

<u>Criterion E: Under-guide and Over-guide Requests (Informational Only)</u>

Major Strengths

None.

Minor Strengths

(E-1): The proposal identifies several credible increased risks to data outages, calibration accuracy, and data discovery in FY30 – FY32 that would impact science and could be reduced by the over-guide request.

Major Weaknesses

None.

Minor Weaknesses

(E-1, E-3): The budget for the over-guide is designed to largely maintain the reduced FY29 budget lines through FY32 and does not seem to be based on demonstrated limits of mission operations, science operations, and data activities.

Magnetospheric Multiscale (MMS)

Proposal Summary

MMS proposes two science objectives (SO) for its next extended mission. SO1 (FY27 – FY28) will "complete the definitive investigation of the kinetic microphysics of reconnection, acceleration, turbulence and shocks" using tight tetrahedron configuration at 20 – 40 km separations and 29 R_E apogee, with six sub-objectives spanning magnetopause, magnetotail, turbulent current sheet, and bow shock physics. SO2 (FY29 – FY32) will "discover how mesoscale (1 – 3 R_E) structures form and evolve in response to solar wind driving, bridging the gap between kinetic-scale processes and system-scale energy transport," enabled by an orbital reconfiguration lowering apogee to 22 R_E and widening spacecraft separations to 1 – 3 R_E. The in-guide budget supports full accomplishment of SO1 and demonstration of SO2 feasibility; complete realization of SO2 requires over-guide funding.

The Mission Operations Center (MOC) and Flight Dynamics Operations Areas (FDOA) at GSFC perform spacecraft bus operations including mission planning, real-time pass operations, orbit determination, and maneuver planning. MMS has transitioned to the GSFC virtualized Multi-Mission Operations Center (vMMOC) and begun cross-training with SDO for consolidation into a multi-mission unit. For FY27 – FY29, the mission will reduce support for non-routine activities, reduce on-call support from 24/7 to business hours by FY29, and evaluate onboard instrument automation leveraging the MEDOS demonstration. For FY30 – FY32, a re-engineering study will define a restructured operations concept, potentially including reducing DSN contacts from 5 to 3 per orbit, extending planning cycles, eliminating routine maneuvering after mid-FY30, and transitioning from science-driven to health-and-safety-driven operations.

The Science Operations Center (SOC) at LASP manages instrument operations, burst data selection via the Scientist-in-the-Loop system, and data distribution. The Science Data Center (SDC) serves as the central hub for data processing, archiving, visualization, and distribution. All science-quality data are archived at NASA SPDF within 30 days of downlink in CDF format with SPASE descriptors and DOI designations. Analysis codes are publicly available through the SPEDAS framework. MMS adheres to SPD-41a and Heliophysics Science Data Management Policy requirements and funds a dedicated SPDF liaison. For FY30 – FY32, potential measures include relaxing data quality and inter-calibration requirements and evaluating data delivery requirements to accommodate smaller teams.

GSFC Space Science Mission Operations (SSMO) leads overall programmatic and mission operations management; SwRI manages the SMART science investigation including the instrument payload and data analysis. The Project Scientist focuses on science leadership and community engagement. Six leadership promotions have occurred since the last Senior

Review, and a "Deputies-in-Training" program is in place for succession planning across key roles including PI, PS, Mission Director, and instrument scientist positions.

Overall Evaluation/Rationale

MMS has addressed all five of its science objectives from the FY24 – FY26 extended mission. However, the proposal does not adequately demonstrate how measurements taken during the current extended mission phase address the science goals and objectives approved from the last senior review. The proposed extended mission does not adequately address the 2023 Senior Review finding (B4) to explore lowering the mission’s operations cost. The proposed pivot from micro- to mesoscale physics paves the way for Links, the next magnetospheric flagship mission. However, the proposal does not adequately describe how configuration adjustment from studying the kinetic scale to mesoscale will address Science Objective SO2. Moreover, the science objective (SO2) would not be addressed until FY30. The proposal does not sufficiently demonstrate how continued observations of MMS in tight tetrahedron formation will complete Proposed Science Objective SO1. The proposal outlined a clear and thorough description of the data products. The proposal outlines a number of important contributions and synergies with the HSO. The primary data products and regions sampled by the MMS upcoming mission represents a unique and clearly highly impactful set of datasets, given the demonstrated record of high-profile publications. However, the utility of MMS for space weather operational needs has not been demonstrated. MMS continues to operate nominally, for the most part, observing the magnetospheric plasma at unprecedented spatial and temporal scales. The mission management plan is robust and includes succession planning and mentorship. The in-guide budget costs for mission operations and science operations are excessive and any efforts to reduce costs or increase efficiency are delayed until FY30 – FY32 (i.e., the next Senior Review). The justification for the overguide based on projecting required operating costs forward from 2020 is not appropriate. The major weaknesses outweigh the strengths; therefore, the proposal is rated Good/Fair.

Excellent	Excellent/ Very Good	Very Good	Very Good/ Good	Good	Good/ Fair	Fair	Fair/ Poor	Poor
					X			

Criterion A: Scientific Success in Previous Investigation

Major Strengths

(A-1): MMS addressed all five of its science objectives from the FY24 – FY26 extended mission. Specific accomplishments include: The discovery of Earth's reconfiguration into

Alfvén wings during the April 2023 CME (SO1), publication of a 16-paper ISSI book compiling reconnection discoveries (SO2), the first direct measurement of 500 keV ions accelerated by turbulent electric fields in magnetotail reconnection (SO3), measurements of turbulent plasma thermodynamics significantly advancing our understanding of turbulent dissipation in collisionless plasmas (SO4), and detection of the highest-energy electrons ever recorded at Earth's bow shock (500 keV) due to a new "reinforced shock acceleration" mechanism (SO5). The "string-of-pearls" campaign generated more than 10 papers using 2024 data from dayside and flank phases, many led by early career scientists.

Minor Strengths

None noted.

Major Weaknesses

(A-1): The proposal does not adequately demonstrate how measurements taken during the current extended mission phase address the science goals and objectives approved from the last Senior Review. Most of the major science accomplishments for the third extended mission cited in the proposal are based on MMS data taken prior to the third extended mission. The proposal highlights four studies as major accomplishments addressing science objectives from the third extended mission FY24 – FY26. One is the extreme reconfiguration of the magnetosphere during the April 2023 CME event (Chen et al., 2024), another is the high particle energization in a turbulent magnetotail region using MMS data from 2019 (Qi et al., 2024), another is Manzini et al (2024) looking at the thermodynamics of plasma turbulence using MMS data from 2018, and the fourth is an analysis of the particle energy spectrum in the Earth's bow shock using data from 2017. The proposal lists several papers in preparation based on 2024 dayside and flank observations but does not show how new spatial and temporal sampling methods that were proposed have been used in the current extended mission's science investigation.

(A-2): The proposed extended mission does not adequately address 2023 Senior Review finding B4 to explore lowering the mission's operations cost. The 2023 Senior Review identified a concern for the high cost-to-science ratio of MMS and indicated methods to lower cost operations should be explored. The proposal does demonstrate how science investigation costs have been reduced, but the major cost drivers of Mission operations and Science operations do not realize any savings until after a re-engineering study is completed. To be responsive to the 2023 Senior Review findings, the mission should have conducted these types of studies already and been prepared to implement significant cost savings in these areas earlier than the FY30 – FY32 timeframe. Most proposed cost savings in response to 2023 Senior Review weakness B4 will not be realized in the 3-year extended operations covered by this review.

Minor Weaknesses

None noted.

Criterion A Rating

Excellent	Very Good	Good	Fair	Poor
		X		

<u>Criterion B: Evaluation of the Proposed Science Investigation</u>

Major Strengths

(B-1): The proposed pivot from micro- to mesoscale physics could pave the way for Links, the next magnetospheric flagship mission. SO2 addresses mesoscale physics (1 – 3 R_E structures), investigating how kinetic processes drive system-scale energy transport. Understanding the mesoscale consequences of kinetic scale reconnection is crucial for making the connection to space weather effects in the inner magnetosphere (e.g., radiation belt fluxes) and in Low Earth Orbit (e.g., thermospheric heating and expansion driven by magnetospheric particle precipitation and field-aligned currents).

Minor Strengths

(B-1): The proposed science objective SO1 is important for improving our understanding of a wide range of phenomena in plasma physics.

(B-2): SO2's orbital reconfiguration (lowering apogee from 29 R_E to 22 R_E in November 2028 and widening spacecraft separations to 1 – 3 R_E) is feasible given remaining fuel.

(B-1, B-2): The proposal identifies specific gaps (e.g., limited magnetotail EDR observations from 2019 – 2024) and how the orbit addresses them.

(B-3): The science questions align with the Decadal Survey's guiding questions.

Major Weaknesses

(B-1): The second of the two science objectives would not be addressed until FY30. It is not clear why the proposed science and change in orbit must wait for two years. Under the current plan, this science objective would effectively not be addressed until the next Senior Review.

(B-2): The proposal does not sufficiently demonstrate how continued observations of MMS in tight tetrahedron formation will complete Proposed Science Objective SO1. The proposal states that there are gaps/needs for more EDR observations to address SO1.1 ("determine how the microphysics that enables reconnection varies across geospace") and lists a variety of observing campaigns within Phases 12 and 13 targeting various sub-objectives but does not adequately demonstrate what specific additional types of measurements are needed in the extended mission beyond what has already been observed in the last 10 years to complete the definitive investigation.

(B-2): The proposal does not adequately describe how configuration adjustment from studying the kinetic scale to mesoscale will address Science Objective SO2. There is a preliminary analysis of the configuration adjustment needed to transition from kinetic scale to mesoscale investigation (slide 20), but this analysis does not demonstrate how the observations will be used to address each gap and need identified on slide 19. The proposal does not identify any specific theories or hypotheses it will test, but simply states it will identify, quantify, and establish fundamental knowledge of mesoscale structures and their behavior. The role of coordinated observations with other platforms (e.g. THEMIS) is mentioned but not adequately described, especially important if upstream solar wind conditions are needed.

Minor Weaknesses

None noted.

Criterion B Rating

Excellent	Very Good	Good	Fair	Poor
			X	

<u>Criterion C: Contribution to the Heliophysics System Observatory and National Priorities</u>

Major Strengths

(C-1): The primary data products and regions sampled by the MMS upcoming mission represents a unique and clearly highly impactful set of datasets, given the demonstrated record of high-profile publications. MMS is currently the only mission to resolve the structure and dynamics of magnetospheric current sheets in regions that act as sources of meso- and global scale space weather phenomena like geomagnetic storms and substorms. These data products are demonstrably unique and extremely valuable to the heliophysics community.

(C-2): The proposal outlined a clear and thorough description of the data products and production pipeline. The current method that involves providing data products directly to the SPDF and simultaneously to an on-line webserver for the mission complies with the SPD-41a and represents a convincing method for ensuring open access to the mission data products.

The analysis software and the PDMP/CMAD plans appear to be fully compliant with HPD open science policies.

Minor Strengths

(C-3): The proposal outlines a number of important contributions and synergies with the HSO.

Major Weaknesses

None noted.

Minor Weaknesses

(C-2): The proposal did not sufficiently discuss to what degree the SDC at Boulder serves as the primary repository, or if all the data present at the SDC is archived at the SPDF as well.

Criterion C Rating

Excellent	Very Good	Good	Fair	Poor
	X			

<u>Criterion D: Technical Implementation</u>

Major Strengths

(D-1): MMS continues to operate nominally observing the magnetospheric plasma at unprecedented spatial and temporal scales. All four spacecraft are healthy with instruments still meeting L1 requirements. Fuel reserves are sufficient through a 2041 natural re-entry.

(D-4): The mission management plan is robust and includes succession planning and mentorship. The leadership team has ample experience and has demonstrated leadership for the numerous organizations involved in this mission. Six succession promotions have occurred since the last Senior Review, and seven additional leaders in training have been identified with specific proposed role transitions.

Minor Strengths

(D-3): The apogee lowering in 2028 combined with a small perigee raise in 2030 results in natural re-entry in April 2041 complies with debris requirements.

Major Weaknesses

(D-2): The excessive in guide budget costs for mission operations and science operations are not sufficiently justified, and efforts to significantly reduce costs or increase efficiency are delayed until FY30 – FY32 (i.e., next Senior Review). To maintain healthy operations in the FY27 – FY29 timeframe, the project drastically reduces science investigation funding but delays any efforts to reduce operations costs until at least FY30 – FY32 when a re-engineering study is completed. The current cost projections for FY27 – FY29 will continue science operations for SO1 i.e., completing a definitive investigation of kinetic microphysics, which does not differ significantly from objectives and implementation conducted during the current extended mission period FY24 – FY26.

Minor Weaknesses

(D-1): Minor degradations exist (EDI passive mode on MMS 2 and 3, three micrometeorite-damaged spin-plane probes, two disabled DES on MMS4, loss of 3D E-field on MMS4) but none compromise mission-level science.

(D-2): The proposal did not provide a justification for continued funding to retain their primary data archives and services outside of the final repository of record, the HDRL.

Criterion D Rating

Excellent	Very Good	Good	Fair	Poor
			X	

<u>Criterion E: Under-guide and Over-guide Requests (Informational Only)</u>

Major Strengths

None noted.

Minor Strengths

None noted.

Major Weaknesses

(E-3, E-4): The overguide is not well justified. The budget justification was inappropriately based on a validation of their required operating costs in 2020 and then applying it for the future. Using an internal bottom-up process that was completed in 2020 to determine the minimum required funding for the project without external review should not be used for justifying future cost estimates. This effort on future costs should be looked at for each Senior Review using current information necessary for personnel costs and operational costs.

Minor Weaknesses

None noted.

Parker Solar Probe

Proposal Summary

Since its launch in 2018, Parker Solar Probe has transformed heliophysics by venturing deeper into the solar atmosphere than any previous mission and returning unprecedented observations from the Sun's outer corona and inner heliosphere. The mission has achieved historic milestones, including the first direct exploration of the solar corona, the discovery of ubiquitous magnetic switchbacks, direct measurements of the energy flow powering the solar wind, new insights into plasma turbulence and particle acceleration, and breakthrough observations of dust, shocks, energetic particles, and solar eruptions near their source regions. Parker Solar Probe has fundamentally reshaped our understanding of the solar wind, the corona, and the heliosphere, while establishing itself as a cornerstone of the HSO and a catalyst for a new era of solar and space physics discovery.

Throughout the prime mission, Parker Solar Probe progressively approached the Sun while Solar Cycle 25 rose toward solar maximum, enabling humanity's first close-range observations of the young and highly dynamic solar wind under conditions of elevated solar activity. Now, as the mission enters the declining phase of Solar Cycle 25 while maintaining repeated close perihelia at only 8.85 solar radii, Parker Solar Probe is uniquely positioned to explore an entirely new regime of heliophysical science.

The overarching goal of the proposed extended mission is to understand the energy flow, plasma and particle dynamics, and solar activity in the inner heliosphere during the declining phase of the solar cycle, shedding light on how these processes impact and shape the solar environment. Parker Solar Probe's continued close-in observations will, for the first time, allow scientists to directly monitor the solar atmosphere as it evolves from the highly chaotic and variable conditions near solar maximum toward a more organized global structure. The mission will provide unprecedented measurements of the mature fast solar wind emerging from equatorial coronal holes, enabling critical tests of theories of solar wind acceleration, plasma heating, turbulence evolution, and energetic particle transport. At the same time, Parker Solar Probe will remain capable of observing powerful solar storms near their origin, offering unique insight into the mechanisms driving space weather throughout the heliosphere.

Parker Solar Probe is in excellent health, with all systems, instruments, and operations centers performing nominally. Consumables and expected degradation allow for full operations for more than the next decade. During the proposed extended mission, routine operations will occur on a recurring basis, and contingency operations will occur as needed. Delivery of science data from each orbit will be performed within 90 days of the orbit dataset downlink.

Parker Solar Probe has simplified operations and automated processes and will continue to exploit additional opportunities to reduce costs while still achieving revolutionary science.

<u>Overall Evaluation/Rationale</u>

Parker Solar Probe has delivered transformative new science discoveries and has exceeded its science objectives for the prime science mission that ended in September 2025. Understanding the energy flow, plasma and particle dynamics, and solar activity in the inner heliosphere during the solar cycle's declining phase is a compelling and highly appropriate overall science goal for the proposed extended mission. However, the proposal did not demonstrate how the mission would measure or define progress on the science objectives proposed for the next three years. Parker Solar Probe has conducted coordinated observation campaigns with other missions in the HSO and with ground-based observatories during its prime mission, and the proposed extended mission science objectives explicitly call out opportunities for synergistic science with other HSO assets. Parker Solar Probe has returned data volumes that significantly exceed mission requirements on every orbit to date, and these data are publicly available through the appropriate archives. The data and code management plan is thorough, and the needs for each instrument are addressed. The mission remains in excellent health, with all spacecraft systems, instruments, and ground systems operating nominally at the end of the prime mission. The management plan is thorough with clearly defined roles and responsibilities for key positions including the Project Manager, Project Scientist and Mission Systems Engineer. However, the proposal does not demonstrate why such a large team and so much funding is needed to operate Parker Solar Probe and its instruments. The numerous major strengths outweigh the major weaknesses; therefore, the proposal is rated Very Good.

Excellent	Excellent/ Very Good	Very Good	Very Good/ Good	Good	Good/ Fair	Fair	Fair/ Poor	Poor
		X						

<u>Criterion A: Scientific Success in Previous Investigation</u>

Major Strengths

(A-1) Parker Solar Probe has delivered transformative new science discoveries and has exceeded its science objectives for the prime science mission that ended in September 2025. The mission has made numerous exciting new discoveries that were completely unexpected and are redefining our understanding of how the solar corona is heated, the sources of the solar wind and how the wind is accelerated, and the origins and acceleration of solar energetic particles. These discoveries include: (1) "magnetic switchbacks", unexpected highly Alfvénic flows that dominate the near-Sun solar wind, (2) the first direct measurements of the solar wind electric potential, quantifying the contributions of proton pressure, electric pressure, and wave energy to solar wind acceleration, (3) the "helicity barrier", a kinetic phenomenon that reduces the turbulent energy cascade and fundamentally alters the rate of coronal and solar wind heating, and (4) long particle path lengths near the Sun, unexpected intermittent heavy ion rich events close to the Sun, and CIR associated particle well inside 1 AU. Additional discoveries beyond the original objectives include confirming the near century old prediction of a stellar dust free zone around the Sun, discovering a new dust beta stream from the 3200 Phaethon trail, detecting the shortest thermal emission wavelength from Venus's surface, and discovering dust rings along the orbits of Venus and Mercury. The mission science team has an excellent track record of publishing research results and collaborating with scientists outside the core mission team to achieve the best science.

Minor Strengths

(A-1): The Parker Heliophysics Scholars is a unique program that provides opportunities for early career scientists to participate in mission science and learn from more senior scientists.

(A-1): Parker Solar Probe has been widely recognized by the science community as evidenced by 7 prestigious awards.

Major Weaknesses

None noted.

Minor Weaknesses

None noted.

Criterion A Rating

Excellent	Very Good	Good	Fair	Poor
X				

<u>Criterion B: Evaluation of the Proposed Science Investigation</u>

Major Strengths

(B-1, B-3): Understanding the energy flow, plasma and particle dynamics, and solar activity in the inner heliosphere during the solar cycle's declining phase is a compelling and highly appropriate overall science goal for the proposed extended mission. The prime mission covered the rising phase of Solar Cycle 25, from near minimum conditions in 2018 to maximum activity in 2025. The proposed extended mission science will cover a large part of the declining phase of the cycle, thus providing a complete picture of how the Sun and the heliosphere evolve over a full cycle. The extended mission science objectives are clearly laid out in the proposal. These objectives are compelling and highly appropriate for the mission in the declining phase of the solar cycle. (1) The extended mission will make significant progress toward understanding how the near solar environment transitions to a more organized structure during the decline to solar minimum. Parker Solar Probe will provide an unprecedented view of this transition. (2) The extended mission will provide a unique view of post-CME recovery dynamics and how solar energetic particle (SEP) event characteristics change with radial distance. Parker Solar Probe can observe energetic particle sources from the side before making in situ observations. (3) Parker Solar Probe will enable more sustained excursions into the sub-Alfvénic solar wind during the solar cycle declining phase. This will provide answers to some key open questions, including (i) how does the Alfvén surface evolve with the solar cycle, and (ii) what heating/dissipation mechanisms operate in the sub- and super-Alfvénic regions?

Minor Strengths

(B-1, B-3) The extended mission will hold a constant orbit with a perihelion distance of ~9 solar radii, significantly increasing time below 10 solar radii and expanding from 30 to 102 hours by October 2029.

Major Weaknesses

(B-2): The proposal did not demonstrate how the mission would measure or define progress on the science objectives proposed for the next three years. It is not clear that all the proposed science objectives could be achieved before reaching solar minimum, risking that the project will return to the next Senior Review requesting more observations and time to meet the proposed science.

Minor Weaknesses

None noted.

Criterion B Rating

Excellent	Very Good	Good	Fair	Poor
	X			

Criterion C: Contribution to the Heliophysics System Observatory and National Priorities

Major Strengths

(C-1): The data and code management plan is thorough, and the needs for each instrument are addressed. Coordination of science data sharing between instrument teams is beneficial for optimizing the science return from Parker Solar Probe.

(C-2): Parker Solar Probe has returned data volumes that significantly exceed mission requirements on every orbit to date, and these data are publicly available through the appropriate archives. These data are also made publicly available through the instrument team science operations centers (SOCs) and the Parker Solar Probe Gateway.

(C-3): Parker Solar Probe has conducted coordinated observation campaigns with other missions in the HSO and with ground-based observatories during its prime mission, and the proposed extended mission science objectives explicitly call out opportunities for synergistic science with other HSO assets. The mission has conducted extensive encounter campaigns with Hinode, IRIS, SDO, STEREO, NuSTAR, MMS, ARTEMIS, TIMED, and ICON. Ground based observatories with which the mission has conducted coordinated observations include DKIST, BBSO, Kanzelhohe, Hvar, and various radio arrays.

Minor Strengths

None noted.

Major Weaknesses

None noted.

Minor Weaknesses

(C-2): The mission CMAD is far from complete. This has been an ongoing topic of negotiation with the mission team. It is understood that the CMAD provided with this proposal is a draft, and the CMAD will be completed over the first year of an extended mission. This is a minor weakness because the mission team discussed plans for completion of the CMAD with NASA HQ before submitting the senior review proposal and received approval to submit the CMAD in draft form.

(C-2): The proposal did not provide a justification for continued funding to retain copies of the data archives and services outside of the final repository of record, the HDRL.

Criterion C Rating

Excellent	Very Good	Good	Fair	Poor
X				

<u>Criterion D: Technical Implementation</u>

Major Strengths

(D-1): The Parker Solar Probe mission remains in excellent health, with all spacecraft systems, instruments, and ground systems operating nominally at the end of the prime mission. There are sufficient consumables to continue normal operations for many years. The mission has been fully operational 99.7% of the time since launch with zero demotions during encounters. The FIELDS instrument search coil magnetometer radial component anomaly that occurred early in the prime mission has been partially mitigated and does not impact mission success. The proposed extended mission operations are a routine extension of prime mission operations, with no changes planned to the final orbit achieved during the nominal mission. This will enable a significant increase in the time spent taking measurements inside the critical Alfvén surface where the solar wind originates and can be expected to yield new science results. The team has identified opportunities for new staff to take on key roles in mission operations under the mentorship of senior colleagues.

(D-4): The Management Plan is thorough with clearly defined roles and responsibilities for key positions including the Project Manager, Project Scientist and Mission Systems Engineer. No key personnel changes are anticipated from the prime mission to the proposed extended mission. Deputies have been assigned for key roles and leadership succession plans are in place across all four instrument teams.

Minor Strengths

(D-2): The project has simplified operations and has identified potential efficiencies in mission operations, including automation of some processes, although the projected cost savings are modest. These changes include transitioning to an integrated Mission Design and Navigation Team, decreasing from five to three command loads per orbit, automating command generation, upgrading ground software for longevity/security in 2025, and modernizing the telemetry pipeline.

(D-3): Requirements for SCaN support for deep space communications are well understood and are reasonable.

(D-3): The End of Mission Plan is compliant with NASA-STD-8719.14C, with no significant risk against implementation.

Major Weaknesses

(D-2): The proposal does not demonstrate why such a large team and so much funding is needed to operate Parker Solar Probe and its instruments. For example, the proposal does not justify the need for so many systems engineering FTEs and funding, given the mission is now in extended operations. For a mission in extension, major interventions in the spacecraft due to anomalies should not be expected, nor do they need to be solved immediately. In addition, the mission is no longer executing Venus flybys, and the need for large planning and operations efforts is not proven as the spacecraft will simply remain in its current orbit for this extension. The proposal indicates a need for planning the instrument set-up for each encounter, but that should be significantly reduced and automated post-prime mission. The proposal did not justify the requested budget for the project science office during the proposed mission extension.

Minor Weaknesses

None noted.

Criterion D Rating

Excellent	Very Good	Good	Fair	Poor
		X		

<u>Criterion E: Under-guide and Over-guide Requests (Informational Only)</u>

Major Strengths

(E-1): The proposal makes a persuasive argument that over guide requests for FY30 – FY32 would restore science investigation funding, allow for safely operating the instruments and avoid operating below minimum staffing. The proposal makes a case that without over-guides or significant restructuring, no science investigation can be performed from FY31 onward, and the FY32 NOA would not cover safe instrument operations.

Minor Strengths

None noted.

Major Weaknesses

(E-1): The proposal does not justify the need for the two over guide requests. The proposal states that these over guides can be paid for using expected carryover funds in future years. This suggests that the mission does not need all its in-guide funding to accomplish its proposed extended mission science objectives, or the effort included in the over guide requests should be part of the in-guide proposal.

Minor Weaknesses

None noted.

Time History of Events and Macroscale Interactions During Substorms – Acceleration, Reconnection, Turbulence and Electrodynamics of Moon's Interaction with the Sun (THEMIS – ARTEMIS)

Proposal Summary

The THEMIS - ARTEMIS mission proposes to address how localized, transient drivers produce the observed near-Earth space weather responses. Specifically, the proposed mission investigates how magnetotail reconnection outflows and dayside reconnection/transients drive ring current and radiation belt flux enhancements, how the lunar space weather environment varies with solar activity and lunar phase, and how dust and micrometeoroid hazards at the Moon vary with lunar phase and geometry. The approach relies on a redesigned orbit placing the three THEMIS inner probes in equiphased locations so that one probe is always near apogee, enabling routine neutral sheet crossings twice daily and systematic radial conjunctions between probes traversing the inner and outer magnetosphere simultaneously. Instrumentation will be updated via GEANT4-based recalibration of the Solid-State Telescope (SST), extending its energy range to >1 MeV for electrons and >6 MeV for protons to operate in the radiation belt and SEP environments. ARTEMIS will use its dual-spacecraft configuration and recalibrated SST and Electric Field Instrument (EFI) to characterize the lunar radiation and plasma environment in support of NASA's Artemis program. Science analysis will develop data-driven and physics-informed models (AI/ML progressing to PINNs) to build operationalizable space weather forecasting capability.

Operations will emphasize safe, cost-efficient execution with increased reliance on automation, automated scheduling, and simplified science data collection, including longer Fast Survey intervals along the inner probe orbits achieved by either spinning down spacecraft spin rate or averaging consecutive spins. Additional downlinks from Brazil/INPE are under study to supplement the primary Berkeley ground station (BGS), NSN, SSC, and DSN contacts and reduce reliance on NASA networks. The propellant situation is nominal for most probes, with re-entry compliance plans in place or underway; TH-A has a propellant access complication resulting from a micrometeoroid impact on an EFI sphere that displaced the center of gravity, which the team is actively investigating through small-pulse maneuver strategies, with no impact on SR26 science.

All L0 – L2 data are processed through an end-to-end pipeline and archived at SPDF in CDF format with SPASE metadata, with mirror sites in Japan and Europe. Open-source analysis tools (SPEDAS/pySPEDAS) are maintained and distributed. Ongoing activities include continuous calibration updates and L2 reprocessing, metadata modernization, SST/EFI/FGM recalibration campaigns, and community support. Under the in-guide budget, science

operations are sustained through FY32, though science investigation funding declines sharply after FY28 and reaches zero in Q2 FY29.

Overall Evaluation/Rationale

THEMIS delivered on all five Senior Review 2023 science objectives, achieving an exceptional scientific output that includes over 140 refereed publications per year on average. The science objectives will address the global chain of energy flow from the solar wind-magnetopause interaction to the magnetotail to the inner magnetosphere (ring current and radiation belts). THEMIS proposes a new orbital configuration for the three near-Earth spacecraft that will provide improved simultaneous observations of the inner and outer equatorial magnetosphere for coordinated science with other HSO assets. The proposal presents a strong data and code management plan, clearly describing how the mission will continue data archiving, software, and documentation efforts that are compliant with the Senior Review requirements. All spacecraft are operating nominally, meeting or exceeding design requirements. Based on the numerous major strengths and no major weaknesses, the proposal is rated Excellent/Very Good.

Excellent	Excellent/ Very Good	Very Good	Very Good/ Good	Good	Good/ Fair	Fair	Fair/ Poor	Poor
	X							

Criterion A: Scientific Success in Previous Investigation

Major Strengths

(A-1): THEMIS delivered on all five Senior Review 2023 science objectives, achieving an exceptional scientific output that includes over 140 refereed publications per year on average. For SO2 (Storm-time Ring Current), THEMIS demonstrated that Very Near-Earth Reconnection (VNERX) initiates the most powerful flow bursts that drive the ring current during geomagnetic storms. ARTEMIS revealed how Solar Energetic Particles (SEP) reach the Moon from all directions (including >300 Earth radii downtail), how the lunar wake forms and evolves, and how crustal anomalies and exosphere interact with the solar wind (all generally supportive of NASA's Artemis program). The team has addressed findings from the 2023 Senior Review. Three minor weaknesses were identified. Two are no longer applicable. The team has addressed the remaining weaknesses by continuing to automate fault detection.

Minor Strengths

(A-2): The team successfully addressed the only weakness from the previous senior review pertaining to the Code of Conduct.

Major Weaknesses

None noted.

Minor Weaknesses

None noted.

Criterion A Rating

Excellent	Very Good	Good	Fair	Poor
X				

<u>Criterion B: Evaluation of the Proposed Science Investigation</u>

Major Strengths

(B-1): The in-guide science objectives will address the global chain of energy flow from the solar wind-magnetopause interaction to the magnetotail to the inner magnetosphere (ring current and radiation belts). THEMIS's new 9-hour along-track orbit separation ensures one probe is always near apogee so that the neutral sheet is crossed twice per day. Multi-point radial conjunctions will allow simultaneous measurement of flow bursts at source and particle injections in the ring current/radiation belts. SO2 will address how dayside reconnection and foreshock transients drive magnetotail reconnection. The new orbit design will provide global context for downstream effects of the dayside drivers. ARTEMIS will address science objectives that are supportive to near term plans for human exploration of the lunar surface. Specifically, SO4 examines how lunar dust and micrometeoroid impact hazards vary with lunar phase and plasma environment. ARTEMIS will combine electric field dust detection with plasma context to separate intrinsic impact rates from those modulated by the plasma environment. The proposed approach integrates an "Intelligence Architecture" that progresses from machine learning through deep learning reconstruction techniques (e.g., Physics Informed Neural Networks); this will lead to enhanced space weather forecasting capability. The mission is highly aligned with the 2024 Heliophysics Decadal Survey and represents a crucial component of the HSO. THEMIS realizes the HSO concept by integrating distributed space and ground assets into a coordinated, data-assimilative observatory. It serves as a pathfinder for Links (the Decal's highest-priority future mission). ARTEMIS supports the

Artemis human exploration program by characterizing the lunar radiation and plasma environment.

Minor Strengths

(B-1): The event statistics are robust, providing an adequate number of VNERX (Very Near Earth Reconnection) events during storms and substorms.

(B-1): The Solid-State Telescope (SST) recalibration using GEANT4 tools extends energy coverage from 700 keV to > 1 MeV for electrons and > 6 MeV for protons, addressing new science objectives in the ring current, radiation belt and SEP environments.

(B-4): There is sufficient funding in the in-guide budget to safely operate the THEMIS - ARTEMIS satellites and obtain the data through the entire proposal period of performance.

Major Weaknesses

None noted.

Minor Weaknesses

(B-2): The proposal lacked a strong argument for the role of THEMIS in the extended mission in improving predictive capabilities beyond what could be accomplished via competed investigations by external researchers.

(B-3): The proposal did not demonstrate that their proposed real-time data would have operational utility. The newly calibrated particle instruments do not reach the energy levels of interest for radiation protection of human spaceflight missions, and connections and interest from operational space weather groups were not demonstrated.

(B-3): The team did not demonstrate that they worked with space weather warning operators to verify that the timing and data are of value to support the Artemis mission.

Criterion B Rating

Excellent	Very Good	Good	Fair	Poor
	X			

<u>**Criterion C: Contribution to the Heliophysics System Observatory and National Priorities**</u>

Major Strengths

(C-1): The proposal presents a strong data and code management plan. It clearly describes how the mission will continue data archiving, software, and documentation

efforts that are compliant with the Senior Review requirements. The management plan is consistent with Open Science norms as it is designed to ensure broad reuse, interoperability, and long-term preservation. User-facing tools released open-source (SPEDAS/TDAS) with complete documentation. The mission has produced and made available high-quality data (through the Space Physics Environment Data Analysis Software (SPEDAS) IDL software) developed user friendly software tools, and members of the mission team engage with the community, all enhancing the productivity and impact of the mission beyond affiliated scientists.

(C-3): THEMIS proposes a new orbital configuration for the three near-Earth spacecraft that will provide improved simultaneous observations of the inner and outer equatorial magnetosphere for coordinated science with other HSO assets. The proposal includes a plan to recalibrate one of the THEMIS instruments to provide new high-energy particle data that will fill a gap left by the demise of Van Allen Probes and will enable observations of SEP scattering in the lunar environment. The proposal identifies specific opportunities for collaborative science with existing and future HSO assets. The proposal includes tables that clearly show how THEMIS contributes both to national priorities, specifically those identified in the PROSWIFT Act, and NASA strategic priorities.

Minor Strengths

None noted.

Major Weaknesses

None noted.

Minor Weaknesses

(C-2): The proposal did not provide a justification for continued funding to retain their primary data archives and services outside of the final repository of record, the HDRL.

Criterion C Rating

Excellent	Very Good	Good	Fair	Poor
X				

<u>Criterion D: Technical Implementation</u>

Major Strengths

(D-1): All spacecraft are operating nominally, meeting or exceeding design requirements. Instruments are largely nominal, with minor issues either recovered algorithmically or on the ground or not needed for proposed science objectives. The new equiphased orbit repositioning is underway and is expected to be complete by November of 2026. Under the in-guide budget, all mission operations are sustained through FY32. Propellant is not a concern unless orbits are drastically changed. The mission is fully compliant with orbital debris requirements and is a responsible user of SCaN services and spectrum allocation. All probes meet or are on track for the <25-year re-entry requirement levied at mission confirmation.

Minor Strengths

(D-1): The proposed orbit configuration accommodates TH-A's compromised capacity to deplete its fuel due to the micrometeoroid impact.

(D-2): The operations plan seems reasonable.

(D-4): Succession planning has been proactive, and planning is underway to hire two mid-career positions at UCB to cover the pending retirement of the flight dynamics lead.

Major Weaknesses

None noted.

Minor Weaknesses

(D-1): The instruments continue to age and degrade. Some measurements have been lost on some (but not all) satellites.

(D-2): Aside from decreasing science return in the out years, there was minimal discussion of innovative ways to decrease costs.

Criterion D Rating

Excellent	Very Good	Good	Fair	Poor
	X			

<u>Criterion E: Under-guide and Over-guide Requests (Informational Only)</u>

Major Strengths

None noted.

Minor Strengths

(E-1): The over-guide proposal would enable HPD strategic science. The over-guide objectives align well with Decadal Survey recommendations and national priorities expressed in the PROSWIFT Act.

Major Weaknesses

None noted.

Minor Weaknesses

(E-1): The budget for the over-guide is designed to maintain the current FY26 budget and does not seem to be based on the science being accomplished.

(E-2): Some proposed over-guide enhancements like intelligent model development and improvement (e.g., PINN, CINEMA synergies) and expanded space weather data analysis could be accomplished by external studies.

5.2. Simplified Senior Review Evaluations

Global-scale Observations of the Limb and Disk (GOLD)

Proposal Summary

GOLD is a Foundational Science mission launched in 2018 that operates two extreme ultraviolet (EUV) imaging spectrographs providing hemispheric views of the Earth's disk and limb during day and night as a hosted payload on the SES-14 communications satellite in geosynchronous orbit over the Amazon river basin (47.5° W longitude). During the proposed extended mission, GOLD will continue to provide a unique data set of lower thermospheric temperature, composition, and nighttime ionosphere electron density profiles. The GOLD ground station is operated by the commercial host, the Science Operations Center is hosted at CU/LASP, and the Science Data Center is hosted at University of Central Florida.

Overall Evaluation/Rationale

The GOLD mission has continuously provided high-quality mission science data products and associated documentation to NASA archives. The proposal demonstrates the relevance of GOLD observations to national priorities for improving space weather prediction capabilities. Proposal demonstrates that the GOLD mission is in good health and capable of continued operations during the proposed extended mission period. However, a major component of the proposed in-guide budget is not adequately justified. The proposal does not list key personnel on the mission team and does not explicitly describe leadership succession plans. The major strengths slightly outweigh the major weaknesses; therefore, the proposal is rated Very Good/Good.

Excellent	Excellent/ Very Good	Very Good	Very Good/ Good	Good	Good/ Fair	Fair	Fair/ Poor	Poor
			X					

Criterion C: Contribution to the Heliophysics System Observatory and National Priorities

Major Strengths

(C-2): The GOLD mission has continuously provided high-quality mission science data products and associated documentation to NASA archives. The GOLD data pipeline has been routinely making science quality data available on the project's website as well as delivering science data to SPDF in a timely manner. The typical time to public release of the data is 21 days and archiving to SPDF is >99% complete. GOLD data is widely used by the research community to provide critical information on the state of the thermosphere during both active and quiet geomagnetic conditions. The data is of high value to the community as evidenced by >10M downloads/year and a rapidly growing list of publications and citations, indicating a strong scientific impact. There are comprehensive user resources for accessing archived data available on both the GOLD website and SPDF.

(C-3): The proposal demonstrates the relevance of GOLD observations to national priorities for improving space weather prediction capabilities. GOLD T_disk observations provide information on lower thermospheric density variations at high cadence (15 minutes) that have been shown to improve estimates of thermospheric neutral density changes during a recent major geomagnetic storm. GOLD composition measurements provide critical information on thermospheric circulation patterns and ionospheric plasma bubble formation that are needed to validate physics-based models of the coupled I-T system currently used for space weather prediction. GOLD directly addresses implementation item 2.5.3 of the National Space Weather Strategy and Action Plan to “identify, prepare, maintain and augment high-quality datasets for assimilation, model validation, and to optimize utilization.”

Minor Strengths

(C-1): GOLD mission data and code management plans described in the proposal are comprehensive and robust.

(C-2): The science results documented in the proposal were responsive to the weaknesses identified in the previous Senior Review.

Major Weaknesses

None noted.

Minor Weaknesses

(C-3): Although GOLD provides unique geostationary UV imaging of the thermosphere–ionosphere needed to understand the impact of space weather on the Earth’s upper atmosphere, the proposal lacked specific discussion of how GOLD would complement other HSO missions.

Criterion C Rating

Excellent	Very Good	Good	Fair	Poor
	X			

<u>Criterion D: Technical Implementation</u>

Major Strengths

(D-1): The proposal demonstrates that the GOLD mission is in good health and capable of continued operations during the proposed extended mission period. GOLD is a hosted payload on the SES-14 communications satellite that has operated with no major issues, and the mission's operating model does not introduce any major changes that would be expected to post risks to continued operations. The performance of the solar arrays and batteries is expected to support the projected power requirements for the 15-year spacecraft design life. The spacecraft's end-of-life is projected to be beyond February of 2034. Some degradation in instrument sensitivity has occurred, affecting 2 of the 6 science products (Q_EUV and O/N2), but this has been mitigated.

Minor Strengths

(D-2): The proposal lists several cost saving measures including transition from physical to virtual servers, automation of command sequence generation, and use of students.

(D-3): SES-14 has been in compliance with international law, and sustainability and safety standards throughout the lifecycle of this mission.

Major Weaknesses

(D-2): A major component of the proposed in-guide budget is not adequately justified. The proposal does not provide sufficient detail on key components such as SES-14 hosting costs, which may change throughout the duration of the proposed extended mission. In addition, the proposal does not discuss ways to limit costs as directed. For example, the proposal does not adequately describe any plans to further automate the data processing and validation as much as possible to make sure they are limiting costs.

(D-4): The proposal does not list key personnel on the mission team and does not explicitly describe leadership succession plans. There is no list of key personnel needed to evaluate the mission management plan. A succession plan is mentioned but not described in sufficient detail.

Minor Weaknesses

(D-1): The proposal did not demonstrate that the twice daily flat field measurements are sufficient should the GOLD detector temperature trends continue, resulting in temperatures far above 47K in the 2027 – 2029 period.

Criterion D Rating

Excellent	Very Good	Good	Fair	Poor
		X		

Criterion E: Under-guide and Over-guide Requests (Informational Only)

Major Strengths

(E-1): The proposed overguide for development of new L2 and L3 data products will enable valuable new ITM research. The proposed recombination-corrected O/N2 product will provide a thermospheric composition product more reliable for model/data/comparisons and data assimilation experiments. The proposed dayside T/composition profiles and nighttime electron density profiles will expand the list of science products from GOLD and enable new studies of lower thermosphere/ionosphere (E region) dynamics especially at lower latitudes, partially addressing a measurement gap left with the loss of the ICON mission.

Minor Strengths

None noted.

Major Weaknesses

None noted.

Minor Weaknesses

None noted.

Hinode

Proposal Summary

Hinode is a solar physics mission launched in 2006 by the Japan Aerospace Exploration Agency (JAXA) and operated as an international partnership among JAXA, NASA, and the United Kingdom. United States collaboration includes the National Aeronautics and Space Administration (NASA), the Lockheed Martin Solar and Astrophysics Laboratory (LMSAL), the Harvard-Smithsonian Center for Astrophysics (SAO/CFA), and the Naval Research Laboratory (NRL).

The primary objective of the mission is to investigate solar variability sources throughout the solar atmosphere. The Hinode spacecraft is equipped with three scientific instruments designed to provide coordinated observations of the solar atmosphere: (1) the Solar Optical Telescope (SOT), which images the photosphere and chromosphere and measures the strength and direction of photospheric magnetic fields; (2) the Extreme Ultraviolet Imaging Spectrometer (EIS), which provides diagnostics of plasma velocity, temperature, density, and composition in the transition region and corona; and (3) the X-Ray Telescope (XRT), which observes high-temperature plasma and provides critical diagnostics of rapidly evolving coronal structures. The three instruments aboard Hinode are designed to provide coordinated observations of the photosphere, chromosphere, transition region, and corona, enabling studies of the coupling between magnetic fields and plasma dynamics across different layers of the solar atmosphere.

Hinode has strong synergies with recent HSO missions, including Solar Orbiter and Parker Solar Probe. The proposal discusses the benefits to the HSO of continued operations for the period of review (FY27 – FY29). In particular, it also complements next-generation instruments expected to begin operations during the extension period (e.g., MUSE), as well as facilities that are now entering new operational phases. The mission is still functioning well, and the next few years will provide unique opportunities for collaboration with other observatories to provide unrivaled insight into the global solar magnetic field, how fundamental processes create and dissipate explosive phenomena, and how these processes govern coupling across spatial scales that directly addresses to Science Theme 2 of the 2024 Decadal Survey, "A Laboratory in Space: Building Blocks of Understanding." The proposal identifies efficiencies to enable Hinode to continue providing excellent science data for the community under a significantly reduced budget.

Overall Evaluation/Rationale

The Hinode mission provides high-quality mission science data products in its public archives and demonstrates excellent synergy with the HSO, other national observational assets, and upcoming next-generation instruments. The proposed data and code management plan is high-quality, comprehensive, and well-organized. The spacecraft and instruments remain in good health. However, the mission and science operations costs are not sufficiently justified, given that the mission is operated by JAXA. The proposed changes to the science operations are also not well justified and would result in an unacceptable reduction in science data return. The major strengths slightly outweigh the major weaknesses; therefore, the proposal is rated Very Good/Good.

Excellent	Excellent/ Very Good	Very Good	Very Good/ Good	Good	Good/ Fair	Fair	Fair/ Poor	Poor
			X					

<u>Criterion C: Contribution to the Heliophysics System Observatory and National Priorities</u>

Major Strengths

(C-1): The proposed data and code management plan is high-quality, comprehensive, and well-organized. The documentation contains a high level of detail and is well formatted. It will serve as an important reference for mission data and calibration during the extended mission and end-of-mission phases.

(C-2): The Hinode mission provides high-quality mission science data products in its public archives. High-level data products from SOT-SP provide disambiguated vector magnetic fields through the Solar Data Analysis Center (SDAC) and Data Archives and Transmission System (DARTS). Level 1 products for SOT, XRT, and EIS are available at the Hinode Science Center and SDAC. Search tools and data usage guides are available to the community, along with analysis software in IDL and Python.

(C-3): The Hinode mission demonstrates excellent synergy with the HSO, other national observational assets, and upcoming next-generation instruments. The Hinode team has demonstrated outstanding capability in coordinating observational campaigns with recent HSO missions (Solar Orbiter and Parker Solar Probe), other national observational assets (DKIST, SAO Submillimeter array, NASA sounding rockets), and upcoming next-generation instruments (MUSE and EUVST), adding significant value from the high-resolution instruments on Hinode. In particular, the Hinode team conducted unique stereoscopic observations of active regions, flares, and polar regions with Solar Orbiter. These advances significantly enhance the scientific return of the Hinode mission and strengthen its synergy with other HSO instruments.

Minor Strengths

(C-2): The mission is poised to complete two solar cycles of synoptic observations, delivering whole-Sun mosaics of EUV irradiance in several temperature-sensitive channels, along with polar magnetic fields, which together constitute a unique, high-resolution data set.

Major Weaknesses

None noted.

Minor Weaknesses

None noted.

Criterion C Rating

Excellent	Very Good	Good	Fair	Poor
X				

__**Criterion D: Technical Implementation**__

Major Strengths

(D-1): The Hinode spacecraft and instruments remain in good health. X-ray Telescope (XRT), Extreme-Ultraviolet Imaging Spectrometer (EIS), Solar Optical Telescope Spectropolarimeter (SOT/SP), and the Correlation Tracker (SOT/CT) are operating nominally (the Filtergraph has been inoperable and powered off since 2016).

Minor Strengths

(D-2): The mission team conducted a careful assessment to operate at increased efficiency to achieve high science value within a significantly lower budget.

(D-2): Given the mission team's substantial efforts to reduce operational costs while minimizing impacts on scientific return, along with partial financial support from international partners (some of whom are considering extending their contributions), the proposed in-guide cost is reasonable.

(D-4): The Hinode management plan is presented with sufficient detail, outlining the organizational structure across both international and U.S.-based contributors. Most of the management team is new since Senior Review 2023.

Major Weaknesses

(D-1): The proposed changes to the science operations are not well justified and would result in an unacceptable reduction in science data return. In an effort to cut operating costs, the mission put forward a plan that involves either suspending observations entirely or limiting them significantly during certain periods. While this approach may achieve financial savings, it directly leads to a substantial decrease in the amount of scientific data collected. Notably, the proposal fails to address the possibility of optimizing or automating science planning, which could help maintain the expected level of data return for foundational science missions. As a result, the diminished science output ultimately undermines the mission's overall value and its contribution to the scientific community.

(D-2): The mission and science operations costs are not sufficiently justified. Given that the mission is primarily operated by JAXA, the level of funding requested for mission and science operations exceeds what would be reasonable for the role the US Hinode team plays. The main roles of the U.S.-based Hinode team are to support science operations and to process and calibrate science data, which is not currently reflected in the budget.

Minor Weaknesses

None noted.

Criterion D Rating

Excellent	Very Good	Good	Fair	Poor
			X	

<u>Criterion E: Under-guide and Over-guide Requests (Informational Only)</u>

Major Strengths

None noted.

Minor Strengths

None noted.

Major Weaknesses

(E-1, E-2): The over-guide budget request for FY30 – FY32 is not well justified. The budget is based on maintaining FY29 budget level.

Minor Weaknesses

None noted.

Solar Dynamics Observatory (SDO)

Proposal Summary

This proposal is submitted to the 2026 Heliophysics Senior Review for continued operation of the SDO and its three instruments through the next extended mission phase. SDO launched in February 2010 into a geosynchronous orbit that supports near-continuous science downlink to a dedicated ground station at White Sands, New Mexico. The observatory carries three instruments: the Atmospheric Imaging Assembly (AIA), which captures full-disk coronal images in seven extreme ultraviolet bands and two chromospheric channels at twelve-second cadence; the Helioseismic and Magnetic Imager (HMI), which produces full-disk Doppler measurements and both longitudinal and vector magnetograms of the solar photosphere; and the Extreme ultraviolet Variability Experiment (EVE), which measures EUV spectral irradiance across the soft X-ray and EUV bands. Now in its sixteenth year of operation, all three instruments and the spacecraft remain in excellent health, with degradation tracking within expected bounds.

SDO addresses five objectives in solar and heliospheric physics: tracking subsurface flows and structures during the rising and peak phases of solar activity, characterizing magnetic variability across cycle timescales, exploring magnetic connections from the Sun throughout the heliosphere, revealing the fundamental physics of solar atmospheric dynamics and eruptive events, and understanding the space-weather and space-climate impacts of solar variability on Earth and other planets. The mission is currently observing its second complete solar cycle, providing the first multi-cycle baseline at SDO's resolution and cadence and enabling direct comparison of dynamo and active-region behavior across cycles. Cumulative AIA and HMI data products exceed 22 PB; community downloads average 130 TB per month, and SDO data underpin more than 500 refereed publications annually.

SDO is a foundational asset of the HSO and remains the only space-based source of full-disk photospheric magnetograms, the boundary condition required by nearly every operational solar-wind, coronal-mass-ejection propagation, and magnetic-connectivity model. SDO data products are delivered routinely to NOAA's Space Weather Prediction Center, NASA's Moon-to-Mars Space Weather Analysis Office, NASA mission planning, operational modelers, and the broader research community. The mission directly supports national space-weather priorities established under the Promoting Research and Observations of Space Weather to Improve Forecasting Act (PROSWIFT, PL 116-181) and contributes to the science priorities of the 2024 NASEM Heliophysics Decadal Survey.

Overall Evaluation/Rationale

SDO serves as a key asset within the HSO, providing high‑quality, continuous, full‑Sun observations that underpin both scientific discovery and space‑weather prediction capabilities. The SDO spacecraft and its instruments remain healthy and are expected to support operations for several more years. However, the proposed operational costs remain high without a sufficient justification, due to the proposal's lack of sufficient detail in the work description. In particular, the proposed operation costs are too high because SDO has failed to move the archives to SDAC, which has prevented significant cost savings. The proposal did not provide a credible plan to transfer the mission data archive to the official repository of record at the SDAC, as required in the 2026 Senior Review Call for Proposals. The proposed decisions on budgetary priorities are not aligned with a foundational science mission. The absence of rocket underflights for EVE and AIA calibration in the in-guide proposal will lower the quality of future data products from these instruments. Based on the balance of major strengths and weaknesses, the proposal is rated Good.

Excellent	Excellent/ Very Good	Very Good	Very Good/ Good	Good	Good/ Fair	Fair	Fair/ Poor	Poor
				X				

Criterion C: Contribution to the Heliophysics System Observatory and National Priorities

Major Strengths

(C-3): SDO serves as a key asset within the HSO, providing high‑quality, continuous, full‑Sun observations that underpin both scientific discovery and space‑weather prediction capabilities. SDO mission measurements span the deep solar interior through the outer corona, enabling detailed studies of solar variability, magnetic field evolution, atmospheric heating, and eruptive events while supplying essential context for planning, executing, and analyzing all HSO missions. SDO's datasets support cross‑calibration, validation, targeting, and multi‑instrument investigations across the HSO and extend to other disciplines, including Astrophysics, Planetary Science, and Earth Science, as well as to national space‑weather priorities outlined in the PROSWIFT Act. SDO/HMI provides magnetograms to space weather forecasters worldwide as a backup to NSF's GONG network. While SDO is not meant to be an operational asset and should not be operated as such, this specific HMI data is relied upon. In addition, Sun-as-a-star observations from EVE and complementary instruments provide benchmarks for stellar variability and magnetic‑activity studies, helping place the Sun within the broader population of solar-type stars. SDO images and data are therefore deeply integrated across NASA projects and widely used throughout the scientific community.

Minor Strengths

(C-1): The data management plan provides a comprehensive overview of the data acquisition, processing, storage, and distribution activities of the SDO mission.

(C-1): The code management plan (Calibration Measurement and Algorithms Document) provides a detailed description of the calibration, anomaly correction, and data processing procedures.

Major Weaknesses

(C-2): The proposal did not provide a credible plan to transfer the mission data archive to the official repository of record at the SDAC, as required in the 2026 Senior Review Call for Proposals. These activities should be performed within the mission's in-guide budget. While the proposal communicated the substantial size of the SDO archive housed at the Joint Science Operations Center (JSOC) at Stanford University, it did not provide a credible argument for retaining this valuable archive separate from the SDAC. In particular, the proposal does not discuss how, in consultation with NASA, data products for both research and space weather stakeholders will be prioritized for transfer to the SDAC. Despite regular meetings with the SDAC since the 2023 Senior Review, it appears that little to no progress has been made in this direction over the last three years.

Minor Weaknesses

None noted.

Criterion C Rating

Excellent	Very Good	Good	Fair	Poor
	X			

<u>Criterion D: Technical Implementation</u>

Major Strengths

(D-1): The SDO spacecraft and its instruments remain healthy and are expected to support operations for several more years. The health status for the spacecraft, instruments, MOC, and ground systems are nominal. Propellent is available to continue operation for over 50 years. All subsystems have an expected life of more than 5 – 10 years. The mission instruments maintain an exceptionally low fraction of missing data – approximately

0.5% for HMI and less than 0.2% for AIA over the entire mission – indicating that no major changes to the observing plan are required.

Minor Strengths

(D-4): The leadership team includes members at different stages of their careers, creating a balanced mix of mid-career instrument scientists and senior leaders. Cross-training efforts and a transition to a multi-mission team with SDO, MMS, and Wind improve the leadership succession plan.

Major Weaknesses

(D-1): The absence of rocket underflights for EVE and AIA calibration in the in-guide proposal will lower the quality of future data products from these instruments. In-guide budget reductions drive removal of rocket underflights, which is the only path to maintaining absolute EUV accuracy. Without rocket flights, the EVE observations will not meet the Level 1 30% accuracy requirement and the scientific return from the instrument will significantly decrease.

(D-2): The proposal did not justify the proposed high operational costs, due to the proposal's lack of sufficient detail in the work description. Under the in-guide budget, the team anticipates maintaining roughly the same level of performance through FY27, followed by potential interruptions in low-latency observations for space weather users and reduced calibration and validation capabilities, data recovery limitations, and other operational impacts by FY30. The SDO proposal does not articulate clearly what activities would be performed with the remaining budget. The proposal also does not address opportunities to increase automation to reduce operational costs. The SDO proposal shows the mission is currently operating in almost the same way as an "operational" asset that significantly increases operational cost. For instance, the proposal discusses the requirement of about 11 FTEs to support "timely human intervention." Because SDO is a science mission, the "operational" requirements for data delivery do not apply. Therefore, given the mission's age, more risk can be taken, and longer outages can be tolerated. The high operational cost due to a GEO orbit is not justified. The proposal states that GEO spacecraft are more labor-intensive to operate, however many satellites in similar orbits are operated "lights-out." Additionally, there are no major maneuvers or changes to the orbit on a regular basis that are expected to require so much labor.

(D-2): The proposed operation costs are too high because SDO has failed to move the archives to SDAC, which has prevented significant cost savings. The proposal identified JSOC as the primary source of data outages and delays. The age of the systems and equipment contribute to this challenge. These data outages are where the team spends most of their time on nights and weekends recovering the data stream.

Minor Weaknesses

(D-2): The proposal does not demonstrate that in-guide budget reductions would require transitioning the SDO website to primarily static content, given that it should be a fully automated process to display the latest data.

Criterion D Rating

Excellent	Very Good	Good	Fair	Poor
			X	

<u>Criterion E: Under-guide and Over-guide Requests (Informational Only)</u>

Major Strengths

None noted.

Minor Strengths

None noted.

Major Weaknesses

(E-1, E-2): The proposed decisions on budgetary priorities are not aligned with a foundational science mission. The over-guide budget only supports maintaining the current operational level. It provides no flexibility to respond to future degradation risks or evolving scientific priorities, ultimately constraining the mission's potential scientific return and long-term sustainability. In particular, the proposal did not justify why the over-guide budget is used to perform data calibration and validation, which should be the last items to be cut in a foundational science mission, not the first.

Minor Weaknesses

(E-1): The proposal did not adequately justify the over-guide request #2 needed to maintain EUV accuracy for space weather forecasting. However, the EVE line from over-guide request #1 is nearly the same magnitude, and it is unclear why both over-guide requests would need to be fulfilled to maintain the same level of accuracy.

(E-2): The over guide proposal would not fully implement the transition of the SDO archive to the SDAC because it only addresses the archiving of incoming new data.

Solar-Terrestrial Relations Observatory (STEREO)

Proposal Summary

STEREO will continue to operate near 1 AU outside of the Sun-Earth line for the next 3-year extension, and during that time it will continue gathering data and images from its four instrument suites: SECCHI, IMPACT, PLASTIC, and S/WAVES. STEREO will provide coronagraphic images of the Sun and solar wind data from a unique vantage point in the solar system, including from near Sun-Earth L4 in 2026 and 2027. STEREO data continues to be scientifically valuable and is used by space weather forecasters across NASA and NOAA.

Overall Evaluation/Rationale

STEREO data products are well integrated with the HDRL, and STEREO data are easily accessible via both the SDAC and SPDF. STEREO-A's unique orbit off the Sun-Earth line provides valuable space weather data. While STEREO is near Sun-Earth L4, it will be a pathfinder for future L4 missions and provide valuable measurements of SEP events originating near the solar western limb and imaging of CMEs and CIRs during the declining phase of the solar cycle. The STEREO-A spacecraft remains healthy with sufficient fuel to operate for decades, and all instruments are operating nominally. Based on the numerous major strengths and the absence of major weaknesses, the proposal was rated Excellent.

Excellent	Excellent/ Very Good	Very Good	Very Good/ Good	Good	Good/ Fair	Fair	Fair/ Poor	Poor
X								

Criterion C: Contribution to the Heliophysics System Observatory and National Priorities

Major Strengths

(C-1, C-2): STEREO data products are well integrated with the HDRL, and STEREO data are easily accessible via both the SDAC and SPDF. The archival mission products are of the highest quality and are routinely used in space weather forecasting by NASA groups, federal agency partners (NOAA/SWPC), and commercial entities. The proposed data and code management represent a compelling approach for immediate archival with HDRL and integration with key visualization tools, such as the VSO. The data product and the documentation are archived at the STEREO Science Center and within SDAC and SPDF. New CMADs have been produced and are publicly available. Quick-look products are available to the public.

(C-3): STEREO-A's unique orbit off the Sun-Earth line provides valuable space weather data. Via the near real-time space weather beacon, STEREO data are routinely used in development of space weather applications for both human and robotic NASA missions, and the data is also often referenced by space weather forecasters during storm events. STEREO data are particularly critical for tracking coronal mass ejections (CMEs) and solar energetic particle (SEP) events between the Sun and Earth and are routinely used to forecast potentially hazardous space weather conditions. With the loss of MAVEN, STEREO-A provides the only solar wind, magnetic field, and radiation measurements connected to Mars for a significant portion of the Martian orbit, until the arrival of ESCAPADE at Mars in 2027. STEREO data are widely used in research studies involving other HSO assets, as evidenced by the continuing strong publication record of papers utilizing STEREO data.

(C-3): While STEREO is near Sun-Earth L4, it is a pathfinder for future L4 missions and provide valuable measurements of SEP events originating near the solar western limb and imaging of CMEs and CIRs during the declining phase of the solar cycle. This location provides a unique perspective that is valuable for heliospheric model selection, heliospheric model validation, and space weather studies of other planets. This location also provides important resources for new HSO missions, including IMAP, SunRISE, and PUNCH, as well as NOAA's Solar-1.

Minor Strengths

None noted.

Major Weaknesses

None noted.

Minor Weaknesses

None noted.

Criterion C Rating

Excellent	Very Good	Good	Fair	Poor
X				

<u>Criterion D: Technical Implementation</u>

Major Strengths

(D-1): The STEREO-A spacecraft remains healthy with sufficient fuel to operate for decades, and all instruments are operating nominally. The mission has a demonstrated record of operating fully with just STEREO-A and providing useful data products in its current state. The spacecraft, instruments, and project-managed ground system are all in good health. Abnormalities in IMPACT and PLASTIC are resolved or mitigated. The ground system has been upgraded.

Minor Strengths

(D-2): The in-guide budget is sufficient to continue normal operations and to produce both scientific and space weather beacon data products. The costs requested for the extended mission appear reasonable, realistic and of high ROI potential.

(D-4): The proposed management plan appears appropriate and feasible.

Major Weaknesses

None noted.

Minor Weaknesses

None noted.

Criterion B Rating

Excellent	Very Good	Good	Fair	Poor
X				

<u>Criterion E: Under-guide and Over-guide Requests (Informational Only)</u>

Major Strengths

Not applicable; no under-guide or over-guide requested.

Minor Strengths

Not applicable; no under-guide or over-guide requested.

Major Weaknesses

Not applicable; no under-guide or over-guide requested.

Minor Weaknesses

Not applicable; no under-guide or over-guide requested.

Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED)

Proposal Summary

TIMED is a Foundational Science Mission dedicated to Ionosphere-Thermosphere-Mesosphere (ITM) system science. Launched in 2001, TIMED operates four instruments measuring global vertical profiles of temperature and key constituents (SABER), solar extreme ultraviolet (EUV) spectral irradiance (SEE), lower thermospheric neutral winds (TIDI), and ionospheric UV emissions (GUVI) from a high inclination sun synchronous orbit. For the proposed extended mission period, TIMED will continue to provide SABER, SEE, TIDI, and GUVI observations with no changes to the established operating plan. The TIMED Mission Operations Center and Mission Data Center are at JHU/APL. The Mission Data Center is the central facility responsible for telemetry retention and distribution, production of mission position, attitude and other ancillary data, and maintaining mission web services. Data are archived at the Space Physics Data Facility on a monthly basis.

Overall Evaluation/Rationale

The data products provided by TIMED instruments are compelling, openly available, and have demonstrated their utility through extensive publications and community impacts. Extension of the TIMED mission maintains a highly valuable long-term record of key measurements of the Sun and the ITM system that are core to HPD's fundamental mission to understanding the most directly impactful aspects of Space Weather. The proposal demonstrates a healthy mission fully capable of providing continued observations to the ITM science community. The TIMED management structure, key personnel, and roles are clearly defined and well-established. However, required documentation for the data management plan and instrument calibration is incomplete. The major strengths outweigh the weaknesses; therefore, the proposal is rated Excellent/Very Good.

Excellent	Excellent/ Very Good	Very Good	Very Good/ Good	Good	Good/ Fair	Fair	Fair/ Poor	Poor
	X							

Criterion C: Contribution to the Heliophysics System Observatory and National Priorities

Major Strengths

(C-2): The data products provided by TIMED instruments are compelling, openly available, and have demonstrated their utility through extensive publications and community impacts. The data products produced by the TIMED mission are archived in the SPDF in a commonly used and openly accessible format of NetCDF. These data are routinely provided to the HDRL, which is the official HPD data repository, making these products available to the broad community in a usable form. The instrument teams maintain documentation, tools for quick-look and analysis, and data products at the institutional websites.

(C-3): Extension of the TIMED mission maintains a highly valuable long-term record of key measurements of the Sun and the ITM system that are core to HPD's fundamental mission to understanding the most directly impactful aspects of space weather. TIMED/SEE observations fill a critical gap in solar EUV spectral irradiance observations from 105-195 nm that impact thermospheric heating and photochemistry. SABER temperature and composition observations monitor critical energy budget terms at the lower boundary of the ITM system boundary needed to quantify thermospheric density variations affecting atmospheric drag in LEO. GUVI observations provide direct measurements of energy inputs into the high latitude thermosphere. TIDI provides key information on the neutral winds that determine how energy transport is modulated throughout the upper atmosphere by changes in thermospheric circulation. Continued TIMED observations will provide a needed set of foundational data to correctly assess long-term variability in the ITM system due to solar cycle changes and secular trends.

Minor Strengths

(C-1): The proposed data collection and delivery plan would build upon a well-established record of success.

Major Weaknesses

(C-1): Required documentation for the data management plan and instrument calibration is incomplete. The proposal indicates that the Calibration and Measurement Algorithm Document (CMAD) and Project Data Management Plan (PDMP) are incomplete due to insufficient funding. After 20+ years, the CMAD and PDMP should be completed and an overguide should not be needed. TIMED has repeatedly been cited for failure to update and complete the PDMP and TIMED instruments' CMAD. It was identified as a major weakness in the previous Senior review. They have received partial funding for completion of these two documents, and they have reported making progress.

Minor Weaknesses

None noted.

Criterion C Rating

Excellent	Very Good	Good	Fair	Poor
	X			

<u>Criterion D: Technical Implementation</u>

Major Strengths

(D-1): The proposal demonstrates a healthy mission fully capable of providing continued observations to the ITM science community. The spacecraft subsystems are in very good health given the age of the mission. The SABER instrument exhibits remarkable stability and is a testament to solid instrument design and engineering. The proposal clearly demonstrates that the mission is capable of continued operations with delivery of high-quality science data via existing ground systems and processing pipelines.

(D-4): The TIMED management structure, key personnel, and roles are clearly defined and well-established. The mission plan appears both reasonable and appropriate as it continues the well-tested previous methods that have met with success. They have a clear management structure, the proposed effort describes plans to transfer leadership duties to early-career scientists and engineers throughout the project, to include the recently appointed Project Scientist.

Minor Strengths

(D-2): The proposed mission's operations model is appropriate and feasible based on the significant experience and expertise in operating the TIMED spacecraft, instruments, and ground stations.

(D-3): The proposal demonstrates a compliant end of mission plan and responsible use of space resources.

Major Weaknesses

None noted.

Minor Weaknesses

None noted.

Criterion D Rating

Excellent	Very Good	Good	Fair	Poor
X				

Criterion E: Under-guide and Over-guide Requests (Informational Only)

Major Strengths

(E-1): The proposal makes a compelling case for post-2018 calibration assessment of SEE. Calibrating and monitoring the long-term performance of SEE is very important for maintaining the utility of this data set for space weather prediction models as the solar EUV measurements are a main driver of heating and photochemistry in the thermosphere. The SEE instrument's capability to monitor the EUV spectrum 10-195 nm makes it an important long-term reference data set for other solar EUV instruments that only take measurements within specific bands.

Minor Strengths

(E-1): The proposal includes a detailed budget (e.g. FTE assignments) for major overguide tasks proposed.

Major Weaknesses

(E-1): PDMP and CMAD completion should not be an overguide request. Maintaining this documentation should be part of core operations, and expectation is that they should be mostly complete except for any new calibration activities (e.g. SEE) or new operational requirements.

Minor Weaknesses

None noted.

Wind

Proposal Summary

NASA launched the Wind spacecraft on November 1, 1994, as the interplanetary component of the Global Geospace Science (GGS) Program within the International Solar Terrestrial Physics (ISTP) program. The spin stabilized spacecraft – spin axis aligned with ecliptic south – carries eight instrument suites containing a total of 28 individual detectors, 19 of which are nominal, 1 reconfigured, 3 have reduced capabilities or are noisy, and 5 have been turned off or failed over 20 years ago. These instruments provide comprehensive measurements of thermal to solar energetic particles, quasi-static fields to high frequency radio waves, and even gamma-rays. Several of these measurements are completely unique to Wind and are critical components in larger collaborations and the HSO. Wind data has been used in over 8490 refereed scientific publications (not including 2026 publications) averaging ~274 publications/year since launch and ~516 publications/year since 2020. In fact, the number of publications per year have been steadily increasing for the past 10+ years of the mission, illustrating its continued and increasing importance to researchers. Although the mission is over 31 years old, it still has sufficient fuel for over 50 years (if it stays at the Sun-Earth L1 point) and sufficient power for at least 24 years. Wind contributes directly to the 2025 – 2026 NASA Science Plan through Priority 1, the 2022 NASA Strategic Plan through Strategic Goal 1, and is cited as a critical component of the HSO in the 2024 Heliophysics Decadal Survey. Wind has managed to stay within its guideline budget, working with a flat absolute budget between 2008 and 2025, receiving a ~5% increase in FY25. This was accomplished largely due to dozens of measures taken to improve efficiency, automate operations processes, automate instrument recovery and operations, and automating data processing relying on the enormous baseline of data for statistical significance. All these efforts have led Wind to become one of the most cost effective and productive missions ever launched by NASA. Perhaps more impressive, Wind's importance increases each year, as evidenced by the ever-growing number of publications per year. Therefore, a continuation of the mission will result in an even greater return on investment in what has become one of the most important missions in the HSO.

Overall Evaluation/Rationale

Wind serves as a standard for absolute calibration of near-Earth solar wind measurements. Wind is a demonstrated cornerstone of heliophysics science, and the proposal demonstrates synergy with and benefits to the HSO. The Wind spacecraft remains healthy with sufficient fuel to operate for decades, and all currently operating instruments are operating nominally. Operations are highly efficient and automated, achieving cost efficiencies. However, the proposal acknowledges that the current operations model is unsustainable beyond FY27 with a flat budget and may require turning off one or more instruments. The mission is operating with minimal redundancy in staffing, which increases risk to the mission. The major strengths significantly outweigh the lone major weakness; therefore, the proposal is rated Excellent/Very Good.

Excellent	Excellent/ Very Good	Very Good	Very Good/ Good	Good	Good/ Fair	Fair	Fair/ Poor	Poor
	X							

<u>**Criterion C: Contribution to the Heliophysics System Observatory and National Priorities**</u>

Major Strengths

(C-2, C-3): Wind serves as a standard for absolute calibration of near-Earth solar wind measurements. Wind provides the only unambiguous measurement of solar wind electron density. Most other near-Earth Heliophysics spacecraft use Wind data to calibrate their solar wind plasma and particle data.

(C-3): Wind is a demonstrated cornerstone of heliophysics science and the proposal demonstrates synergy with and benefits to the HSO. Wind provides unique, high-quality, and widely used data products. Wind is directly cited as a critical component of the HSO in the 2024 Heliophysics Decadal Survey in multiple places for its long baseline of data, unique measurements, and its critical importance to other missions. Wind data are widely used in research studies involving other HSO assets, as evidenced by the continuing strong publication record of papers utilizing Wind data. The contributions of Wind span multiple scientific fields.

Minor Strengths

(C-1, C-2): Wind data products are made publicly available in a timely way. The data and code management plan is thorough and complete. Wind data products are well integrated with the HDRL, and wind data are easily accessible via the SPDF.

(C-3): Wind also provides the only radio measurements at L1, which play a key role in localizing the source regions of solar wind disturbances for space weather forecasting. This is categorized as a minor strength because the upcoming SunRISE mission will provide improved radio measurements that will fulfil this purpose.

Major Weaknesses

None noted.

Minor Weaknesses

None noted.

Criterion C Rating

Excellent	Very Good	Good	Fair	Poor
X				

__**Criterion D: Technical Implementation**__

Major Strengths

(D-1): The Wind spacecraft remains healthy with sufficient fuel to operate for decades, and all currently operating instruments are operating nominally.

(D-2): Operations are highly efficient and automated, achieving cost efficiencies. The level of automation is "abnormally high" and includes anomaly detection and recovery, mission planning, and much of the data generation. Wind organizational structure is well thought out with an experienced management team. Wind will transition to a multi-mission operations team during the proposed extended mission, with the flight operations team shared with SDO and MMS.

Minor Strengths

(D-2): The in-guide budget is sufficient to continue normal operations.

(D-3): Wind complies with orbital debris requirements and has a clear and simple end-of-mission plan due to its orbit location at the Sun-Early L1 point. Full disposal procedures are not needed per NASA-STD-8719.14C.

(D-4): High level of automation should mitigate to some extent a lack of succession plan.

Major Weaknesses

(D-2): The proposal acknowledges that the current operations model is unsustainable beyond FY27 with a flat budget and may require turning off one or more instruments. The mission is operating with minimal redundancy in staffing, which increases risk to the mission. The workforce is mostly single string in both operational skills and subject matter expertise. Anomaly recovery is mostly automated, but this would only apply to known anomalies, which presents risks on an aging mission. The team may not have the personnel needed to quickly assess and mitigate new anomalies that have not been previously seen. Flat funding is deemed as insufficient to appoint deputies in many areas and train new employees, so a succession plan is lacking.

Minor Weaknesses

None noted.

Criterion D Rating

Excellent	Very Good	Good	Fair	Poor
	X			

<u>Criterion E: Under-guide and Over-guide Requests (Informational Only)</u>

Major Strengths

Not applicable, no under-guide or over-guide requested.

Minor Strengths

Not applicable, no under-guide or over-guide requested.

Major Weaknesses

Not applicable, no under-guide or over-guide requested.

Minor Weaknesses

Not applicable, no under-guide or over-guide requested.

6. List of Panelists

Name	**Affiliation**	**Role/Expertise**
Asal Naseri	HPD Associate Director, Flight	Panel Chair
Simon Plunkett	HPD Operating Missions Program Scientist	Solar, Heliosphere
Ursula Rick	HPD Operating Missions Program Executive	Mission Operations, Management
David Cheney	HPD Operating Missions Deputy Program Executive	Mission Operations, Management
Jared Bell	HPD/GSFC	Data Archives, Magnetosphere
John Dorelli	GSFC	Magnetosphere
Ricky Egeland	JSC	Solar, Space Weather, Human Spaceflight
Hashima Hasan	APD	Astrophysics, Data Archives
Irina Kitiashvili	ARC	Solar
John McCormack	HPD	Ionosphere, Thermosphere, Mesosphere
Michael Obland	ESD	Earth Science, Mission Operations, Management
Mary Voytek	PSD	Planetary Science