Decadal Survey for Solar and Space Physics (2024-2033)
NASA Responses to Decadal Survey Committee Questions

Introduction

This document is intended to record key points and information conveyed from the National Aeronautics and Space Administration (NASA) to the National Academy of Sciences, Engineering, and Medicine (NASEM). These were part of discussions between the Decadal Survey Steering Committee (DSC), its panels, and NASA.

It captures the DSC questions and the NASA response(s). Some text was lightly edited to improve clarity in the transition from a verbal conversation to a written record, but no edit changed the questions' intent or answers' content.

(Some answers contain a section labeled "*Additional information*". This section augments aspects of the NASA response and/or provides additional information not captured in the original discussion. This information was all provided after the meeting.)

The information is sorted by topic, as displayed below. Each broad topic includes several more-specific subtopics, which are categorized by the abbreviation used in the question identifiers (i.e., ChDS-1).

Abbreviation	Title
	General
ChDS	Charge to the Decadal Survey
Budg	NASA Budget (General)
PoR	Program of Record
SotP	State of the Profession
Collabs	Collaborations (Intra-Agency, Inter-Agency, International)
IGSO	Integrating Ground- and Space-Based Observations
A2S	Access to Space
	Programs
GenPg	NASA Programs (General)
R&A	Research and Analysis
EXP	Explorers
LWS	Living With a Star
STP	Solar Terrestrial Probes
SpWx	Space Weather
SSA	Space Situational Awareness
Tech	Technology
	Projects
GenPj	NASA Projects (General, including costing)
DYN	DYNAMIC

GDC	Geospace Dynamics Constellation

Change Log

Rev.	Date	Description of Changes
00	5/3/23	Document creation, capturing questions from Steering Committee Meeting #1 (Kick-off) and Meeting #2
01	8/1/23	Added EXP-1, ENL-2. (Questions from Steering Committee Meeting #2) Added SpWx-5, SpWx-6. (Questions from Space Weather Panel Meeting #1)
02	8/2/23	Added GenPj-4, ISGO-1, DYN-4, GenPj-5. (Questions from the Integrating Ground- and Space-based Observations Working Group Meeting #1)
03	11/30/23	Added A2S-1 through -8, Tech-1 through -5. (Questions from Access to Space Working Group Meeting) Added Appendix A (Meeting Summary from Integrating Ground-and Space-Based Observations Meeting)
04	4/17/2024	Added Collabs-8, GenPg-2.
05	5/3/2024	Updated hyperlinks
06	6/7/2024	Updated hyperlinks

General

ChDS-1. **Is there a top-down message that NASA is being given that would help the DSC better answer the charge for space weather (SpWx) and space situational awareness (SSA)?**

Government working groups are in place to develop the top-down message, and the Decadal Survey (DS) should look to them.

Additional information: The Space Weather Supplemental Presentation identifies the National Space Weather Strategic Action Plan and the PROSWIFT Act as governing guidance. (Other relevant documents and guidance can be found in the Space Weather Operations, Research and Mitigation Subcommittee [SWORM] publications.)

Within the Space Situational Awareness/Orbital Debris (SSA/OD) Supplemental Presentation, the NASA Office of Inspector General report, the National Orbital Debris Research And Development Plan, and the National Orbital Debris Implementation Plan all provide guidance and include earlier governing documents and guidance. For instance, the Implementation Plan, Action 2.3.1, identifies NASA as the Lead and relates to the Orbital Debris Tiger Team activity discussed in Question SSA-2.

Below are links to some of the committees and working groups active in space weather that NASA participates in or works with. These are in addition to the links and other documents included in the Space Weather and SSA/OD Supplementation presentations.

- Space Weather Roundtable (National Academy of Sciences)
- Space Weather Council (NASA)

For both space weather and SSA, there are on-going Government discussions. If those efforts produce a public guidance document during the DS process, NASA will notify the DSC and provide a link where the document can be accessed.

ChDS-2. **Is the DSC able to build scenarios with recommendations that do not rely solely on the mission proposed budget assets we anticipate will be there?**

When talking about flexibility in implementation, recommendations should not give prescribed implementation and should be more science-focused to give Heliophysics Division (HPD) flexibility to pivot when new science emerges. Providing scenarios such as that is a great way to enable the flexibility and ability to support DS-recommended science.

Additional information: During the Kick-off Presentation, NASA requested an ambitious but realistic strategy that has flexibility, does not prescribe

implementation, and does not rely on only a small number of large investments (Slides 3, 21).

In the 2024 Decadal Survey Study Approach's NASA-specific guidance, the survey is asked to prioritize goals and objectives for projects for the Living With a Star (LWS), Solar Terrestrial Probes (STP), and Space Weather Programs. NASA expects recommendations for LWS and STP to include a range of project sizes (i.e. Missions of Opportunities to large missions), and recommendations for Space Weather to include a restricted range of project sizes (i.e. not large missions).

ChDS-3. **How do we maximize on the number of possible measurements and how do we facilitate collaboration with our international partners?**

HPD has a lot of examples of international collaboration in the current fleet. We would love to see comments on the strength of how we're enabling compelling science with international collaborations, including if we could be doing something better. When writing recommendations, the DS should look at the big science goals and then the balance of implementation between the organizations to address those science goals.

ChDS-4. **Would creating a strategy for the Heliophysics System Observatory (HSO) be a beneficial recommendation? How could the DS help with that?**

[This question was rolled into the surrounding discussion.]

Additional Information: NASA does not prescribe exactly how the DS addresses the HSO, but did request that the survey consider balance of investments and fully budget for the associated costs.

NASA has asked the DSC to consider a few specific aspects of portfolio balance:

- Science area, timing, cost
  - See: 2024 Decadal Survey Study Approach, General guidelines; Kick-off Presentation, Slides 5-9
- Across mission programs
  - See: 2024 Decadal Survey Study Approach, NASA-specific guidelines
- Project sizes
  - See: 2024 Decadal Survey Study Approach, NASA-specific guidelines; Kick-off Presentation, Slide 21; Question ChDS-2
- Extended mission portfolio
  - See: Kick-off Presentation, Slide 18
- Execution of spaceflight science investigations and laying the groundwork for investigations in the following decades

- See: 2024 Decadal Survey Study Approach, NASA-specific guidelines

As part of its definition and framing of portfolio balance, the DS could outline a strategy for the HSO that considers the above aspects and others identified by the DSC.

ChDS-5. **How does continuity fit in for the HSO? Would NASA welcome or want recommendations for something that looks operational because that is the need? Or does that go to the National Oceanic Atmospheric Administration (NOAA)/Air Force or whomever to put together what is needed?**

NOAA invests in operational activities, and funding those would be a big hit to the NASA budget. If there is compelling science for NASA that would also happen to enable the operational measurements, that falls within NASA's HSO.

Additional information: Recently, there have been additional NOAA-NASA collaborations on operational interests (NOAA) and science projects (NASA). Below are two sample collaborations. HPD does not have a policy on either, but they are offered as examples that the DSC can use in its consideration of cross-agency activities.

1. NOAA support for marginal increases in NASA projects' scope of work that would be helpful for operational activities (e.g. producing additional data sets).
2. The 2017 Earth Science Decadal Survey prioritized science goals that required the maintenance of long-term measurement continuity. One aspect of that maintenance is advancing scientific and measurement capabilities. Those capabilities are in NASA's domain. One particular activity that came out of the DS' implementation-agnostic science recommendation was Earth Venture Continuity, where NASA and NOAA established an agreement about the development and demonstration of innovative new technology and/or techniques.

In all potential collaborations, NASA and the partner agency would maintain clear lines of funding responsibility and authority. The project sponsor would support and control the mission's standard operations, and the partnering agency would fund the additional work effort. If a project's priority within the sponsor's portfolio fell to the point of termination, the two agencies could discuss a transfer of the mission's ownership.

ChDS-6. **How does NASA view the relationship between Artemis and heliophysics? Is it an additional resource to the Heliophysics program? How should we look at those opportunities in comparison to the core science program? Should**

there be a separate Artemis-related list as a "would be cool do to" or include it within the list?

Artemis is enabling and emerging. We also look at it as both there is great science that can be done on the Moon and what are we doing to find that great science. The DS should think about what science could HPD complete by using Artemis as a service (either robotically or with humans)?

Additional information: The Human Exploration, Artemis, Moon & Mars Supplemental Presentation discusses Lunar Infrastructure (Slides 13-16) and Gateway (Slides 17-20) that could be used to complete heliophysics science.

PoR-1. **How does NASA view the Program of Record? How should the DS handle it, especially the projects in pre-formulation and the accompanying budget assumptions?**

[This question was conveyed in email conversations between NASA and NASEM. The response below is a summary of comments NASA made at Steering Committee Meeting #2 in anticipation of the question being asked, with additional clarifying information.]

The Program of Record is those activities which will continue as planned through the next decade in the absence of recommendations from the Decadal Survey to make changes.

For projects in pre-formulation, NASA is in a planning phase and has not committed to those listed. NASA would determine whether to move into formulation (i.e., enter Phase A) based upon programmatic discussions and priorities.

The anticipated budget requirements for projects in pre-formulation are not captured in the future program budgets. Unless recommended otherwise, the Decadal Survey is expected to include the anticipated budget requirements into its enabling budget recommendations. If an activity does not lead to project formulation, NASA expects to assign any available budget to other projects, with consideration to programmatic needs and the Decadal Survey priorities and decision rules.

Note: NASA provided the Program of Record Supplemental Presentation, detailing the programs and projects for the Decadal Survey Committee (pre-formulation activities are on Slides 15-21). In the Decadal Survey Kick-off Presentation (Slides 16-18) NASA provided focused requests for Decadal Survey recommendations on the Program of Record.

PoR-2. **On the Research Program slide in the Budget Supplemental Presentation, what caused the funding drop in 2022?**

Congress appropriated more money for the research program prior to 2022. In 2022, those appropriations dropped. If we received favorable appropriations, we would increase the R&A funding again.

SotP-1. **Regarding the State of the Profession expectations in the 2024 Decadal Survey Study Approach, is it that NASA does not want any recommendations for specific actions to improve the state of the profession, or that NASA does not want the DSC to try to solve all the challenges that the community is currently facing?**

The latter. There is no way the DSC can come up with actions to solve all the challenges, but NASA does want to know what those challenges are and the recommendations the Committee is able to develop.

Collabs-1. **Where are the lines drawn between the fundamental physics, applied science, transitioning, and operations of missions between the programs/agencies?**

NOAA and NASA interact on transitioning operational capabilities through the Research to Operations to Research (R2O2R) program. That uses a tri-agency agreement between NASA, the National Science Foundation (NSF), and NOAA. We are working on a quad-agency agreement to include Department of Defense (DoD).

We are asking what should our Space Weather Program should focus on. It is new since the last decadal survey. We want guidance and recommendations for what the program should be, similar to the request for the Technology Program.

Living With a Star (LWS) addresses the heliophysics science that impacts life and society.

Solar Terrestrial Probes (STP) addresses the high-level fundamental heliophysics science.

For our programs, we want to remove any constraints or cost caps that were imposed in the last decadal survey.

Additional information: One of the constraints imposed in the 2013 Decadal Survey was the link between the HPD programs and the project implementation. The 2013 Decadal Survey Mid-term Assessment (Section 6.2) identified this as not effective for long-term sustainability. In the *Strategic Space Flight Programs: Structures and Implementations* document, NASA agreed.

NASA sees these STP, LWS, and Space Weather projects being defined by the science objectives and science goals they are prioritized for. They are not defined by the measurements, instruments, or science capabilities involved. It is understood that a project in STP may produce data useful for non-STP investigations (e.g. GNSS-Radio Occultation data) or start a model capability that could be further developed for transition to operational use (as discussed in the *Structures and Implementations* document, Section 3).

Collabs-2. **To what extent should the DSC come up with recommendations as to what the agencies should work jointly on that falls between operational activities and research/investigations?**

That's exactly what NASA wants to see from the DS. There is a lot in the middle area between operational activities and research. Our partnerships and working groups with NSF and NOAA are pretty consistent, so recommendations on improving those collaborations are great.

Collabs-3. **How do you see heliophysics entering the exoplanetary research environment without contributing a mission that makes further inroads into studies astrophysics is doing? Should Astrophysics Division (APD) be coming to HPD asking for their support? What can HPD do in a meaningful, tangible way?**

HPD is the Division with the most cross-divisional abilities; it has overlap with Planetary Science Division (PSD), APD, and Earth Science Division (ESD). HPD wants to open those boundaries beyond the traditional "solar" application by asking: where else can we take heliophysics? What other Divisions can contribute to heliophysics?

Additional information: HPD participates in Habitable Worlds and Exoplanets Research with PSD and APD. In those programs, it supports proposals that perform sun-star studies or otherwise leverage our heliophysics expertise to exoplanetary systems.

Collabs-4. **HPD's budget is half the size of APD's budget, which is half the size of PSD's budget. Would NASA be open to the DSC suggesting the conduit between various divisions and jointly sponsoring programs?**

NASA must be careful with that: HPD can't recommend to APD that they jointly fund something. The DS' focus is the science, not necessarily the mission implementation. If the science can be jointly recommended, that's good but

exercise caution in jointly recommending missions. This is especially true with a Division that has already had their DS recommendations published.

Additional information: In the Kick-off Presentation, NASA charged the Decadal Survey Committee with determining the compelling science investigations to be completed in the next decade, and then to identify the budget necessary to support those investigations. It is expected that the Decadal Survey will recommend an ambitious but realistic budget for HPD (Slide 3). Further, NASA has requested decision rules for the cases where future budgets are more favorable and less favorable than recommended.

Collabs-5. Can HPD contribute to planetary missions, in a sense of contributing instruments or operation strategies? Has that been successfully done before?

It's possible but always challenging. PI-led missions are mass- and power-constrained, not only budget-constrained; this often leads to de-scope of instruments. However, we can do heliophysics science anywhere (space weather pipeline, for example). If there is an opportunity to contribute to a planetary mission and an ability to provide information on a potential HPD-contributed instrument on the necessarily timeline, we will.

Additional information: As stated during the DSC meeting, there are strong constraints on planetary missions, and proposers require information on potential contributions as early as possible (ideally more than two years before a proposal due date). However, this is a situation where DS strategic input is valuable for future planning. HPD has the ability to work with our PSD colleagues on offering heliophysics-relevant contributions in their AOs. If the DS recommends HPD hardware contributions to planetary missions, the useful information would be the strategic science/measurement goals (e.g., what kind of science/measurements, where in the heliosphere) and a level of support (e.g., budget, decision rules of what recommended activity the contribution would replace).

Collabs-6. Should the DSC be empowered to comment on HPD's interactions with planetary aspects [e.g., Radiation Assessment Detector (RAD) on Mars]?

Yes. HPD does want to see those recommendations/commentary and does want to hear the DS' views. This is both on the portfolio HPD currently has and on whether HPD should continue supporting those activities. HPD encourages the DSC to discuss hosted payloads and interactions with other SMD Divisions.

Collabs-7. Budget is the way philosophy is implemented. How do you see the budget being reflected by opening those cross-divisional pathways?

NASA seeks ground-breaking, barrier-breaking, aspirational science and encourages the DSC to not be constrained. If there's something new and exciting that will push the boundaries, the DSC should not say "X can't be done because it's not within Y lane."

Collabs-8. What is NASA's current and planned engagement with smaller space agencies (e.g., South Korea, India, South Africa, Ethiopia, Nigeria, Brazil, Chile, Peru)? What kinds of contributions and commitments do these agreements cover?

NASA has agreements with some of the Committee-identified space agencies and is formulating others. The contributions and commitments within an agreement are specific to each activity, and to each partner's capabilities (to contribute/commit) and requests (for NASA contribution/commitment).

NASA is exploring potential partnerships with new and emerging international space science organizations, but does not announce details until they are finalized. The list of countries with smaller space agencies that NASA is currently in discussions with includes Argentina, Australia, Brazil, Chile, India, Korea, New Zealand, Peru, and South Africa.

Project/activity agreements may result from both Principal Investigator-initiated collaborations and NASA-led initiatives. The standard Announcement of Opportunity permits the inclusion of contributions in proposals, and NASA does not place restrictions on smaller space agencies provided that their contributions enable completion of the project objectives. NASA-initiated agreements can involve spaceflight hardware and/or non-spaceflight contributions/commitments (e.g., ground station support, ground-based observations, facility access, scientific/technical collaboration).

IGSO-1. Can the DS recommend science investigations that require both ground- and space-based observations? If so, how should the DS present those recommendations?

[During the July 2023 Integrating Ground- and Space-based Observations Working Group meeting, the WG and DSC members had discussions with the sponsor agencies. This question and answer was distilled out of that discussion, and may include comments raised at different points during the meeting.]

Yes. The DS is charged to prioritize the compelling science goals where measurable progress can be made (Statement of Task [SoT], Item 2.a), and to include in the research strategy consideration of where the combination of ground- and space-based investigations would enhance that progress.

The way for the DS to present these recommendations is displayed graphically in the *Ground- and Space-Based Coordination* presentation (Slides 10-14).

The DS identifies a science goal (also called a "science question"), and one or more completable objectives that would produce significant advances on that goal. When those objectives would combine both ground- and space-based projects, the process for the DS is the same as for other recommended activities:

1. Write a recommendation for the completion of the objective(s) that require both ground- and space-based investigations to the relevant agencies.
    a. It is critical that this recommendation clearly state the prioritization. A recommendation that requires significant coordination between agencies is likely to be implementable only if it is the top priority for those agencies.
2. As sub-recommendations, clearly recommend the ground-based investigation and the space-based investigation separately to the appropriate agencies.
    a. As shown in the NASA response (see above), it is understood and expected that those agency-specific sub-recommendations will be for a subset of the recommended combined objectives (in Item 1, above).

IGSO-2. **What guidance do the sponsor agencies have for the Decadal Survey with regards to capturing recommendations that integrate ground- and space-based observations?**

[During the July 2023 Integrating Ground- and Space-based Observations Working Group meeting, the WG and DSC members had discussions with the sponsor agencies. After that meeting, NASA summarized the main discussion threads and delivered that document to the DSC. That summary can be found in Appendix A.]

A2S-1. **Many of the mission concepts submitted to the Survey consist of large constellations of satellites in multiple orbit planes (24 - 72 satellites). This leads to the following sub-questions:**

1. **Where do these large Helio constellations missions potentially fit in the program portfolio?**
2. **The cost caps and launch accommodations (e.g., single launch vehicle, ESPA) limit the size of constellations possible under the Explorers opportunities (to approx. <10) and orbit planes achievable.**
3. **These constellations under consideration are envisioned as multiple Class D satellites. However, current NASA policies would**

drive these satellites to a Category 2, Class B or Class C based on total mission cost. Has NASA considered special provisions and risk postures for development of large constellations with lower class payloads?

[During the July 2023 Access to Space Working Group meeting, the WG and DSC members had discussions with the sponsor agencies. This question was sent before the meeting and this response was prepared in writing.]

NASA looks to the Decadal Survey for compelling science priorities and objectives that can serve as the basis for heliophysics investigations. When NASA begins (pre-) formulation of a new project, the referenced policies serve as an input to internal NASA decisions. These policies are agnostic to mission-specific details and are not determined by the Decadal Survey process.

For completeness and National Academy insight, NASA provides the following answers for the sub-questions:

1. Space flight investigations are selected based upon the science returns rather than mission architecture. NASA has no pre-determined balance of constellation missions vs. single-spacecraft missions within its portfolio.

   Any program may develop a constellation mission if the project investigation fits within the scientific scope of that program. In the Decadal Survey Study Approach, NASA requested recommendations for all Heliophysics strategic programs (STP, LWS, Space Weather) be based upon relevant science objectives and without specific mission implementations. The request specified the full range of project sizes (Missions of Opportunity through large projects) for STP and LWS, and a restricted range of project sizes (no large projects) for Space Weather. All recommendations should provide for sustainable programs, and for a balance across all programs.
2. The Decadal Survey Study Approach specified that the Decadal Survey should not recommend the project management paradigm (PI-led vs. directed) for any space flight investigation. Further, the Explorers Program uses a fully open and competitive Announcement of Opportunity process that does not solicit pre-specified investigations. Decadal Survey-specified investigations are to be directed to the appropriate strategic program (STP, LWS, Space Weather), with mission concepts used as a tool for assessing technical readiness and budget feasibility.

   PI-led projects are solicited for completion within NASA-defined cost caps, and it is understood that not every mission architecture is feasible within every cost cap. For directed projects or AOs to implement a

specific project (e.g. IMAP, DYNAMIC), NASA considers many potential launch scenarios.

3. Heliophysics is in a time when capabilities and scientific needs are rapidly growing and evolving. The tools that will be available for future project implementations include those that have not yet been developed. NASA policies do not constrain those tools, but provide a framework for appropriate program management and methods to address project and program risks. This sub-question has three distinct aspects: a) project categorization, b) project risk class, and c) observatory risk class.
    a. Project categorization is defined in NPR 7120.5F, Table 2-1. This categorization specifies the level of Agency oversight and the approval requirements. While the SMD Associate Administrator is permitted to recommend a modification of the category, that decision is made as NASA moves into formulation.
    b. Project risk classes are defined in NPR 8705.4A, Appendix C. This classification is used to guide the safety and mission assurance objectives for a project. The risk considerations are treated holistically, and Mission Directorates can and do incorporate programmatic factors. The final risk classification is determined as NASA moves into formulation.
    c. Observatory risk class uses the project risk classifications defined in NPR 8705.4A, Appendix C. Observatory risk class is not necessarily the same as project risk class, and NASA expects there to be opportunities for constellations to include payloads with a higher risk class than the project itself. For PI-led projects, NASA has developed a guidance document for constellation architectures proposed to the 2022 Heliophysics SMEX AO. For directed projects, NASA has added Class D elements to the GDC payload. NASA continues to improve the guidance and process for soliciting, evaluating, and managing constellation-based investigations, based on opportunity-/project-specific lessons learned and cross-opportunity/-project internal activities.

A2S-2. **Based on the FY24 President's Budget Request, will the planned cadence of the Explorer program (SMEX, MIDEX, and MoO) be impacted? Per the SMD planning document (Aug 2022), the following Heliophysics AOs are planned for FY2025: Heliophysics Medium-Class Explorers, Q2, (ROSES 2025) Heliophysics Low-Cost Access to Space, (ROSES 2025) Heliophysics Flight Opportunities for Research and Technology?**

NASA looks to the Decadal Survey for compelling science priorities and objectives that can serve as the basis for heliophysics investigations. NASA

expects the Decadal Survey report to be delivered in time to inform the FY27 budget request. The compelling science strategy and healthy cadences for all heliophysics programs would be integrated into that planning cycle.

For completeness, NASA notes that the President's Budget Request is the beginning of the appropriations cycle. The next step is congressional legislation, which the President signs into law. When the FY24 appropriations are completed, NASA will issue any necessary updates to the list of planned opportunities.

A2S-3. **The constraints on Heliophysics AO cadences are not well-understood. This leads to the following sub-questions:**

1. **What are the bounds of capability on the Helio AO cadence? Besides budget, what factors limit the feasible AO cadence (e.g., AO preparation, proposal evaluation)?**
2. **Sometimes two missions are selected under the same AO but the start of one is delayed. What drives the approach to a single AO rather than phased?**
3. **Why are MoO and full missions combined opportunities (time-wise) rather than separated on the FY24 President's Budget Request? Will the planned cadence of the Explorer program (SMEX, MIDEX, and MoO) be impacted?**

SMD Divisions offer AOs based on the programmatic needs and constraints. There may be small adjustments in schedules due to workforce concerns within the community and/or within NASA.

1. The feasibility of AO cadences is driven solely by NASA budget availability. In practice, AO schedules may be shifted slightly to reduce overlap between the Divisions' opportunities or with other community activities.
2. Making multiple selections from a single opportunity rather than single selections from multiple opportunities reduces the time and money expended in proposal preparation (by the community), in the AO preparation (by NASA), and in the review process (by NASA and the reviewers).
3. The Decadal Survey has been charged to provide a compelling science strategy and is not constrained by current NASA planning. NASA expects for the Decadal Survey report to be delivered in time to inform the FY27 budget request. The compelling science strategy and healthy cadences for all heliophysics programs would be integrated into that planning cycle.

A2S-4. **How are launch services going to be handled in the future AOs? For example, will Explorer missions or MoO's allow PI provided access rather than through LSP?**

AOs offer NASA-provided access to space, including the new Venture-Class Acquisition of Dedicated and Rideshare (VADR) contract. VADR achieves lower launch costs through FAA-licensed commercial launches. These launches utilize a lower level of mission assurance and more commercial practices while still meeting the mission assurance and modified technical oversight approach requirements stated in NASA's Launch Vehicle Technical Oversight Policy, Attachment C (NPD 8610.23C).

SMD may elect to offer PI-provided access to space on a specific AO. Proposals that leverage PI-provided launch services must demonstrate that the launch service meets NASA requirements. The launch service contract must meet the requirements specified in NPD 8610.23C. The proposal must demonstrate that project can manage and provide the appropriate level of mission assurance for the launch service, commensurate with the project's risk posture.

A2S-5. **How will rideshares be handled in future AOs? Recent experiences indicate that the expected rideshares don't always materialize causing uncertainty and stress on mission development. This leads to the following sub-questions:**

1. **Once a mission is selected, how will NASA manage rideshare missions within this uncertainty?**
2. **Can NASA comment on NASA's response to the findings of the "Committee on Solar and Space Physics: Agile Responses to Short-Notice Rideshare Opportunities for the NASA Heliophysics Division (2020)"?**

NASA has a management framework for projects where NASA is responsible for acquiring the launch service. Recent challenges with rideshares include those for PI-provided access to space (where NASA was not directly involved) or where projects introduced new or changing requirements (which can force a change from rideshare to primary). Regarding projects with set, well-understood requirements, NASA provides the following answers for the sub-questions:

1. Following the NASA Rideshare Policy, SMD matches compatible rideshare missions with Primary SMD missions when the launch service has excess performance. If a rideshare mission is not compatible with an SMD NLS-II launch (with respect to launch readiness date, Do No Harm, and trajectory requirements of the primary), the Rideshare mission will go through the VADR contract.
2. SMD has leaned forward in the spirit of the CSSP report by standing up the SMD Rideshare Office. This Office organizes and fosters more rideshare opportunities and supports the standardization of services and interfaces where possible. SMD, working closely with the Launch Services Program, created the VADR contract. As an instrument-level activity, Heliophysics Division has led the development of a payload

pipeline for the Space Weather program, with the purpose of being prepared to take advantage of short-notice launch opportunities.

A2S-6. **Can NASA discuss how CubeSat missions will be accommodated in the portfolio? This leads to the following sub-questions:**

1. **Will they still be solicited through ROSES with launch support through CubeSat Launch Initiative (CSLI)?**
2. **The NASA CubeSats, Balloons, and Sounding Rockets Supplemental Presentation (Slide 6) states that CubeSats are equivalent to a Mission of Opportunity. Does this statement imply a different solicitation in the future?**

CubeSats implemented under NPR 7120.8A are solicited in and managed through the Heliophysics Flight Opportunities in Research and Technology (H-FORT) program. This leads to the following answers to the sub-questions:

1. CubeSats will continue to be solicited through ROSES. The launch support is an evolving situation that SMD is managing. CSLI is not part of SMD, and has been updating their rules based on demands and constraints that are outside of SMD's control. NASA is considering other launch opportunities, including the same VADR services that CSLI leverages, but there are no decisions or revised plans to publish at this time.
2. The Supplemental Presentation's statement is a comment on the amount and complexity of work that a CubeSat project must complete. It does not state a NASA intention to manage them like projects in the Explorers, STP, LWS, or Space Weather programs.

   For a CubeSat, projects are responsible for the platform as well as the instrument (unlike Sounding Rockets, where the platform is provided). This leads to the same types of technical, cost, and schedule challenges that larger projects face.

A2S-7. **The CubeSats, Balloons, and Sounding Rockets Supplemental Presentation (Slide 7) mentions increases in NASA management of these small projects. This leads to the following sub-questions:**

1. **Is this increased management effective from a cost/benefit perspective?**
2. **Is this increased management at odds with the purposes of the CubeSat program?**

The Supplemental Presentation described maintaining the Principal Investigator's freedom on how the project work is conducted ("light touch" management philosophy) while formalizing project management and lifecycle review processes. These increases in management were in direct response to an

unacceptable percentage of projects not delivering in cost and on schedule and completing their proposed science objectives. This NASA perspective leads to the following answers to the sub-questions:

1. Yes. NASA has the responsibility to oversee the usage of taxpayer funds. The increased management, including engineering and programmatic support, was put in place to increase the return on NASA's investment (the percentage of projects delivering in cost and on schedule). The level of program involvement (e.g. engineering reviews) is now analogous to the Sounding Rocket Program.
2. No, it is in direct alignment with the purpose of the governing NASA program. Heliophysics CubeSats implemented under NPR 7120.8A are solicited in and managed through the Heliophysics Flight Opportunities in Research and Technology (H-FORT) program. The H-FORT solicitation defines the program's purpose and the requirements on projects. Those include CubeSat delivery within a set time interval and within the available funding, and either the completion of a well-defined science investigation or the on-orbit demonstration of science-enabling technology.

A2S-8. **The program management structure of Heliophysics CubeSats, Balloons, and Sounding Rockets is not easily visible from an external viewer. Can NASA provide additional insights? This leads to the following sub-questions:**

1. **What is a realistic number of missions that can be managed in the H-FORT/H-LCAS/H-FOS Program line?**
2. **How does NASA form program offices with management and oversight responsibilities of balloons, sounding rockets, and cubesats?**
3. **Although the CubeSats, Balloons, and Sounding Rockets Supplemental Presentation (Slide 5) states "Current program funding level permits a healthy project cadence" for sounding rockets and balloon missions, the current ROSES solicitation indicates that no balloon mission solicitations will occur until 2028. Is there a plan to provide alternate options or increase solicitations in other areas (e.g., sounding rockets)?**

On behalf of all of SMD, Astrophysics Division manages the Balloon Program and Heliophysics Division manages the Sounding Rocket Program. Information is available on the Balloon Program Office and Sounding Rockets Program Office websites. Each Division manages their own CubeSats, and day-to-day program management of Heliophysics CubeSats is tasked to the Special Projects and Small Satellites Program Office at Wallops Flight Facility.

1. For the current management workforce, the most effective maximum number of concurrent projects is 15-20, but H-FORT has previously supported up to 25 concurrent projects.

2. NASA establishes program offices based primarily on Center expertise, capabilities, and available workforce. These processes are based in Agency practices that are outside the scope of the Decadal Survey.
3. No. The Sounding Rocket Program's launch rate is healthy, sustainable as-is, and in-line with 2013 Decadal Survey recommendations.

Programs

GenPg-1. **Is it incumbent on the DSC to bucket recommendations under specific programs or can the DSC recommend the science and let NASA determine where it falls under the program?**

NASA wants to do as much science as possible. You can bucket it if it makes sense, but you don't have to. When making budget sandcharts, it is most helpful to assign projects to programs. But, if you explain in the recommendation what the assumption was around program/project assignments, NASA will work with that.

GenPg-2. **NASA modified the Heliophysics Senior Review process in 2020 and 2023. These changes were discussed at the Heliophysics Advisory Committee meetings (2019, 2023) and the Committee on Solar and Space Physics (CSSP) meeting (2023). Could NASA summarize these changes for the Decadal Survey Committee's reference, with an emphasis on the following sub-questions:**

- **What motivated NASA to modify the process?**
- **What were the modifications made in 2020? What additional modifications were made in 2023?**
- **What were the key factors considered for the Senior Review 2020 and 2023 continuation decisions?**
    - **In the 2023 CSSP presentation, NASA stated that a transition to Heliophysics System Observatory (HSO) Infrastructure was not a de-emphasis of the value of a mission's science and, in fact, has benefits to the project. Can that point be expanded upon?**

The Senior Review is the Heliophysics Division's (HPD's) implementation of the Congressionally mandated assessment of NASA operating missions. Title 51 U.S.C. §30504 requires:

> *(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.*

NASA's paradigm for mission extensions is documented with Announcements of Opportunity [example]. Mission operations and science operations are to receive "bare-bones" support, and no funds are to be available for detailed scientific analysis. In practice, NASA has often provided a funding level above that

"barebones" level to enable the project to support a science investigation based on the new observations acquired in extended operations.

HPD documented this for the Decadal Survey Committee in the document *NASA Space Flight Programs and Projects: Budget Elements*, in the section "Extended Mission Budgets":

> Budgets are decreased in extended mission. There is no set policy that prescribes the schedule for this decrease, but historical data can show what happened to mission budgets in previous years. However, it must be remembered that each mission currently in continued operations has different specific needs, launched at different times, and experienced different budget realities.
>
> Averaging over all missions and all years, historically, the budgets for individual extended missions have decreased ~6-7 percentage points (of the original Phase E budget) per year for the first five years of continued operations. After the sixth year, budget reductions have decreased to ~1-2 percentage points per year. After around fifteen years of continued operations, the budget no longer decreases (although that conclusion is based on a small number of missions). (Note: These figures are given in percentage points, not percentages. A budget that decreases 10 percentage points per year will have decreased 50% after five years, not 41%.)

As noted by the National Academy of Sciences' 2016 report *Extending Science: NASA's Space Science Mission Extensions and the Senior Review Process*, these budget decreases disproportionally fall on project-funded science activities (p. 59):

> **Finding:** After the first few years of extended operations, most missions have implemented all (or almost all) practical steps to reduce costs. Further budget cuts often then result in disproportionate cuts to project-funded science activities, increasing risks that science will be diminished or not performed at all.

However, that recommendation did not consider the realities of a constrained budget and the tradeoffs that NASA must consider if both increasing costs for extended operations and the requirements of a growing fleet of new missions cannot be accommodated within the available budget.

In planning for the mission cadences recommended by the 2013 Decadal Survey, NASA assessed the challenges presented by a growing portfolio within a constrained budget. (The expectation for a near-term doubling in extended mission costs, and continued growth afterwards, was discussed in the Decadal Survey Kick-off Presentation [Slide 18].) NASA determined that modifications to the Senior Review process were necessary to meet the statutory requirements while maximizing the production of useful and usable archival science data by the HSO.

In Senior Review 2017 and earlier, NASA requested higher-level "Prioritized Science Goals". These Goals did not clearly distinguish between the output from the project-funded science investigation and the output from community-conducted research using the mission data sets.

Senior Review 2020 required projects to propose Science Objectives that would be completed in a project-funded science investigation, and to separately discuss the compelling science (outside of the project's Science Objectives) that is enabled or enhanced by the mission's continued operations. With this delineation, Senior Review 2020 introduced a category of operations termed "HSO Infrastructure" for projects that were not funded for a science investigation. (There were additional changes, not detailed here, related to White House and NASA policies on open science.)

Projects in the HSO Infrastructure category would be funded only to continue operations and associated activities (e.g., data validation, archiving). NASA would perform the triennial assessment on these projects via a programmatic review (with community subject matter experts) that is more focused and streamlined than the full Senior Review process.

Senior Review 2023 made minor adjustments and clarifications to the Senior Review 2020 framework (the most significant were related to open science and inclusion activities). However, instructions to the projects included the programmatic note that NASA could significantly reduce the current total budget for extended operations, and that any reduction would be accomplished by a combination of science descopes, transitions to HSO Infrastructure (even if a project-funded science investigation was proposed), and terminations.

As was discussed at the 2023 CSSP meeting, the changes implemented in Senior Reviews 2020 and 2023 were driven by program management goals and budget realities.

NASA's goals for the HSO include effective program/project management, maximizing continued operations within a sustainable framework, ensuring the availability and usability of high-value data products, and integrating the HSO projects into Division strategic efforts.

Within a realistic budget scenario, it is not possible to support both the continued production of the HSO's high-value data sets and all project-led science investigations. NASA prioritizes the production of those high-value data sets that can be used by the broader science community.

Not separating the project-funded investigation and the project-enabled community science (pre-2020), levied a burden on projects. A project without funding for a project-led science investigation had an implicit requirement to

anticipate what the science community would do with the mission data over the next three years, and then to track and report what research the community published. Further, there was pressure within the proposal/evaluation process to present new science every Senior Review to receive a high rating, which is a challenge for long-operating projects.

When the project-funded investigation and the project-enabled community science are separated (2020-onward), a project is responsible for any project-funded science investigation and for discussing the scientific value that its mission data continues to provide. If a project does not have funding for a project-led science investigation, then the Senior Review only assesses the scientific value of the continued provision of the mission data.

Decisions for the Senior Review 2020 and 2023 outcomes were based on the combination of the project-specific reviews and programmatic considerations. All but one of the projects directed to transition to HSO Infrastructure submitted proposals that showed that they already were, or would by 2026, be operating in that mode by 1) allocating no funding for a science investigation, 2) showing science investigation funding ramping down in the coming three-year period, and/or 3) stating that the budget was already at a minimum sustainable level and that any budget cuts would impact science operations.

These projects were already at the lowest funding level that would ensure the continued delivery of high-quality data products. Their transition to HSO Infrastructure includes a few key aspects. They are not required to conduct a science investigation that their funding level does not support. They are relieved of the implicit responsibility for activities outside of their control (e.g., community research using the mission data). Lastly, removing the pressure to fund a specific science investigation allows the project and NASA to focus time and budget on those activities that directly lead to enhanced science return from the mission data. These include but are not limited to the necessary funding for 1) the scientists performing data validation without being required to justify those activities within a defined science investigation, 2) the production and archiving of existing and new data products, and 3) science leadership and expertise to support the community's use of the mission data sets.

[This response can also be found as a stand-alone document.]

R&A-1. **What are the plans for Diversify, Realize, Integrate, Venture, Educate (DRIVE) Centers going forward? Are these plans reflected in the budget information?**

[This question was conveyed in email conversations between NASA and NASEM. The response below is a summary of comments NASA made at Steering

Committee Meeting #2 in anticipation of the question being asked, with additional clarifying information.]

HPD intends to continue the DRIVE Centers in the future, and are expanding the use of that model to space weather research.

DRIVE Centers are funded out of the Research Program budget. The research funding line can support one Center cycle every eight years (or so) without disrupting the other programs.

LWS-1. **NASA sponsored a Living With a Star Architecture Committee and delivered their final report to the Decadal Survey Committee. How was this report generated and how is the DSC expected to use it?**

[This question was conveyed in email conversations between NASA and NASEM. The response below is a summary of comments NASA made at Steering Committee Meeting #2 in anticipation of the question being asked, with additional clarifying information.]

The 2013 Decadal Survey Mid-term Assessment recommended that NASA task the next decadal survey to "[define] distinct science goals and implementation strategies for NASA's Solar Terrestrial Probes and Living With a Star programs".

In NASA's response to the Mid-term Assessment, NASA agreed with the importance of distinct science goals and implementation plans, but identified internal discussions to distinguish the scopes and boundaries of those programs. As promised in that response, NASA delivered the *Strategic Space Flight Programs Structures and Implementations* document for the Decadal Survey's use.

That document structured LWS' mission activities in a similar manner to the LWS competed research activities, using Focused Mission Topics (FMT) instead of Focused Science Topics (FST).

The FMTs are envisioned as scientific priorities for the LWS program that flow down from the LWS Strategic Science Areas. Each FMT is defined by strategic science needs from which one or more completable science objectives flows. Each FMT could be addressed by one or more projects, and a single project could address one or more FMTs. One goal with this formulation was to provide clear traceability while providing flexibility in NASA's implementation.

As part of its pre-decadal survey preparation, HPD tasked Johns Hopkins University/Applied Physics Laboratory to manage the LWS Architecture Committee in its production of sample FMTs based on community input (analogous to Heliophysics Mission Concept Studies for STP). This committee

repeatedly solicited community input (e.g., community mailing lists) and briefed their effort at public meetings (e.g., NASA's Heliophysics Advisory Committee).

NASA intends the Architecture Study as a resource for the Committee. The DSC can leverage particular FMTs as written; it can add to, subtract from, or modify those FMTs; or it can refer to those FMTs when creating its own.

STP-1. **There has never been more than one STP mission in development at the same time. Has the limiting factor been budget or management? If the next decadal survey were to recommend more than one STP mission at a time, would NASA have the management capability for them?**

The limiting factor is budget. NASA has the management capability. When we need mission managers, we can draw upon the entire agency. We are NASA, and we have a deep bench.

Additional information: This is true for all programs, not just STP. For instance, LWS previously had both Parker Solar Probe and the Solar Orbiter Collaboration developing concurrently, and STP is currently developing both Interstellar Mapping and Acceleration Probe (IMAP) and Carruthers. With the recent growth in the Explorers portfolio, more individuals were hired as mission managers.

SpWx-1. **Is NASA looking for guidance on growing the Space Weather MIDEX program? SMEX program?**

We're open to recommendations. The DSC shouldn't get caught up in the existing budget and future "free energy" available. NASA doesn't want to constrain the DSC on their recommendations.

SpWx-2. **We're expanding human presence beyond low Earth orbit. What does HPD view the role that NASA has in space weather for astronauts on the moon and ultimately Mars?**

HPD's been involved with the Agency regarding how we're going to support it. By what kind of science is enabled by these activities and how to further that science through measurements and infrastructure put in place to protect the astronauts. NASA are asking the DS for specific recommendations on Artemis and Moon to Mars.

SpWx-3. **Should the DSC continue the traditional divide between NASA and NOAA as it relates to space weather activities relevant to astronauts and human exploration?**

NASA and NOAA recently signed an inter-agency agreement on radiation support to astronauts, so that provides some guidance as to the roles and responsibilities. NASA and NOAA are working closely together to determine the roles, and there was a summit to discuss them.

To summarize the split: Cutting edge development, research, and deep analysis is NASA. Operations is NOAA.

SpWx-4. Is HPD looking for how different space weather programs are working together or is there an overarching strategy?

There's synergy among the LWS and Space Weather Programs, but they have their separate goals and vision. Space Weather has its own program and goals, and LWS is fundamental science.

SpWx-5. What is NASA's definition of "space weather research"?

At the very top level, the applied aspect of heliophysics is space weather. If one can draw a straight line from the research to a space weather application, it's space weather research.

SpWx-6. How much flexibility does NASA need to respond to changes within the space weather domain within the next decade?

NASA needs flexibility in implementation and the focuses we go after. The overall strategy is unlikely to change significantly, but the implementation and prioritization of activities may change.

Since the last strong solar cycle, technologies functioning during low solar activity have been developed. The NASA space weather research program must be flexible to respond to such technology advancements and large-scale solar variability.

SSA-1. Does HPD have an obligation to advance and improve science for SSA and should topics in the obligations space be prioritized differently than the opportunity space?

HPD does not have a current obligation for SSA/OD. It is outside of the 2013 Decadal Survey because it is new/emerging, and wasn't mentioned during the last one (or, if it was, it was in Chapter 7).

Additional information: Orbital debris was discussed in the 2013 Decadal Survey as a motivating factor for studying space weather [Chapter 7, p. 135]:

> *Understanding space weather and climate is a prerequisite for fulfilling at least two directives of U.S. national space policy:*
>
> 1. *[…]*
>
> 2. *Preserve the space environment, in part by pursuing "research and development of technologies and techniques . . . to mitigate and remove on-orbit debris, reduce hazards, and increase understanding of the current and future debris environment" and by leading "the continued development and adoption of international and industry standards to minimize debris." Satellite drag is relevant to orbit and reentry prediction and to long-term mitigation of orbital debris. The recent inability, for example, to forecast the demise of the Upper Atmosphere Research Satellite (UARS) spacecraft underscores limitations in current capabilities for modeling and understanding the interaction of Earth-orbiting objects with the upper atmosphere. Space junk now exceeds 22,000 objects larger than a softball (Figure 7.1); collisions are expected to become more frequent (and may have propelled the UARS satellite into a less stable orbit).*

SSA-2. HPD supported a Tiger Team to study a potential SSA/OD mission concepts. Can NASA share the Tiger Team budget/costing study results with the DSC as they form recommendations around the science?

There is an internal report, but HPD would need to check if it can be shared with the DSC. The mission concept study done at Goddard is a high-level mission concept study and was done in response to an Office of the Inspector General (OIG) action. Since SSA/OD is new and has emerged since the last Decadal, HPD wants DS recommendations around how to deal with SSA/OD and other new and emerging issues.

Additional information: The SSA/OD report is an internal document and was not written for release. The budget that HPD provided (in the Budget Workbook, under *HPD Prog. of Rec., future costs*) is an enveloping profile that the study showed would support the highest-priority aspects without tailoring to specific providers or implementations.

SSA-3. Does HPD anticipate a new strategic mission line for SSA/OD, or would it fall under the NASA Space Weather Program? If it's prioritized in the DS, will it take funding away from another source/mission?

This is where NASA wants the DSC to enable the cutting-edge science and develop the recommendations. If a new strategic mission line for SSA/OD seems like the best recommendation, that is what NASA wants to see.

Additional information: This discussion used the term "strategic mission line" to mean a new program (like LWS, Space Weather, Technology, etc.). In the Decadal Survey recommendations' budget requirements, the SSA/OD program would need to be shown separately and fully capture all SSA/OD funding needs.

SSA-4. **For SSA/OD, can NASA do anything by itself without collaborating with the other space agencies, particularly the Chinese agency?**

It's an international effort. For instance, there are requirements levied on orbital assets. NASA is asking the DS what recommendations would help HPD further the science and knowledge of orbital debris.

Additional information: As stated in the discussion, fully solving the orbital debris problem is an international effort. However, NASA follows requirements on orbital assets and has internal activities related to orbital debris.

HPD approaches orbital debris with a focus on furthering scientific understanding. These include the National Orbital Debris Research and Development Plan's general topical areas and the National Orbital Debris Implementation Plan's recommended efforts on orbital debris-associated plasma waves (Action 2.2.7), new technologies to characterize the orbital debris environment (Action 2.3.1), and developing collaborative open science platforms (Action 2.7.2). Through other activities, such as the Orbital Debris Program Office (under the Office of Safety and Mission Assurance), NASA has taken the lead in developing the technical consensus for adopting mitigation measures.

Tech-1. **Through what mechanisms does Heliophysics Strategic Technology Program Office (HESTO) invest in new technologies to achieve its goal of enabling novel and transformative new capabilities and mission concepts in Heliophysics?**

[During the July 2023 Access to Space Working Group meeting, the WG and DSC members had discussions with NASA. This question was sent ahead of time and answered in writing.]

HESTO assists Heliophysics Division (HPD) in the management of the funded technology projects, and provides support to the principal investigators (PIs) to advance their technologies. HESTO also supports the PIs in identifying opportunities to mature their technologies (such as rideshares on suborbital platforms and small satellites). The Heliophysics Division (HPD) competitively

selects and funds technology projects through the ROSES/HTIDeS program, and mission concept projects through the ROSES/HFOS program. HPD manages all aspects of the solicitations, competitions, and investments. HPD uses the Heliophysics Gap and Trend Analysis, led by HESTO and incorporating community input, to inform the solicitations and program priorities.

Tech-2. Does HESTO manage or provide oversight to specific missions within the Heliophysics portfolio beyond those selected under HTIDeS and HFOS?

[During the July 2023 Access to Space Working Group meeting, the WG and DSC members had discussions with NASA. This question was sent ahead of time and answered in writing.]

No, HESTO is not involved in management of projects outside of those selected through HTIDeS and HFOS.

Tech-3. Is HESTO likely to evolve beyond its current set of roles and responsibilities? If so, in what direction?

[During the July 2023 Access to Space Working Group meeting, the WG and DSC members had discussions with NASA. This question was sent ahead of time and answered in writing.]

No, NASA does not intend to evolve HESTO beyond its current set of roles and responsibilities.

Tech-4. Has HESTO actively participated in the release of topics under Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) solicitations?

[During the July 2023 Access to Space Working Group meeting, the WG and DSC members had discussions with NASA. This question was sent ahead of time and answered in writing.]

No, HESTO is not involved in developing, selecting or managing SBIR/STTR projects. The SBIR/STTR solicitations are managed by the Space Technology Mission Directorate. The HPD Deputy Chief Technologist participates in the definition of the Heliophysics SBIR subtopics. HPD involves HESTO after selections have been made and are ready for public announcement through the Heliophysics technology website.

Tech-5. **In what way does HESTO interact with Space Technology Mission Directorate's (STMD's) programs (for example STMD's Small Spacecraft Technologies program) to leverage capabilities for Heliophysics?**

[During the July 2023 Access to Space Working Group meeting, the WG and DSC members had discussions with NASA. This question was sent ahead of time and answered in writing.]

HESTO does not interact with STMD's programs. SMD, including its Division representatives, interact with STMD through the SMD Technology Federation (TechFed).

Projects

GenPj-1. **For Partner Institution (PI)-led missions, where do things like the management office get captured?**

It's in the budget spreadsheet as a separate line under each program and it needs to be included. Program Management is a background cost that is always there.

GenPj-2. **Is there a single number we should assume for missions that move into extended missions? There are a lot of missions in development now. Is there a cap for extended missions in the next decade? Is the main concern budget creep? Is NASA looking for decision rules for extended missions?**

NASA is not trying to prescribe how the DS treats extended missions. The conservative position is to plan a flat budget for any mission that moves into extended missions.

All missions are invited into Senior Review. In principle, if the budget is available and the science is good, any and all missions could continue into an extended mission.

The DS should think of all of the ramifications of the recommendations. They must balance all of the strains when NASA extends a mission.

Additional information: In this and previous discussions with the DSC, HPD referenced historical decreases in extended mission budgets (see the provided document, *NASA Space Flight Programs and Projects: Budget Elements*), a flat budget in current dollars (not adjusted for inflation), and a flat budget in constant dollars (adjusted for inflation). Further, HPD created the HSO Infrastructure

category to decrease demands on long-lived missions (Program of Record Supplemental Presentation, Slide 7).

HPD does not prescribe what combination of these or other options the DS recommends for extended missions. However, the recommendation must be clearly stated and budgeted for.

Additionally, any decision rules regarding how to treat extended mission budgets that grow faster than anticipated would be helpful.

GenPj-3. **For the 2013 Decadal Survey's budgeting of the Explorers program, what contributed to the underbudgeting aside from launch vehicle cost? How can the budget be so wrong in a cost-capped profile (in the previous DS)? Would it be helpful to provide the DSC with NASA's launch costs?**

[This question was rolled into the surrounding discussion. The Committee noted that the launch vehicle costs provided in the supplemental documents cover a wide range, and they asked for clearer bounding cases.]

Additional information: The Committee noted that the launch vehicle costs provided in the supplemental documents cover a wide range, and they asked for clearer bounding cases.

It is NASA's expectation that the Technical Readiness and Cost Evaluation (TRACE) process (like in previous decadal surveys) will provide a launch vehicle cost for any project they study.

Therefore, the NASA-provided launch vehicle costs would only be useful for developing budget requirements for MO-, SMEX-, and MIDEX-class recommendations for the Explorers, STP, LWS, SpWx, and Technology programs. This information is being included as part of the response to the Committee's question on sustainable Explorers cadences.

GenPj-4. **What would NASA do about certain space-based observations that would be useful to many different investigations but might be challenging to get through an AO competition?**

[This question was part of a larger question that NASA addressed separately.]

NASA has thought about infrastructure. If you look at the DYNAMIC AO, you will see the auroral imager offered as Government Furnished Equipment. We know that an auroral imager is useful to a number of investigation but may be a challenge to propose on its own.

GenPj-5. **How can the Decadal Survey address space-based capabilities that are aging and not easily replaced?**

[This question was part of a larger question that NASA addressed separately.]

NASA thinks about this a lot. A lot of old missions are significantly relied on, and there is not a plan for what happens when they go away. The 2017 Earth Science Decadal Survey discussed continuity measurements in the context for their long-baseline climate record. The Heliophysics Decadal Survey does not focus on the long baseline observations, it focuses on science. NASA considers it within the Decadal Survey's purview to discuss the high-priority items that are necessary to complete the recommended science objectives. However, there is not enough funding to complete all of the objectives.

DYN-1. **Should the Committee assume that Dynamical Neutral Atmosphere Ionosphere Coupling (DYNAMIC) is going forward and include it in the current program?**

DYNAMIC was confirmed by the 2013 Decadal Survey Mid-term Assessment as the highest priority science to move forward with. There is a community announcement coming out soon that will go through solicitation details.

However, NASA does invite the DS to comment on whether it is still endorsed as a priority. NASA doesn't expect DYNAMIC to be reprioritized as a project, but rather a confirmation that the science involved in it is still a high priority.

NASA invites the DS to talk about the contribution in the recommended science strategy.

DYN-2. **Beyond the commitment to affirm the continued priority of the DYNAMIC science, which is mentioned in the Midterm Assessment, what does NASA want the committee to recommend? The DSC has been tasked to not reprioritize missions that have gone past Key Decision Point (KDP) B at the time of the report publication. What is the schedule for DYNAMIC so that Committee can ensure their comments are useful?**

NASA asks the Decadal Survey Committees to affirm the Program of Record, which includes those missions in early formulation. Additionally, NASA is asking for recommendations around the methods we used to complete the previous Decadal Survey's recommendations, such as using a slightly different implementation but achieving the science.

DYNAMIC KDP B will be close to the report publication, and likely around the same time as Geospace Dynamics Constellation's (GDC) KDP B. We invited the Committee's comments for transparency, but also to help inform future mission formulations.

Additional information: In the Decadal Survey Kick-off Presentation (Slide 17), NASA invited the DSC to provide input on the formulation of recommended missions. DYNAMIC is being formulated with a dependence on GDC-provided measurements. SMD has this flexibility for missions that will be in science operations concurrently (see the provided document, *Formulation of NASA Space Flight Investigations: A Framework to Enable Discussions*). This cost-effective implementation enables 2013 Decadal Survey-recommended science with a smaller-than-anticipated budget, and could be leveraged in and following the 2024 Decadal Survey.

DYN-3. When the decadal survey report is published, would DYNAMIC be at a stage implementation could be changed?

It would be a significant change, and it would mean GDC and DYNAMIC likely wouldn't fly at the same time.

DYN-4. How does NASA have the flexibility for an implementation of DYNAMIC using GDC, and where does the SoT (and other delivered documentation) call for and describe that?

[This answer summarizes NASA's response in the longer discussion.]

NASA's implementation of DYNAMIC is what the *Formulation of NASA Space Flight Investigations: A Framework to Enable Discussions* document refers to as a "dependent" investigation.

In NASA's Kick-Off Presentation (Slide 17) requests the Decadal Survey's input on this approach, where one decadal-recommended investigation is implemented in a more cost-effective manner by leveraging another project in concurrent development. (This kind of implementation, as would be displayed in a Decadal Survey budget sand chart, was illustrated graphically on Slide 14 of the *Ground- and Space-Based Coordination* presentation.)

A recommended "dependent" investigation like this could be a specific investigation (e.g. DYNAMIC), or it could be general project size (e.g. MO, SMEX-class, MIDEX-class).

GDC-1. **The Decadal Survey Committee has been tasked to not reprioritize missions that have gone past KDP B at the time of the survey publication. What is the schedule for GDC so that Committee can ensure their comments are useful?**

GDC KDP B will occur close to publication. It may have just gone through KDP B before the report is published, but the current schedule would have it going through KDP B right after the report is published. NASA invited the Committee's comments for transparency, but also to help inform the formulation of future missions.

Additional information: In the Decadal Survey Kick-off Presentation (Slide 17), HPD invited the DSC to provide input on the formulation of recommended missions. For instance, GDC is being formulated with the consideration of space weather interests, such as the provision of low-latency data products and the development of science capabilities necessary for GDC but could later be transitioned to operations. Input to inform future mission formulations that could similarly realize cross-agency benefits is welcome.

ENL-1. **What should the DSC do about ESA/NASA Lower Thermosphere-Ionosphere Science (EN-LoTIS)?**

EN-LoTIS is not a project right now. It is a joint study with the European Space Agency (ESA). The study is looking at the science priorities, technologies required, etc.

NASA invites the DS to discuss the potential contribution of EN-LoTIS to recommended science strategy.

Additional information: EN-LoTIS is a potential partnership that is being organized between ESA and NASA from the beginning. The EN-LoTIS study is listed in Program of Record as a project in pre-formulation as part of NASA's transparency with the Decadal Survey Committee.

For the DSC's reference, here are links with additional information on the state of EN-LoTIS.

- NASA and ESA Exploring New Joint Satellite Mission Concepts (NASA)
- EN-LoTIS Working Group Town Hall presentation (CEDAR Workshop)

Acronyms

Acronym	Term
AO	Announcement of Opportunity
DoD	Department of Defense
DRIVE Centers	Diversify, Realize, Integrate, Venture, Educate Centers
DS	Decadal Survey
DSC	Decadal Survey Committee
DYNAMIC	Dynamical Neutral Atmosphere Ionosphere Coupling
ENLoTIS	ESA-NASA Lower Thermosphere-Ionosphere Science
ESA	European Space Agency
ESD	Earth Science Division
FMT	Focused Mission Topic
FST	Focused Science Topic
GDC	Geospace Dynamics Constellation
HESTO	Heliophysics Strategic Technology Program Office
HPD	Heliophysics Division
HSO	Heliophysics System Observatory
IMAP	Interstellar Mapping and Acceleration Probe
KDP	Key Decision Point
LWS	Living With a Star
MIDEX	Medium-class Explorer
MO	Mission of Opportunity
NASA	National Aeronautics and Space Administration
NASEM	National Academy of Sciences, Engineering, and Medicine
NOAA	National Ocean and Atmospheric Administration
NSF	National Science Foundation
OIG	Office of Inspector General
R2O2R	Research to Operations to Research
SMD	Science Mission Directorate
SMEX	Small-Class Explorer
SoT	Statement of Task
SpWx	Space Weather
SSA[/OD]	Space Situational Awareness[/Orbital Debris]
STP	Solar Terrestrial Probes
TRACE	Technical Readiness Assessment and Cost Estimate
UARS	Upper Atmosphere Research Satellite

Cited Documents

Document	Associated Questions
2013 Decadal Survey Mid-term Assessment	Collabs_1, LWS_1, DYN_1
2024 Decadal Survey Study Approach	ChDS_2, ChDS_4
EN-LoTIS Working Group Town Hall presentation	ENL_1
Exoplanets Research	Collabs_3
Formulation of NASA Space Flight Investigations: A Framework to Enable Discussions	DYN_2
Habitable Worlds	Collabs_3
Human Exploration, Artemis, Moon & Mars Supplemental Presentation	ChDS_6
Kick-off Presentation	ChDS_2, ChDS_4, PoR_1, DYN_2, GDC_1
Living With a Star Architecture Study	LWS_1
NASA's Efforts to Mitigate the Risks Posed by Orbital Debris [NASA OIG]	ChDS_1
NASA Response to Mid-term Assessment	LWS_1
NASA Space Flight Programs and Projects: Budget Elements	GenPj_2
National Orbital Debris Implementation Plan	ChDS_1, SSA_4
National Orbital Debris Research And Development Plan	ChDS_1, SSA_4
National Space Weather Strategic Action Plan	ChDS_1
Program of Record Supplemental Presentation	PoR_1, GenPj_2
PROSWIFT Act	ChDS_1
Space Situational Awareness/Orbital Debris (SSA/OD) Supplemental Presentation	ChDS_1
Space Weather Council	ChDS_1
Space Weather Operations, Research and Mitigation Subcommittee [SWORM] publications	ChDS_1
Space Weather Roundtable	ChDS_1
Space Weather Supplemental Presentation	ChDS_1
Strategic Space Flight Programs: Structures and Implementations	Collabs_1, LWS_1

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Appendix A

Decadal Survey for Solar and Space Physics (2024-2033)
Integrating Ground- and Space-Based Observations
Meeting Summary
(July 11, 2023 Meeting)

The Decadal Survey was charged with recommending a science strategy where ground- and space-based investigations were combined (Statement of Task, Item 3.a). The framework for this was described in the Decadal Survey Statement of Task (including which recommendations go to which specific sponsors), the Study Approach (NASA-specific section), and the *Formulation of NASA Space Flight Investigations* document (under "coupled investigation"). The *Integrating Ground- and Space-Based Observations* presentation illustrated NASA's expectations (Slides 10-14) for how the Decadal Survey would present the recommendation.

The sponsor agencies asked the National Academy of Sciences for a decadal strategy that combines ground- and space-based investigations to significantly advance progress on the prioritized science goals (Statement of Task, Item 3.a).

Functionally, the Decadal Survey should recommend the whole science objective involving combined ground- and space-based observations. The Decadal Survey is read by agency stakeholders that strongly benefit from having the bottom line up front. For those recommendations involving combined ground- and space-based investigations, it would be most impactful for the recommendation to specify the agencies involved in the combined investigation.

Underneath any top-level recommendation for such a combined investigation, per the Statement of Task's direction, the Decadal Survey should recommend to NASA the appropriate space-based investigation, and should recommend to NSF and/or NOAA the ground-based investigation(s) . These sub-recommendations would be accompanied by specific project-level cost and schedules in the agency-specific recommended-budget tables and sand charts.

In drafting any such recommendation (and sub-recommendations) for a combined ground- and space-based investigation, the Decadal Survey should be aware that inter-agency agreements take time (at least one year) and for the purpose of strategic alignment would need to be in place before NASA starts project formulation activities.

From a NASA point of view and assuming ground-based projects to have longer design lifetimes than space-based projects, the most effective scheduling would be for the non-NASA ground-based project to start before the NASA space-based project. This would enable NASA to take advantage of any decision rules or adjustments to prioritization if the ground-based project did not start as envisioned.

The Decadal Survey was encouraged to provide a strategy for ground-based investigations and infrastructure. NASA endorsed NSF's specification that recommendations should address *ground-based capabilities*.

The Decadal Survey is the one single document that stakeholders look to for input to a National heliophysics strategy. However, there has never been a clear or coherent strategy for ground-based investigations or infrastructure.

The 2013 Decadal Survey identified a small number of specific facilities and advocated for ground-based observations. The 2013 Decadal Survey Mid-term Assessment recommended the coordination of ground- and space-based observations. Even the recent Space Weather Advisory Group recommendations addressed ground-based networks to support space-based missions.

An implementation strategy for ground-based infrastructure needs to contain specific details, including observation capabilities (including geographic distribution), the expected new starts, the expected lifetimes, and the enabling budget.

NOAA, NSF, and NASA all emphasized that a compelling strategy must have specific benefits for each involved agency. A recommendation for one agency to support a capability or project primarily (or solely) for the benefit of another agency lessens the compelling nature of a strategy.

The Heliophysics System Observatory (HSO), NASA's fleet of heliophysics space flight missions, is developed through a combination of PI-led projects and NASA-managed projects. The 2013 Decadal Surveys explicitly prioritized the Explorers Program over strategic investments (e.g. Solar Terrestrial Probes, Living With a Star) for the HSO. The 2024 Decadal Survey was asked to recommend robust, sustainable strategies for the Solar Terrestrial Probes (STP), Living With a Star (LWS), and Space Weather Programs. This explicitly includes a range of science objectives and mission sizes, and invites leveraging NASA flexibility discussed in the *Formulation of NASA Space Flight Investigations* document.

There are two aspects to strategic HSO planning: the missions selected for development, and the missions approved for continued operations.

For selection for development, NASA does not place strong scientific constraints or requirements on proposals to an Explorers Announcement of Opportunity (AO), outside of addressing the Explorers Program high-level goals and objectives listed in the AO. When the 2013 Decadal Survey prioritized Explorers, it greatly diminished strategic options.

Further, the recommendations for the STP and LWS Programs were for moderate-scale and larger stand-alone projects. Programs that only have larger projects present challenges to sustainability.

In the Statement of Task package (Study Approach, NASA-specific section), NASA requested a range of mission sizes and recommended investigations for each (non-Explorers) Program. The mission sizes were requested to cover the range from Missions of Opportunity to large missions, and the investigations were requested to be in terms of science objectives (narrow aspects of broader science goals/questions that can be completed by single space flight projects). (The formulation paradigms for STP and LWS are discussed in the *Strategic Space Flight Programs Structures and Implementations* document, previously delivered to the Decadal Survey Committee.)

For STP, NASA requested program-level science objectives. NASA did not provide specific examples of the requested recommendations, but expects that the 2024 Heliophysics Decadal Survey could frame its recommendation(s) in a similar fashion to the 2011 and 2022 Planetary Science and Astrobiology Decadal Surveys' recommendations for the New Frontiers Program (although focused on science objectives, rather than the New Frontiers' mix of science objectives, measurements and other mission-implementation details, and operational capabilities).

For LWS, NASA envisioned "Focused Mission Topics" (FMTs), as described in the *Structures and Implementations* document. Before the Decadal Survey process began, NASA supported the Living With a Star Architecture Committee to assess the current state and potential future needs for the LWS Program (see final report). In that effort, the group produced example FMTs for the Decadal Survey's use. These FMTs were based on input from the science community, and some of the science objectives were written at a higher level in order to not prescribe or constrain the Decadal Survey Committee.

Within the *Formulation of NASA Space Investigations* document, NASA described different types of investigations. The "dependent" and "coupled" investigations are where NASA could most easily implement strategic decisions for the HSO. (NASA's formulation of DYNAMIC is an example of a dependent investigation. DYNAMIC requires GDC capabilities, but GDC does not require DYNAMIC.)

(One important note is that dependent and coupled investigations are expected to have prime science operations concurrent with the mission with which it is coordinated. The more separated the prime operations, the more risk NASA would be exposed to. The *Ground- and Space-Based Coordination* presentation shows an example of relative timing of two projects on Slide 14.)

For the approval for continued operations, NASA requested the Decadal Survey recommend a strategic approach for the HSO (NASA Decadal Survey Kick-off Presentation, Slide 18).