NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL
DIVISION ON ENGINEERING AND PHYSICAL SCIENCES

A Decadal Strategy for Solar and Space Physics (Heliophysics)

STATEMENT OF TASK

The Space Studies Board shall establish a Heliophysics Survey Committee to develop a comprehensive science and mission strategy for heliophysics research for a 10-year period beginning in approximately 2013. The survey committee, informed by up to 5 study panels that will also be established by the Board, will broadly canvas the field of solar and space physics and:

1. Provide an overview of the science and a broad survey of the current state of knowledge in the field, including a discussion of the relationship between space- and ground-based science research and its connection to other scientific areas;
2. Identify the most compelling science challenges that have arisen from recent advances and accomplishments;
3. Identify—having considered scientific value, urgency, cost category and risk, and technical readiness—the highest priority scientific targets for the interval 2013-2022, recommending science objectives and measurement requirements for each target rather than specific mission or project design/implementation concepts; and
4. Develop an integrated research strategy that will present means to address these targets.

Scope

This "decadal survey" follows the NRC's previous survey in solar and space physics, *The Sun to the Earth--and Beyond: A Decadal Research Strategy in Solar and Space Physics*, which was completed in 2002 and published in final form in 2003. The scope of the study will include:

- The structure of the Sun and the properties of its outer layers in their static and active states;
- The characteristics and physics of the interplanetary medium from the surface of the Sun to interstellar space beyond the boundary of the heliosphere; and
- The consequences of solar variability on the atmospheres and surfaces of other bodies in solar system, and the physics associated with the magnetospheres, ionospheres, thermospheres, mesospheres, and upper atmospheres of the Earth and other solar system bodies.

In order to ensure consistency with other advice developed by the NRC for NASA, the following additional scope guidance is provided:

- With the exception of interactions with the atmospheres and magnetospheres of solar system bodies, which are within scope, planetary phenomena are out of scope (these other topics are being addressed by an ongoing decadal survey in planetary science);
- Basic or supporting ground-based laboratory and theoretical research in solar and space physics are within scope, noting that the findings and recommendations in the present survey should be harmonized with those developed and reported by the ongoing astronomy and astrophysics decadal survey; and
- Consistent with the current astronomy and astrophysics decadal survey, recommendations related to ground-based implementations (e.g., ground-based solar observatories) will be directed to the NSF.

Without undertaking a detailed analysis of operational space weather user or provider requirements, the survey committee will describe the value of these services to society and examine the role of NASA and NSF research in underpinning and improving these services.
In addition to an integrated review of the current state of scientific knowledge and recommendations for future basic research directions to advance our understanding, the survey will provide implementation recommendations separately for NASA and NSF.

For each science target, the committee will establish criteria on which its recommendations depend and identify developments of sufficient significance that they would warrant an NRC reexamination of the committee's recommendations. The Committee will also make recommendations to the agencies on how to rebalance programs within budgetary scenarios upon failure of one or more of the criteria.

APPROACH

The decadal survey will focus on the research aspects of the broad range of solar and space physics (within NASA, referred to as "heliophysics"). As such, it will address primarily the responsibilities of NASA and NSF and will provide recommendations to these two agencies. However, the survey will also address issues of particular interest to NOAA and the DoD, including the current state of capabilities and future directions in space weather monitoring and operations. We note that basic research and derived applications share a common knowledge base and community of experts and practitioners.

The Space Studies Board, working through its Committee on Solar and Space Physics, will establish a Survey Steering Committee ("Committee") of approximately 16 members. The Committee will be responsible for the overall organization and execution of the new study, as well as the production of a final consensus report that will undergo the usual NRC review processes. The final report will represent a comprehensive and authoritative analysis of the subject domain and a broad consensus among research community stakeholders. To do so, it is anticipated that the Committee will utilize approximately five specialized study subpanels, with allocation of the domain of study among them to be determined by the Committee and the Space Studies Board. The specific structure of the Survey will be determined following a planning meeting and workshop to be held in spring 2010. An important role of the panels will be to solicit broad input from the research community about issues of scientific and programmatic priorities in the field.

The work of the study subpanels will not result in separate, independent reports; subpanel conclusions and recommendations will be considered by the Committee and used to prepare a single final report.

It is essential that the study activity solicit and aggregate inputs from across the solar and space physics community and the country via town hall meetings, sessions at geographically dispersed professional meetings, solicitation of white papers, and aggressive use of electronic communications and networks. The Committee may also convene focused workshops on special topics of interest, such as how to better accomplish the transition from research to operations or the potential for small satellites to advance space science and address ongoing issues related to workforce and training.

It is critically important that the recommendations included in the final report be achievable within the boundaries of anticipated funding. To that end, it is anticipated that NASA and NSF will provide an up-to-date understanding of these limitations at the time of survey initiation. In designing and pricing the study, the NRC will include resources for independent, expert cost analysis support, which will be used when appropriate to improve cost estimations, expose and bound uncertainties, and facilitate cost comparisons among missions with varying heritage and technical maturity.

In addition to a review of the current state of scientific knowledge and recommendations for future directions to advance our understanding, implementation recommendations are sought for NASA and NSF. These three central tasks are described below:

A. Scientific Assessment and Recommendations

The report should provide a clear exposition of the following:

- An overview of heliophysics science--what it is, why it is a compelling undertaking, the relationship between space- and ground-based science research; and its connections to other scientific areas of scientific inquiry; for example, fundamental processes in astrophysical plasmas; another connection is with basic plasma physics
- A broad survey of the current state of knowledge; and
- An inventory of the top-level scientific questions, prioritized by value, urgency and technical readiness, that should guide NASA flight mission selections and supporting research programs and NSF's primarily ground-based investigations and supporting research programs.

In order to ensure consistency with other advice developed by the NRC, specific guidelines for the scientific scope of the survey are as follows:

- With the exception of interactions with the atmospheres and magnetospheres of solar system bodies, which are within scope, planetary phenomena are out of scope (these other topics are being addressed by an ongoing decadal survey in planetary science); and
- Basic or supporting ground-based laboratory and theoretical research in solar and space physics are within scope, except those covered by the ongoing astrophysics decadal survey.

B. Implementation Recommendations for NASA

As was done in the previous heliophysics decadal survey, the section of the report that provides recommendations to NASA will reflect the agency's charter to conduct flight mission investigations and, consistent with the current astronomy decadal survey, recommendations related to ground-based implementations (e.g., ground-based solar observatories) will be directed to the NSF. The prioritized science goal inventory from the previous section will form the basis for flight mission prioritization. NASA will provide an axiomatic budget runout for the survey decade, and the Committee will allocate these resources into “budget packages.” Recommended budget packages are:

- Small flight investigations appropriate for the Explorer class;
- A mix of small, medium, and large strategic flight investigations appropriate to goals of the Solar-Terrestrial Probes program and the Living With a Star program; and
- If budget guidelines permit, flagship flight investigations may also be recommended.

Life cycle cost classifications defined by NASA currently are: very small/Mission of Opportunity, less than $250 million; small, $250-500 million; medium, $500-750 million; large, $750-1000 million; and flagship, over $1 billion. These cost ranges are inclusive of launch vehicles costs.

The survey should address the role of missions of different sizes (small, medium, and large), based on these cost bracket categories. Note that candidates for individual Explorer and lower-cost flight projects, including sub-orbital programs, should not be prioritized; they will be solicited and selected as PI-led missions on the basis of science merit via NASA's standard Explorer AO and NRA processes. However,

the strategic value of these smaller mission programs to the overall science agenda should be appraised and described.

The Survey should prioritize “science targets” for the mission implementation opportunities, recommending science objectives and requirements for these missions rather than specific mission design/implementation concepts. However, mission conceptual designs should be used within each prioritized science area to establish feasibility within its notional budget package. This budget feasibility will be demonstrated by the NRC's costing subcontractor on the basis of nominal point designs. Concept mission designs should not be represented in the final, prioritized list; missions to be flown will be solicited and selected by NASA on the basis of science and implementation merit versus risk via NASA's standard AO processes.

The prioritized flight program list recommended in the report should be provided in terms of scientific problems and measurements, with validated feasibility, and their associated “budget packages,” not in terms of specific missions. Missions prescribed in *The Sun to the Earth--and Beyond* and other recent NRC reports that are not yet in formulation or development must be reprioritized. In contrast, the Solar Orbiter, Solar Probe Plus, and IRIS missions are in formulation and should not be prioritized. The flight investigations priority list should be supported by a summary of the assumptions underlying the relative rankings. This summary should, to the extent possible, be accompanied by decision rules that could guide NASA in adjusting the queue in the event of major unanticipated scientific developments or technical, cost, or other programmatic changes. It is understood that initiation of missions on this list will depend on actual resource availability and programmatic factors.

For Solar Probe Plus (SP+), cognizant of the fact that the previous decadal survey ranked Solar Probe as their highest priority for a "large-class" mission, the Decadal Survey will consider how the scientific rationale for a solar probe mission is substantially affected by:

a. Scientific developments since the completion of the 2002 decadal survey; and
b. The projected timeline and instrument complement of the particular implementation of the previous survey's recommendation, Solar Probe Plus.

In the context of the committee's charge to establish criteria on which its recommendations depend and to identify developments of sufficient significance that they would warrant a reexamination of the committee's recommendations, the Committee will also make recommendations in order to maintain program scientific balance. The Committee will make recommendations to NASA (including for SP+) on programmatic or cost trigger points for consideration of possible rescoping, deferral, cancellation, application of additional resources at the possible expense of other Heliophysics Division programs, or a reassessment by the NRC or by the NASA Advisory Council's Heliophysics Subcommittee.

Other welcome recommendations would include those that address NASA-funded supporting research programs to maximize the science return from the currently operating and pending flight mission investigations and a discussion of strategic technology development needs and opportunities relevant to NASA heliophysics science programs. All such recommendations must by achievable within the constraints of anticipated funding.

The Committee report shall reflect an awareness of the science and space mission plans and priorities of potential foreign and U.S. agency partners and identify opportunities for cooperation, as appropriate and achievable within budget constraints. Examples would be the proposed Japanese Solar-C or SCOPE projects. SMD will provide authoritative, formal NASA policy and heliophysics program documentation, as required.

C. Implementation Recommendations for NSF

For NSF, the survey and report shall encompass all ground-based observational techniques, as well as analysis of data collected and relevant laboratory and theoretical investigations (including modeling and simulation). Thus, the study will assess the NSF-supported infrastructure of the field, including research and analysis support, the educational system, instrumentation and technology development, data distribution, analysis, and archiving, and theory programs. The Committee shall also recommend any changes to this infrastructure that it deems necessary to advance the science and to capture the value of facilities in place.

In addition, the survey will examine the NSF's "CubeSat" program, which is developing small satellite science missions to advance space weather and atmospheric research, as well as providing opportunities to train the next generation of experimental space scientists and aerospace engineers.

The Committee shall review relevant programs of other nations and will comment on NSF opportunities for joint ventures and other forms of international cooperation.