

# Review of the Draft 2019 Science Mission Directorate Science Plan

Committee on the NASA Science Mission Directorate Science Plan

Space Studies Board

Division on Engineering and Physical Sciences

A Consensus Study Report of

*The National Academies of*

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## Preface

In a letter dated June 12, 2019 (reprinted in Appendix A), Associate Administrator Thomas H. Zurbuchen of NASA's Science Mission Directorate (SMD) informed the Space Studies Board (SSB) that SMD planned to release a new version of its Science Plan in October 2019. In keeping with its practice of the last several decades, Dr. Zurbuchen requested that the SSB initiate a study to review the draft Science Plan and provide feedback to SMD. Subsequent discussions between the SSB and SMD resulted in the definition of a statement of task for an ad hoc committee that would undertake the review. The discussions further established that a draft of the plan would be available at the beginning of July 2019 and that a final report would be delivered to NASA 12 weeks later.

In response to SMD's request, the National Academies of Sciences, Engineering, and Medicine established the Committee on the NASA Science Mission Directorate Science Plan on July 12. The committee's membership consisted of two individuals with expertise in each of SMD's four principal space science disciplines—astronomy and astrophysics, planetary science, heliophysics, and Earth science and applications. These individuals were supplemented by experts in engineering and space technology and space science policy. Given the expedited schedule for the completion and delivery of the review, the majority of the committee members were recruited from the ranks of the SSB and the board's four standing committees—the Committee on Astronomy and Astrophysics (CAA), the Committee on Astrobiology and Planetary Science (CAPS), the Committee on Solar and Space Physics (CSSP), and the Committee on Earth Science and Applications from Space (CESAS)—and the Aeronautics and Space Engineering Board (ASEB).

To broaden the scientific and technical scope of the review committee's assessment, the draft Science Plan was shared with the members of the SSB, ASEB, CAA, CAPS, CSSP, and CESAS. Their comments were shared with the review committee, who held a single meeting at the National Academy of Sciences building in Washington, D.C., on August 1-2. To ensure that the members of the review committee understood the purpose and scope of the draft Science Plan, the agenda for the August meeting included extensive discussions with Dr. Zurbuchen and other individuals at NASA headquarters responsible for drafting the plan.

An initial draft of the review committee's report was assembled during the week following the August 1-2 meeting. The report's text was finalized on August 14 and sent to external reviewers for comment on August 15. The report was revised in response to reviewer comments during the first 2 weeks of September and approved for release on September 23.

The work of the committee was made easier thanks to comments and other important contributions made by the following individuals: Megan Donahue, Michigan State University; Tom Greene, NASA Ames Research Center; Ellen Gertsen, NASA Headquarters; Stephen J. Mackwell, American Physical Society; David J. McComas, Princeton University; William B. McKinnon, Washington University; Clive Neal, University of Notre Dame; Michael New, NASA Headquarters; Meenakshi Wadhwa, Arizona State University; and Thomas H. Zurbuchen, NASA Headquarters.

This Consensus Study Report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published report as sound as possible and to ensure that it meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following individuals for their review of this report: Roger D. Blandford, NAS,<sup>1</sup> Stanford University; Stacey W. Boland, Jet Propulsion Laboratory; Lennard A. Fisk, NAS, University of Michigan; James F. Kasting, NAS, Pennsylvania State University; Robert A. Lindeman, NAE,<sup>2</sup> Northrop Grumman Mission Systems, retired; and George W. Sutton, NAE, Analysis and Applications, Inc.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of this report nor did they see the final draft before its release. The review of this report was overseen by Louis J. Lanzerotti, NAE, New Jersey Institute of Technology. He was responsible for making certain that an independent examination of this report was carried out in accordance with the standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content of the report rests entirely with the authoring committee and the National Academies.

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<sup>1</sup> Member, National Academy of Sciences.

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## Summary

At the request of NASA’s Science Mission Directorate (SMD), the Space Studies Board (SSB) of the National Academies of Sciences, Engineering, and Medicine initiated a study to review a draft of SMD’s *2019 Science Plan* and provide feedback to SMD. The request for this review was made at a time when SMD is engaged in the development of a new vision for the advancement of space science goals via the codification of a series of leadership priorities and management principles. As such, the 2019 document represents a radical, but welcome, departure from more traditional science strategies and plans adopted by SMD over the past two decades. The draft document is potentially a very important one spelling out SMD’s values, priorities, and principles. The committee believes that its comments help to develop the document into the transformative, inspiring, ambitious, and forward-looking plan it was intended to be.

In conducting its review of the draft *2019 Science Plan* (hereafter, the draft document), the Committee on the NASA Science Mission Directorate Science Plan was charged to comment on the following specific areas:

1. Level of ambition of the specified strategies in light of current and emerging opportunities to advance Earth and space science over the next 5 years (see Chapter 3, “Level of Ambition”);
2. Ability of SMD to meet the science objectives in the most recent decadal surveys through implementation of specified strategies (see Chapter 4, “Ability to Meet Science Objectives in Decadal Surveys”);
3. Identification of additional strategies for SMD’s consideration (see Chapter 5, “Identification of Additional Guiding Principles”); and
4. General readability and clarity of presentation (see Chapter 2, “Readability and Clarity of Presentation”).

In response to these four tasks, the committee offers 17 recommendations to SMD.

Very early in its review, the committee discovered issues related to the readability of the material contained in the draft document. However, the purpose and intent of the draft document were much more clearly presented in oral form by SMD officials during the committee’s one and only meeting. The committee’s attempts to address its four tasks as ordered in the statement of task led to difficulties in the organization of this report. Therefore, the committee has altered the order of discussion to lead with item four in the statement of task (i.e., the topic of readability and clarity of presentation). This reordering of the tasks allowed the committee to propose new language that enabled a clearer and more logical discussion of items one, two, and three.

### READABILITY AND CLARITY OF PRESENTATION

The title of the draft document does not sufficiently describe its contents. Moreover, the draft document lacks a description of its purpose and target audience, and it does not contain necessary

contextual information and definitions. Specific areas where these and other issues of readability and clarity were a concern are called out in subsequent sections of this report.

**Recommendation: Change the title to *Priorities and Principles for Leadership of NASA Science: A Vision for Scientific Excellence*, or something similar, to better reflect its apparent purpose and content.**

**Recommendation: Include critical context explicitly in the introduction of the document. This information can be drawn, in part, from background information presented to the committee by NASA officials.**

Interpreting the draft document as a statement of leadership priorities and guiding principles that NASA SMD will employ in implementing its mission, instead of the focus areas and strategies in the draft, can directly benefit the SMD enterprise by providing a powerful tool for communication with internal and external stakeholders.

**Recommendation: Rename focus areas as leadership priorities and strategies as guiding principles.**

## LEVEL OF AMBITION

The draft document's stated guiding principles for SMD—pursuit of greater cross-disciplinary and cross-divisional collaboration, encouragement of a culture of entrepreneurship, and increased emphasis on research with high intellectual risk but potentially high impact—are ambitious. This approach will help the science divisions within SMD hew to a common vision of their integration of space missions and supporting scientific investigations. Some leadership priorities described in the draft document can be achieved in the short term, whereas others are broader statements of principle. Regrettably, the draft document does not effectively connect the leadership priorities contained in its first half with the division summaries contained in its second half.

**Recommendation: Outline the ways in which SMD's four science divisions will seek to embody the presented guiding principles.**

**Recommendation: Consistently frame the guiding principles, either as declarations of a desired state or as near-term directions or tasks.**

## ABILITY TO MEET SCIENCE OBJECTIVES

The draft document provides a solid framework for carrying out SMD's mission; the leadership priorities and guiding principles highlight the need to tackle the science objectives outlined in the decadal surveys relevant to each of SMD's four divisions, as well as participate in human exploration and technological innovation. The need to identify the optimal balance in risk-taking is also an important topic that spans intellectual and technological activities. However, the draft document does not specify, even via general examples,

1. How the guiding principles will be implemented,
2. How SMD's management will evaluate the success of each of the four divisions in adopting the principles,

3. How the guiding principles are relevant to fulfilling decadal survey objectives. Most puzzling is the omission of any mention of the 2018 decadal survey of Earth science and applications from space.

These discrepancies are exemplified most strongly by the disconnect between the description of the guiding principles and leadership priorities and the subsequent summaries of the activities of SMD's four divisions. In addition, although the guiding principles spell out the role of technology, the key role of foundational science is not well articulated.

**Recommendation: Broaden the “Innovation” leadership priority to include aspects that go beyond technology and high-risk science.**

**Recommendation: Spell out clearly the key role of fundamental science as a foundation for exploration and technology development.**

**Recommendation: Highlight the means to implement science that spans multiple divisions and makes seamless collaboration across NASA directorates a target.**

**Recommendation: Outline how the fundamental science can be enhanced and widened in scope to encompass interactions with user communities, including universities, private industry, not-for-profit organizations, and other government agencies.**

**Recommendation: Elevate risk-taking from innovation to a wider context. For example, outline actions that would contribute to the realization of higher-risk projects that have high intellectual yield.**

## ADDITIONAL GUIDING PRINCIPLES

The draft document begins by reviewing NASA's core values and adding a fifth one, leadership, under the umbrella of SMD. Although there is no doubt that leadership is required to deliver on NASA's four core values, its addition to SMD's list of core values risks the appearance of challenging the smaller list of core values that NASA has adopted at the highest level.

The mix of finite objectives and states of being that SMD wants to achieve could be better rationalized to support the establishment of these as enduring principles, as does the use of the term “strategies” instead of “guiding principles” and “focus areas” instead of “leadership priorities.” In addition, the draft document does not address how the presented principles might be pursued, which in turn hinders an understanding of how SMD will determine whether progress has been made.

The committee identified workforce development, mentoring, recruitment, and retention as a guiding principle that was not clearly called out in the draft document. Similarly, under the “Innovation” leadership priority, the draft document did not identify programmatic innovations that could improve efficiency and reduce costs. Examples could include management, contracting, oversight, and considerations for continuity of observations. Furthermore, increasing diversity of thought and backgrounds is best described as a contribution to the section on “Innovation” rather than the section on “Inspiration.”

The roles of universities, research institutions, and industry were not adequately stressed as a means of achieving excellence and diversity as well as contributing to workforce development.

Finally, the draft does not describe how NASA, SMD, and the broader science community would determine when these guiding principles have been implemented within SMD.

**Recommendation:** Do not insert leadership as a fifth core value. Rather, the importance of leadership should be asserted when introducing the four leadership priorities.

**Recommendation:** Describe the guiding principles in enough detail to provide definition, context, and examples whenever possible.

**Recommendation:** Describe the desired future state. The “2024 Future State” slide presented to the committee may be an appropriate starting point for a section on this topic.

**Recommendation:** Move the guiding principle “Increase the diversity of thought and backgrounds represented across the entire NASA Science portfolio through a more inclusive environment” from the section on “Inspiration” to the section on “Innovation.”

**Recommendation:** Spell out the aim and means to effectively collaborate with universities, research institutions, and industry in carrying out SMD’s programs as well as developing the diverse future workforce.

**Recommendation:** Expand the discussion of diversity and inclusion by recognizing the variety of approaches necessary to achieve this goal.

**Recommendation:** Add a new guiding principle 4.1, “Develop the Future SMD Workforce.” This principle should explicitly incorporate the importance of mentorship, recruiting, training, as well as link to the principle about increasing diversity of thought and backgrounds (in *Innovation*).

## CONCLUSIONS

Unlike earlier SMD science strategies and plans, the 2019 draft does not include details about current scientific thrusts and plans for missions among its four science divisions. Instead, it focuses on guiding principles and leadership priorities that could effectively lead to fulfillment of recommendations in decadal surveys and in the development and deployment of human capital. If the draft document can be revised as recommended here, the divisional commitment to the stated leadership priorities and guiding principles made more explicit, and the writing overall imbued with language equal to the magnitude of the vision, the draft document could guide SMD to a future that is ambitious, forward looking, and inspiring.

## 1

**Introduction**

The 2019 NASA Science Plan, entitled *Explore Science 2019-2024: A Vision for Scientific Excellence*, (hereafter the draft document) defines a new set of principles to guide the organization of and setting of priorities for NASA SMD.<sup>1</sup> From an overarching vision to “Lead a globally interconnected program . . .” (Figure 1.1), the draft document describes components of its mission, values, and leadership priorities that guide how SMD’s four science divisions—Astrophysics, Earth Science and Applications, Heliophysics, and Planetary Science—could address important science questions and the observations needed to support that science. Generally, the document expresses principles and priorities that will guide SMD, without specific goals in the 2019-2024 timeframe. The 2019 draft document, the sixth in a series reviewed by the Space Studies Board,<sup>2,3,4,5,6</sup> is much more concise (~25 pages versus 126 pages) than its 2014 predecessor,<sup>7</sup> hence the review is much shorter. The NASA draft document appears to be a credible early draft containing elements of what the SSB had looked for, but not found, during its reviews of prior draft NASA science plans and strategies.<sup>8</sup> Whereas NASA’s previous documents were criticized as being mainly catalogs of missions, programs, and desires, the current draft document appears to contain the principles to guide how those missions and programs should be managed and the desires realized.

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<sup>1</sup> NASA, *Explore Science 2019-2024: A Vision for Scientific Excellence*, [http://sites.nationalacademies.org/SSB/CurrentProjects/SSB\\_194794](http://sites.nationalacademies.org/SSB/CurrentProjects/SSB_194794).

<sup>2</sup> National Research Council (NRC), “On NASA’s Office of Space Science Draft Strategic Plan,” letter report from SSB Chair Claude R. Canizares to Wesley T. Huntress, Jr., associate administrator for NASA’s Office of Space Science, August 27, Washington, D.C., 1997.

<sup>3</sup> NRC, “On the Space Science Enterprise Draft Strategic Plan,” letter report from SSB Chair Claude R. Canizares to Edward J. Weiler, associate administrator for NASA’s Office of Space Science, May 26, Washington, D.C., 2000.

<sup>4</sup> NRC, “On Assessment of NASA’s Draft 2003 Space Science Enterprise Strategy,” letter report from SSB Chair John H. McElroy to Edward J. Weiler, associate administrator for NASA’s Office of Space Science, May 29, Washington, D.C., 2003.

<sup>5</sup> NRC, “A Review of NASA’s 2006 Draft Science Plan,” letter report from A. Thomas Young, chair of the ad hoc Committee on Review of NASA Science Mission Directorate Science Plan, to Mary Cleave, NASA’s associate administrator for the Science Mission Directorate, September 15, Washington, D.C., 2006.

<sup>6</sup> NRC, *Review of the Draft 2014 Science Mission Directorate Science Plan*, The National Academies Press, Washington, D.C., 2013.

<sup>7</sup> NASA, *Science Plan 2014*, [https://smd-prod.s3.amazonaws.com/science-red/s3fs-public/atoms/files/2014\\_Science\\_Plan\\_PDF\\_Update\\_508\\_TAGGED\\_1.pdf](https://smd-prod.s3.amazonaws.com/science-red/s3fs-public/atoms/files/2014_Science_Plan_PDF_Update_508_TAGGED_1.pdf).

<sup>8</sup> Fortunately, the reviewers of the draft 2014 SMD Science Plan included in their report (Appendix C of *Review of the Draft 2014 Science Mission Directorate Science Plan*) a summary of the key comments from the reviews of the 1997, 2000, 2003, and 2006 Science Plans. Prior Science Plans contained extensive catalogues of missions and programs with few indications of how decisions were to be made. The summary comments from Appendix C that particularly resonated with the members of the current committee was the one stating the following: “Several reviews noted that . . . NASA’s Science Plan was not “strategic” and, thus, of limited utility in planning.

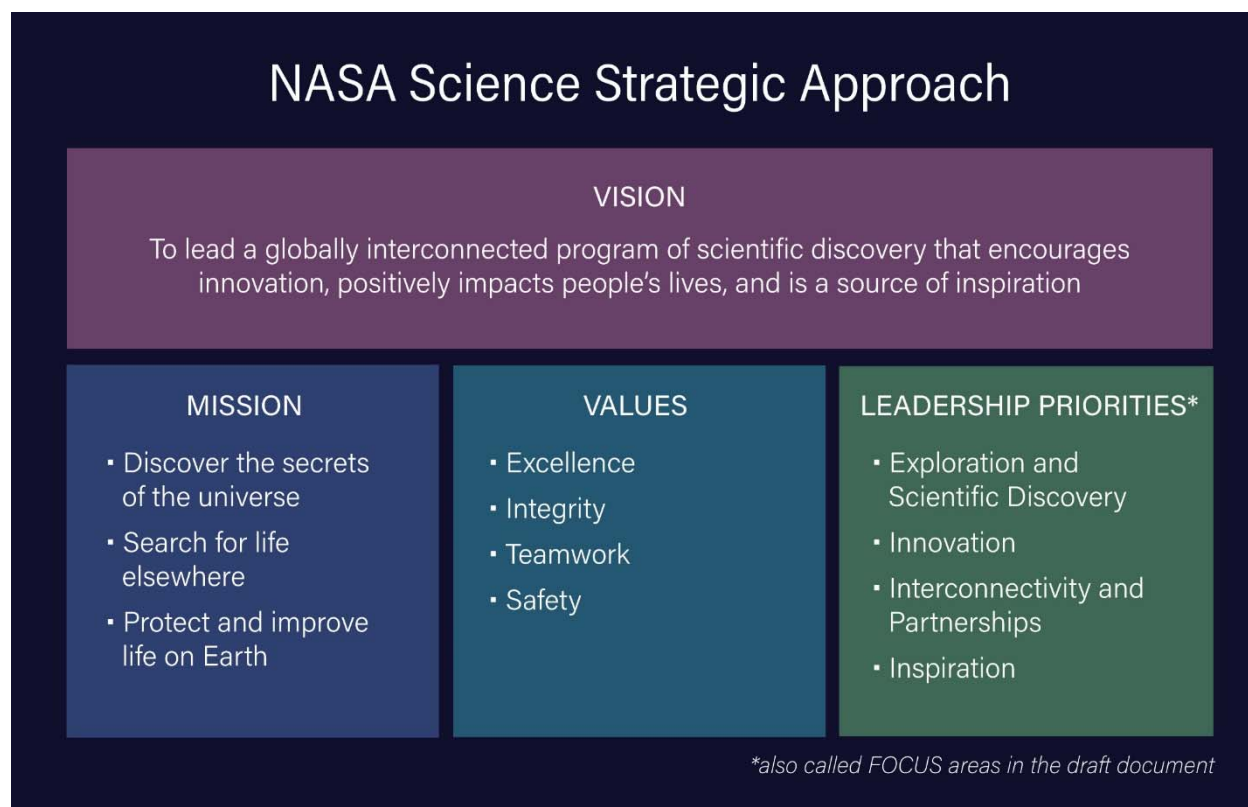


**FIGURE 1.1** Structure to guide organization and priorities for NASA’s Science Mission Directorate. SOURCE: Adapted from Thomas H. Zurbuchen, NASA SMD Associate Administrator, presentation to the committee.

An expanded and annotated version of the draft document’s table of contents can be found in Appendix B.

The Committee on the NASA Science Mission Directorate Science Plan supports SMD’s efforts to formulate a more principled approach to managing its portfolio of missions and programs but has a range of concerns that translate into a set of recommendations. Because some recommendations fall into multiple categories, and some reorganization of topics and priorities is recommended, the organization of this report is somewhat different from that outlined in the committee’s statement of task (in Appendix A). The order here is as follows:

1. General readability and clarity of presentation (see Chapter 2, “Readability and Clarity of Presentation”);
2. Level of ambition of the specified strategies in light of current and emerging opportunities to advance Earth and space science over the next 5 years (see Chapter 3, “Level of Ambition”);
3. Ability of SMD to meet the science objectives in the most recent decadal surveys through implementation of specified strategies (see Chapter 4 “Ability to Meet Science Objectives in the Decadal Surveys”); and
4. Identification of additional strategies for SMD's consideration (see Chapter 5, “Additional Guiding Principles”).

In response to these four tasks, the committee offers 17 recommendations to SMD.

## 2

## Readability and Clarity of Presentation

The draft document provided to the committee was less polished than one would normally expect for such an important guiding publication being sent to the National Academies for review. The target audience for the document is not clearly specified, but the committee infers that it is dominantly aimed at NASA employees, contractors, and the community funded by SMD missions and research and analysis programs. The committee recognizes that the draft document represents a novel approach that seeks to motivate and facilitate change, but successfully achieving change requires inspiring the target audience to believe that changes will benefit them and the organization. Unfortunately, the draft document does not present the subject matter in an inspiring way. The draft document could have been developed more to fully evaluate the comprehensiveness of the proposed strategies nor their sufficiency to achieve SMD's scientific objectives. Furthermore, the document lacks context and terminology that are consistent with the content, and it requires clarification in several areas.

### TITLE AND CONTEXT

Notably, the focus of this document has changed relative to prior NASA science plans;<sup>1,2,3</sup> it no longer represents a plan for executing missions and conducting science but instead conveys a set of guiding principles adopted by the SMD, recognizing the key role of the decadal surveys in setting priorities and science goals.<sup>4,5,6,7</sup> As such, the draft document's title, *Explore Science 2019-2024: A Vision for Scientific Excellence*, does not present it as a "science plan." The draft document introduces four cross-cutting foci under the heading of "Science Leadership Priorities"—Exploration and Scientific Discovery, Innovation, Interconnectivity and Partnerships, and Inspiration—and describes strategies within these focus areas. However, the title of the draft document does not clearly convey the content.

**Recommendation: Change the title to *Priorities and Principles for Leadership of NASA Science: A Vision for Scientific Excellence*, or something similar, to better reflect its apparent purpose and content.**

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<sup>1</sup> NASA, *The Space Science Enterprise Strategic Plan: November 2000*, NP-2000-08-258-HQ, NASA Headquarters, Washington, D.C., 2000.

<sup>2</sup> NASA, *Science Plan For NASA's Science Mission Directorate 2007-2016*, NP-2007-03-461-HQ, NASA Headquarters, Washington, D.C., 2007.

<sup>3</sup> NASA, *Science Plan 2014*, NASA Headquarters, Washington, D.C., 2014.

<sup>4</sup> National Research Council (NRC), *New Worlds, New Horizons in Astronomy and Astrophysics*, The National Academies Press, Washington, D.C., 2010.

<sup>5</sup> NRC, *Vision and Voyages for Planetary Science in the Decade 2013-2022*, The National Academies Press, Washington, D.C.

<sup>6</sup> NRC, *Solar and Space Physics: A Science for a Technological Society*, The National Academies Press, Washington, D.C., 2013.

<sup>7</sup> National Academies of Sciences, Engineering, and Medicine, *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space*, The National Academies Press, Washington, D.C., 2018.

A major deficiency of the draft document is its lack of critical context. The introduction explains neither its origins, purpose, intended audience, nor its relationship to the NASA Strategic Plan and other key documents.<sup>8</sup>

**Recommendation: Include critical context explicitly in the introduction of the document. This information can be drawn, in part, from background information presented to the committee by NASA officials.**

The four foci in the document are more straightforwardly described as leadership priorities (a term the draft document uses as a heading). This designation follows logically from the desire to include leadership at the core of how NASA SMD operates.

Each of the four focus areas is associated with a number of strategies (Figure 2.1).<sup>9</sup> However, these strategies are better described as guiding principles. Because the document is not a science plan in the model of previous science plans, this language would be more consistent with the ambition of the document.

**Recommendation: Rename “focus areas” as “leadership priorities” and “strategies” as “guiding principles.”**

## CLARITY OF PRESENTATION

As already mentioned, the committee was asked to comment on the draft document’s clarity of presentation. The draft document delivered to the committee was much less polished than had been anticipated. Issues relating to clarity of presentation include the following:

- Much of the text is not sufficiently mature to fully evaluate the comprehensiveness of the proposed strategies nor their sufficiency to achieve SMD’s scientific objectives.
- Inaccurate statements detract from the draft document’s credibility. For example, the statement that “NASA Science will continue to seamlessly collaborate with the Human Exploration and Operations and Space Technology Mission Directorates” does not accurately reflect the community’s experience.<sup>10</sup>
- The draft document does not define what “NASA Science” means. The phrase appears multiple times in the draft document in different contexts. Does it include only NASA civil servants, its funded investigators, and/or the broader scientific community?
- The graphics in the draft do not represent well the guiding principles.
- The pictures included in the draft document lack captions, and the photograph illustrating, for example, “New American Exploration Partnerships” does not represent a diverse workforce.
- The draft lacks references or cross linkages to critical supporting documents such as roadmaps or plans.
- The draft includes material SMD had already decided to eliminate: for example, the incomplete section “Outer Planets and Ocean Worlds Program” and the appendix describing NASA Science Performance Goals.

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<sup>8</sup> NASA, *NASA Strategic Plan 2018*, NASA Headquarters, Washington, D.C., [https://www.nasa.gov/sites/default/files/atoms/files/nasa\\_2018\\_strategic\\_plan.pdf](https://www.nasa.gov/sites/default/files/atoms/files/nasa_2018_strategic_plan.pdf).

<sup>9</sup> A complete listing of the four focus areas and 15 strategies can be found in Appendix B.

<sup>10</sup> See, for example, National Research Council, *Vision and Voyages for Planetary Science in the Decade 2013-2022*, The National Academies Press, Washington, D.C., 2013, pp. 56-63.



**FIGURE 2.1** The four focus areas and the 15 strategies associated with their implementation, as presented in the draft document and explained to the committee by SMD Associate Administrator Thomas H. Zurbuchen. As explained in the text, the focus areas and strategies are more appropriately called leadership priorities and guiding principles, respectively. SOURCE: Figure adapted from slides presented by NASA/SMD.

### 3

## Level of Ambition

The draft document represents a departure from the style and structure of previous NASA SMD science plans and is better described as a document of guiding principles. Whereas previous science plans presented detailed outlines of ongoing and near-term activities within individual science divisions, the current document presents high-level principles that NASA SMD will adopt in its operations. But the draft document does not adequately describe how the implementation of these principles will enable SMD to address current and emerging opportunities to advance Earth and space science goals.

### PRINCIPLES AND REALIZATION OF SCIENCE GOALS

The guiding principles (called “strategies” in the draft document) are appropriately ambitious (see Figure 2.1).<sup>1</sup> Organizing SMD’s planning and decision-making around these guiding principles will require a twofold change: a substantial shift in both mindset and execution relative to current operations and a careful mapping of the guiding principles onto the plans of the individual science divisions within SMD. However, the ways in which each division would seek to embody the guiding principles are not clearly articulated in the draft document.

Ongoing SMD planning and decision-making will directly benefit from having the clear guiding principles and ambitious goals outlined in the draft document. This approach could enable stated organizational ambitions to be incorporated in a way that would not normally be part of a traditional science plan. Some examples of particularly ambitious aspects of the plan are as follows:

1. The level of cross-disciplinary and cross-division collaboration required of SMD divisions by several of the guiding principles (i.e., NASA *Strategies 1.2, 1.3, and 1.4*) represents an ambitious departure from business as usual within NASA;
2. The goal of developing a culture of entrepreneurship is highly ambitious; and
3. The emphasis on embracing high intellectual risk and high-impact research investments will require changes to the current decision-making processes.

The brief “Implementation” section in the draft document is vague. Moreover, the summaries of the activities of SMD’s four divisions only list ongoing scientific efforts and programs and do not speak to the guiding principles that form the core of the draft document. Although the information in division summaries is valuable, the existing text could be moved to an appendix or to another document (cited by this one) that provides information about existing and planned missions and activities.

Making the guiding principles truly manifest across SMD requires not only a detailed planning effort within the four science divisions but also a targeted process for achieving consensus about the importance of the outlined principles at all levels within SMD. The division-specific sections, if they are to be included in the final version of the plan, will need to be clearly integrated with the guiding principles and leadership priorities.

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<sup>1</sup> A listing of all of the draft document’s Strategies can be found in Appendix B.

**Recommendation: Outline the ways in which SMD’s four science divisions will seek to embody the presented guiding principles.**

Although some of the guiding principles are indeed laid out as principles, others define specific near-term directions or objectives. For example, “Develop a directorate-wide, target-audience focused approach to applied programs” (i.e., *Strategy 1.4*) is a specific task that can be accomplished in the 2019-2024 timeframe. On the other hand, “Execute a balanced science program” (i.e., *Strategy 1.1*) is a longstanding principle that describes a desired and achievable state with no specific endpoint. Additional examples include “Actively engage with other Federal agencies to make more informed decisions” (i.e., *Strategy 3.3*), which implies a specific direction of change over the next 5 years relative to the past, whereas “Pursue public-private partnerships” (i.e., *Strategy 3.5*) is a more general principle about how SMD seeks to operate in the long term.

**Recommendation: Consistently frame the guiding principles, either as declarations of a desired state or as near-term directions or tasks.**

## 4

## Ability to Meet Science Objectives in Decadal Surveys

The science objectives that the decadal surveys prioritize for each division are among the highest priorities in SMD. A clear set of guiding principles and leadership priorities could enable SMD to more effectively and efficiently achieve these objectives. This new approach requires buy-in from each division's management and a clear plan for how to embody this new approach in executing the decadal surveys' priorities, as well as specific ways to evaluate success.

### MEETING SCIENCE OBJECTIVES

The overarching leadership priorities (see Figure 1.1) provide a framework for carrying out SMD's mission. Inclusion of activities that encompass human exploration and innovation support the main mission to carry out the decadal surveys' science objectives. However, the draft document does not make clear how SMD plans to relate the guiding principles to science questions or to the objectives of its four science divisions. Nor does the draft document indicate how SMD will collaborate with NASA's other directorates (e.g., the Human Exploration and Operations Mission Directorate). Although three of the four space science decadal surveys are explicitly mentioned in the text, the omission of any mention of the fourth—the 2018 decadal survey of Earth science and applications—is puzzling.

Many of the descriptions of leadership priorities lack mechanisms of effectuation or examples in the division-specific sections (i.e., the materials in the second half of the draft document describing SMD's four science divisions). Actual implementation details could be described at length in another document (which could be cited), with brief descriptions included in the draft document. For example, *Strategy 2.3* explains the mechanisms by which a focus on research investments with both high intellectual risk and high impact could be achieved, but not all sections include this level of detail. The draft document could, for example, outline actions that would contribute to realization of higher-risk projects that have high intellectual yield.

The “Innovation” leadership priority (i.e., the draft document's “Focus 2”) as written is limited to innovations in technology and science. However, programmatic innovations are not mentioned. Such innovations could improve efficiency, reduce costs, and thereby enable a wider range of science to be investigated. The most cost-effective innovation often comes from establishing a user perspective into projects and internal processes. Areas where programmatic innovations could be explored include management, contracting, oversight, and considerations for continuity of observations. For example, earlier reports from the National Academies have recommended innovative ways to make missions more economical.<sup>1</sup>

**Recommendation: Broaden the “Innovation” leadership priority to include aspects that go beyond technology and high-risk science.**

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<sup>1</sup> See, for example, National Research Council, *Landsat and Beyond: Sustaining and Enhancing the Nation's Land Imaging Program*, The National Academies Press, Washington, D.C., 2013.

This recommendation might be implemented by adding an additional guiding principle or by broadening one of the existing guiding principles.

The draft document does not contain material that would describe how a balanced program is established or how to assess whether the call to “Execute a balanced science program based on discipline-specific guidance from the National Academies” (i.e., the draft document’s *Strategy 1.1*) is reached..

The decadal surveys define scientific objectives and observations needed to meet them; there is reason to believe that the draft document’s leadership priorities and guiding principles could advance the ability of SMD to accomplish decadal survey goals. Currently, however, the ways in which the activities of SMD’s divisions, as presented in the draft document, will embody the guiding principles are not described well. In other words, it is not possible to assess what actions will be taken at the division level based on the contents of the draft document, or how adoption of the leadership priorities and guiding principles would enable the divisions to better fulfill the decadal survey targets.

**Recommendation: Spell out clearly the key role of fundamental science as a foundation for exploration and technology development.**

Some of the guiding principles are commendable. For example, “Advance discovery in emerging fields by identifying and exploiting cross-disciplinary opportunities between traditional science disciplines” (i.e., *Strategy 1.3*) is important for the future, but it is unclear by what methods it will be realized or how success will be assessed.

**Recommendation: Highlight the means to implement science that spans multiple divisions and makes seamless collaboration across NASA directorates a target.**

The draft document outlines the need to find an optimal balance for risk-taking, which currently is commonly perceived by the scientific and engineering communities to be too low. This important topic spans intellectual and technological activities and the balance between the large strategic missions and the smaller ones under the direction of a principal investigator.

**Recommendation: Elevate risk-taking from innovation to a wider context. For example, outline actions that would contribute to the realization of higher-risk projects that have high intellectual yield.**

Although the importance of technology to NASA’s ambitious quests is well spelled out in the draft document, the key role of fundamental science is not described as clearly. What is needed is a clear articulation of the role of NASA, which provides observations and supports progress in fundamental science, and other entities, which add information and context, to protect public and private assets.

**Recommendation: Outline how the fundamental science can be enhanced and widened in scope to encompass interactions with user communities, including universities, private industry, not-for-profit organizations, and other government agencies.**

Another admirable guiding principle is *Strategy 1.4*, “Develop a Directorate-wide, target-audience focused approach to applied programs, including Earth Science Applications, Space Weather, Planetary Defense, and Space Situational Awareness,” which addresses areas where fundamental research has potential for applications. But, in many cases, these fields are not sufficiently mature to produce readily usable applications or services and will require basic research in close interaction with the potential user communities to offer opportunities for bridging research to the commercial or governmental user communities.

## 5

## Identification of Additional Guiding Principles

NASA officials specifically asked the committee to identify any strategies (see Figure 2.1)—that is, what the committee believes are more appropriately termed guiding principles—that the draft document misses. In addition to identifying possible new guiding principles, the committee also identified concerns with the overall framework.

### LEADERSHIP PRIORITIES AND GUIDING PRINCIPLES

The draft document’s introduction of leadership priorities appropriately asserts that leadership is required for SMD to deliver on NASA’s four core values (i.e., safety, integrity, teamwork, and excellence). However, the addition of leadership as a core value (see Figure 1.1) within SMD leads the committee to question whether the values of SMD are distinct from those of NASA itself. Rather, the importance of leadership by and within SMD can be asserted when introducing the directorate’s four leadership priorities. This could be achieved by moving portions of the text in the “leadership” section of the draft document into the preamble of the section “Who We Are.”

**Recommendation: Do not insert leadership as a fifth core value. Rather, the importance of leadership should be asserted when introducing the four leadership priorities.**

The high-level headings (the guiding principles) as written do not include language to make clear the mechanism(s) by which they will be fulfilled; thus, there is no way of knowing how SMD might determine in the future whether or how progress has been made.

**Recommendation: Describe the guiding principles in enough detail to provide definition, context, and examples whenever possible.**

Some descriptions of guiding principles do not include definitions that sufficiently or accurately explain the intended meaning. Some are not sufficiently developed with helpful examples. However, some of the examples that are included are odd, inappropriate, and/or inconsistent with the stated principle. A specific instance can be found in the text related to the guiding principle, “Pursue public-private partnerships in support of shared interests with industry” (i.e., the draft document’s *Strategy 3.5*). The example given refers to a private foundation, a foreign space agency, and a not-for-profit organization and begs the question of why these specific endeavors were chosen as examples. The selection of examples requires care, as readers will attach significance to the examples chosen.



**FIGURE 5.1** The *2024 Future State*. SOURCE: Thomas Zurbuchen, NASA/SMD, presentation to the committee.

## EVALUATION OF ACHIEVEMENTS

SMD Associate Administrator Thomas H. Zurbuchen’s presentation to the committee included a list of items representing the *2024 Future State* (Figure 5.1). This list provides a sense of what the successful implementation of the draft document might look like in 2024. However, this topic is not included in the draft document reviewed by the committee. As it stands, there are currently no measures of success identified in the draft document. Without such measures, sustainable improvement will be difficult to assess.

**Recommendation: Describe the desired future state. The *2024 Future State* slide presented to the committee may be an appropriate starting point for a section on this topic.**

## DIVERSITY, INCLUSION, AND THE WORKFORCE

The draft document appropriately identifies that a key NASA SMD principle is the “importance of diverse teams to most effectively tackle strategic problems and maximize scientific return” (see explanatory text for *Strategy 4.1*). However, diversity of thought and backgrounds is not a means toward “Inspiration,” the current location of *Strategy 4.1*; it is, rather, a critical contributor to achieving “Innovation.”

**Recommendation: Move the guiding principle “Increase the diversity of thought and backgrounds represented across the entire NASA Science portfolio through a more inclusive environment” from the section on “Inspiration” to the section on “Innovation.”**

The draft document describes the benefits of diversity and inclusivity well. However, the only specific approach for achieving these goals is listed as “initiating several efforts designed to address the problem of harassment” (see explanatory text for *Strategy 4.1*). The elimination of harassment is certainly essential but by itself does not achieve a diverse and inclusive environment. The National Science Foundation and American Geophysical Union have particularly thorough documents addressing these goals and the elements needed to achieve them;<sup>1,2</sup> they may serve as a basis for developing a NASA SMD strategy for achieving diversity and inclusivity.

**Recommendation: Expand the discussion of diversity and inclusion by recognizing the variety of approaches necessary to achieve this goal.**

The draft document does not discuss workforce development as a part of its leadership priority on inspiration. Effective development of the workforce requires recruiting, mentoring, and retaining a diverse workforce.

**Recommendation: Spell out the aim and means to effectively collaborate with universities, research institutions, and industry in carrying out SMD’s programs as well as developing the diverse future workforce.**

**Recommendation: Add a new guiding principle 4.1, “Develop the Future SMD Workforce.” This principle should explicitly incorporate the importance of mentorship, recruiting, and training, as well as link to the principle about increasing diversity of thought and backgrounds (in “Innovation”).**

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<sup>1</sup> NSF Diversity Initiatives, 2019, <https://www.nsf.gov/od/odi/diversity.jsp>.

<sup>2</sup> AGU Diversity and Inclusion Strategic Plan, 2019, <https://ethics.agu.org/agu-diversity-and-inclusion/>.

## 6

### Conclusions

The draft document reviewed by the committee is qualitatively unlike the NASA science plans that have come before. In fact, it is not really a science plan, nor is it a strategic or implementation plan more generally. It is, however, something potentially very important.

Any effective organization requires leadership that clearly expresses not only its organization's values, but also its enduring, high-level priorities and principles that will steer the organization toward realizing those values. An SMD organization that is aligned in its values, leadership priorities, and guiding principles is much more likely to achieve successful outcomes in scientific product, in fulfillment of the decadal surveys, as well as in the development and deployment of human capital.

As it stands now, the draft document is not inspiring. It lacks the clarity of purpose and vision required to achieve its intended impact, and it is too internally disconnected between the top leadership and the four science divisions that form the core of SMD's management. If the draft document can be revised as recommended here, the divisional commitment to the stated leadership priorities and guiding principles made more explicit, and the writing overall imbued with language equal to the magnitude of the vision, the document has the potential to be transformative for SMD: ambitious, forward looking, and inspiring.



## **Appendixes**



## A

### Letter of Request

National Aeronautics and  
Space Administration



**Headquarters**  
Washington, DC 20546-0001

JUN 12 2019

Dr. Margaret Kivelson  
Chair, Space Studies Board  
National Academies of Science, Engineering, and Medicine  
500 5th Street, NW  
Washington, DC 20001

Dear Dr. Kivelson:

NASA's Science Mission Directorate (SMD) is currently drafting the next version of its Science Plan, with the objective of issuing a new version in October 2019. This document outlines SMD's vision for the next five years and identifies cross-cutting strategies to advance the entire science portfolio. As we have done with our past Science Plans, we are seeking a National Academies review of the new draft plan and comments in the following areas:

- Level of ambition of the specified strategies in light of current and emerging opportunities to advance Earth and space science over the next five years;
- Ability of SMD to meet the science objectives in the most recent Decadal Surveys through implementation of the specified strategies;
- Identification of additional strategies for SMD's consideration; and
- General readability and clarity.

The draft plan will be available for your review by the end of June 2019. We also expect to be able to brief the plan to the committee at your request. We expect a formal report back no later than 12 weeks from the date of delivery of the plan. SMD is already undertaking initiatives that are aligned with the strategies in the plan and will continue to do so while we await your report.

I would like to request that you submit a plan for execution of the proposed report. Once agreement on the scope, cost, and schedule of the proposed study has been achieved, the contracting officer will issue a task order for implementation.

I look forward to having your input to this critically important activity. SMD's point of contact for this study will be Ms. Ellen Gertsen, who can be reached at (202) 358-0812 and [ellen.gertsen@nasa.gov](mailto:ellen.gertsen@nasa.gov).

Sincerely,



Thomas H. Zurbuchen, Ph.D.  
Associate Administrator,  
Science Mission Directorate

## B

### Summary of the Draft *Explore Science 2019-2024: A Vision for Scientific Excellence*

The draft *Explore Science 2019-2024: A Vision for Scientific Excellence* (i.e., the 2019 Science Plan), as delivered to the SSB on July 12, consisted of the following major sections and subsections below.

|            |                                                                                                                                                                                                                                                |                                                                                        |
|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Page 1     | Cover graphic and title “Explore Science 2019-2024 A Vision for Scientific Excellence”                                                                                                                                                         |                                                                                        |
| Page 2     | <b>Welcome Message</b>                                                                                                                                                                                                                         | Title only, no text                                                                    |
| Page 3     | <b>Table of Contents</b>                                                                                                                                                                                                                       | Complete text                                                                          |
| Pages 4-5  | <b>Who We Are</b>                                                                                                                                                                                                                              | Vision/mission statements for NASA/SMD, 4 NASA and 5 SMD values:                       |
|            | <ul style="list-style-type: none"> <li>• <i>Excellence</i></li> </ul>                                                                                                                                                                          | Short paragraph of text                                                                |
|            | <ul style="list-style-type: none"> <li>• <i>Leadership</i></li> </ul>                                                                                                                                                                          | Short paragraph of text                                                                |
|            | <ul style="list-style-type: none"> <li>• <i>Integrity</i></li> </ul>                                                                                                                                                                           | Short paragraph of text                                                                |
|            | <ul style="list-style-type: none"> <li>• <i>Teamwork</i></li> </ul>                                                                                                                                                                            | Short paragraph of text                                                                |
|            | <ul style="list-style-type: none"> <li>• <i>Safety</i></li> </ul>                                                                                                                                                                              | Short paragraph of text                                                                |
| Pages 6-7  | Introduction                                                                                                                                                                                                                                   | SMD’s three key science themes                                                         |
| Page 8     | Science Leadership Priorities                                                                                                                                                                                                                  | SMD’s four cross-cutting foci                                                          |
| Pages 9-11 | <b>Focus 1 Exploration and Scientific Discovery</b>                                                                                                                                                                                            | Four introductory paragraphs                                                           |
|            | <ul style="list-style-type: none"> <li>• <i>Strategy 1.1</i> “Execute a balanced science program on discipline-specific guidance from the National Academies”</li> </ul>                                                                       | Paragraph of explanatory text                                                          |
|            | <ul style="list-style-type: none"> <li>• <i>Strategy 1.2</i> “Participate as a key partner and enabler in the agency’s exploration initiative, focusing on scientific research of and from the Moon, lunar orbit, Mars, and beyond”</li> </ul> | Two paragraphs of explanatory text indicating how SMD collaborates with HEOMD and STMD |
|            | <ul style="list-style-type: none"> <li>• <i>Strategy 1.3</i> “Advance discovery in emerging fields by identifying and exploiting cross-disciplinary opportunities between traditional science disciplines”</li> </ul>                          | Paragraph of explanatory text                                                          |

|             |                                                                                                                                                                                                                                                                     |                                                      |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|
|             | <ul style="list-style-type: none"> <li>• <i>Strategy 1.4</i> “Develop a Directorate-wide, target-audience focused approach to applied programs, including Earth Science Applications, Space Weather, Planetary Defense, and Space Situational Awareness”</li> </ul> | Paragraph of explanatory text                        |
| Pages 12-14 | <b><i>Focus 2 Innovation</i></b>                                                                                                                                                                                                                                    | One introductory paragraph                           |
|             | <ul style="list-style-type: none"> <li>• <i>Strategy 2.1</i> “Foster a culture that encourages innovation and entrepreneurship across all elements of the NASA Science portfolio”</li> </ul>                                                                        | Two paragraphs of explanatory text                   |
|             | <ul style="list-style-type: none"> <li>• <i>Strategy 2.2</i> “Foster a culture that encourages collaboration in pursuit of common goals”</li> </ul>                                                                                                                 | Paragraph of explanatory text                        |
|             | <ul style="list-style-type: none"> <li>• <i>Strategy 2.3</i> “Enhance our focus on high intellectual risk/high impact research goals”</li> </ul>                                                                                                                    | Paragraph of explanatory text                        |
|             | <ul style="list-style-type: none"> <li>• <i>Strategy 2.4</i> “Drive innovation in focused technology areas to capitalize on the rapid evolution of commercial capabilities”</li> </ul>                                                                              | Paragraph of explanatory text                        |
| Pages 15-17 | <b><i>Focus 3 Interconnectivity and Partnerships</i></b>                                                                                                                                                                                                            | Paragraph of introductory text                       |
|             | <ul style="list-style-type: none"> <li>• <i>Strategy 3.1</i> “Actively engage with the NASA Centers to make more informed strategic decisions that further NASA’s scientific goals and are aligned with each Center’s unique capabilities”</li> </ul>               | Paragraph of explanatory text                        |
|             | <ul style="list-style-type: none"> <li>• <i>Strategy 3.2</i> “Actively seek collaborations with international partners based on their unique capabilities and mutual scientific goals”</li> </ul>                                                                   | Paragraph of explanatory text                        |
|             | <ul style="list-style-type: none"> <li>• <i>Strategy 3.3</i> “Actively engage with other Federal agencies to make more informed decisions, cooperate in scientific research, and pursue partnerships that further national interests”</li> </ul>                    | Paragraph of explanatory text                        |
|             | <ul style="list-style-type: none"> <li>• <i>Strategy 3.4</i> “Provide increasing opportunities for research institutions, including academia and non-profits, to contribute to NASA Science’s mission”</li> </ul>                                                   | Paragraph of explanatory text                        |
|             | <ul style="list-style-type: none"> <li>• <i>Strategy 3.5</i> “Pursue public-private partnerships in support of shared interested [sic] with industry”</li> </ul>                                                                                                    | Long paragraph of explanatory text with two examples |
| Pages 18-20 | <b><i>Focus 4 Inspiration</i></b>                                                                                                                                                                                                                                   | Very short paragraph of introductory text            |

|             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                 |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             | <ul style="list-style-type: none"> <li>• <i>Strategy 4.1</i> “Increase the diversity of thought and backgrounds represented across the entire NASA Science portfolio through a more inclusive environment”</li> </ul>                                                                                                                                                                                                                                                                                 | Three paragraphs of explanatory text                                                                                                                                                                                                                            |
|             | <ul style="list-style-type: none"> <li>• <i>Strategy 4.2</i> “Purposefully and actively engage with audiences and learners of all ages to share the story of NASA’s integrated science program”</li> </ul>                                                                                                                                                                                                                                                                                            | Three paragraphs of explanatory text, plus complex graphic                                                                                                                                                                                                      |
| Page 20     | <b>Implementation</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Two brief paragraphs of explanatory text                                                                                                                                                                                                                        |
| Pages 21-23 | Astrophysics Division <ul style="list-style-type: none"> <li>• <i>Division Overview</i></li> <li>• <i>Strategy and Management Philosophy</i></li> <li>• <i>Summary of Portfolio by Programs</i> <ul style="list-style-type: none"> <li>— Physics of the Cosmos</li> <li>— Cosmic Origins</li> <li>— Exoplanet Exploration</li> <li>— James Webb Space Telescope</li> <li>— Astrophysics Strategic Missions</li> <li>— Astrophysics Explorers</li> <li>— Astrophysical Research</li> </ul> </li> </ul> | One paragraph of explanatory text<br>One paragraph of explanatory text<br>One paragraph of explanatory text<br>One paragraph of explanatory text<br>One paragraph of explanatory text<br>One paragraph of explanatory text<br>One paragraph of explanatory text |
| Pages 24-27 | Earth Science Division <ul style="list-style-type: none"> <li>• <i>Division Overview</i></li> <li>• <i>Strategy and Management Philosophy</i></li> <li>• <i>Summary of Portfolio by Programs</i> <ul style="list-style-type: none"> <li>— Earth Systematic Missions Program</li> <li>— Earth System Science Pathfinder Program</li> <li>— Earth Science Research Program</li> <li>— Applied Sciences Program</li> <li>— Earth Science Technology Program</li> </ul> </li> </ul>                       | One paragraph of explanatory text<br>One paragraph of explanatory text<br>Two paragraphs of explanatory text<br>One paragraph of explanatory text<br>One paragraph of explanatory text                                                                          |
| Pages 28-30 | Heliophysics Division <ul style="list-style-type: none"> <li>• <i>Division Overview</i></li> <li>• <i>Strategy and Management Philosophy</i></li> <li>• <i>Summary of Portfolio by Programs</i> <ul style="list-style-type: none"> <li>— Living with a Star (LWS)</li> </ul> </li> </ul>                                                                                                                                                                                                              | Paragraph of explanatory text                                                                                                                                                                                                                                   |

|             |                                                       |                                                                                                                                                         |
|-------------|-------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
|             | — Solar Terrestrial Probes (STP)                      | Paragraph of explanatory text                                                                                                                           |
|             | — Heliophysics Explorers                              | Paragraph of explanatory text                                                                                                                           |
|             | — Space Weather Science and Applications (SWxSA)      | Paragraph of explanatory text                                                                                                                           |
|             | — Heliophysics Research                               | Paragraph of explanatory text                                                                                                                           |
| Pages 31-34 | Planetary Science Division                            |                                                                                                                                                         |
|             | • <i>Division Overview</i>                            |                                                                                                                                                         |
|             | • <i>Strategy and Management Philosophy</i>           |                                                                                                                                                         |
|             | • <i>Summary of Portfolio by Programs</i>             |                                                                                                                                                         |
|             | — Discovery Program                                   | Paragraph of explanatory text                                                                                                                           |
|             | — New Frontiers Program                               | Paragraph of explanatory text                                                                                                                           |
|             | — Solar System Exploration Program                    | Paragraph of explanatory text                                                                                                                           |
|             | — Mars Exploration Program                            | Paragraph of explanatory text                                                                                                                           |
|             | — Planetary Research                                  | Long paragraph of explanatory text                                                                                                                      |
|             | — Planetary Defense Program                           | Paragraph of explanatory text                                                                                                                           |
|             | — Technology                                          | Long paragraph of explanatory text                                                                                                                      |
|             | — Outer Planets and Ocean Worlds Program              | Heading only, no text                                                                                                                                   |
|             | — Lunar Discovery and Exploration Program             | Paragraph of explanatory text                                                                                                                           |
| Page 35     | – <b><i>Appendix A: Science Performance Goals</i></b> | Paragraph of text plus chart indicating how each of SMD’s four divisions contribute to NASA Science Performance goals in NASA’s Annual Performance Plan |
| Page 36     | <b><i>Appendix B: Acronym List</i></b>                | Title only, no text                                                                                                                                     |
| Page 37     | Rear cover graphic and title “EXPLORE with us”        |                                                                                                                                                         |

## C

### Committee Biographical Information

JEFF DOZIER, *Chair*, is a Distinguished Professor Emeritus at the Bren School of Environmental Science and Management at the University of California, Santa Barbara. Dr. Dozier founded the Bren School and served as its first dean for 6 years. His research interests are in the fields of snow hydrology, Earth-system science, remote sensing, and information systems. He has led interdisciplinary studies in two areas: one addresses hydrologic science, environmental engineering, and social science in the water environment; the other involves the integration of environmental science and remote sensing with computer science and technology. Dr. Dozier was a principal investigator on the Landsat 4 and 5 programs, when the satellites carrying the first Landsat Thematic Mapper instruments were launched. He served as the senior project scientist for NASA's Earth Observing System when the configuration for the system was established. He is a fellow of the American Geophysical Union (AGU) and the American Association for the Advancement of Science (AAAS), a Distinguished Scientist in the Chinese Academy of Sciences, and a recipient of the NASA Public Service Medal and the NASA/USGS Pecora Award. Dr. Dozier also helped Disney Animation Studios win the 2014 Oscar for Best Animated Feature, for the film *Frozen*. He received a Ph.D. in geography from the University of Michigan.

VICTORIA E. HAMILTON, *Vice Chair*, is a staff scientist and acting section manager at Southwest Research Institute (SwRI) in the Department of Space Studies. Dr. Hamilton has extensive experience with laboratory spectroscopy and Mars data analysis, as an affiliate of the Mars Global Surveyor TES science team, and as a participating scientist on the Mars Odyssey and Mars Science Laboratory missions. She is a science team co-investigator and deputy instrument scientist on the OSIRIS-REx asteroid sample return mission. She has published on laboratory mineral and meteorite spectroscopy, numerical modeling of infrared spectra, Martian surface composition, Martian atmospheric aerosol composition, and surface thermophysical properties. Dr. Hamilton has built, operated, and managed a NASA-supported spectroscopy laboratory equipped with three spectrometers for measuring visible, near infrared, and thermal infrared properties of rocks, minerals, and meteorites in reflectance and emission. She has received the NASA Group Achievement Award for the MSL Science Office Development and Operations Team. She received her Ph.D. in geology from Arizona State University.

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