Assessment of the NASA Applied Sciences Program

Committee on Extending Observations and Research Results to Practical Applications: A Review of NASA's Approach, Geographical Sciences Committee, National Research Council

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ASSESSMENT OF THE NASA APPLIED SCIENCES PROGRAM

Committee on Extending Observations and Research Results to Practical Applications: A Review of NASA's Approach

Geographical Sciences Committee

Board on Earth Sciences and Resources

Division on Earth and Life Studies

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COMMITTEE ON EXTENDING OBSERVATIONS AND RESEARCH RESULTS TO PRACTICAL APPLICATIONS: A REVIEW OF NASA'S APPROACH

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PREFACE

The Applied Sciences Program (ASP) is the focus for Earth science applications at the National Aeronautics and Space Administration (NASA) today. NASA's draft plan for the present structure of ASP was reviewed by the National Research Council (NRC, 2002a) and in 2004, NASA published its draft plan in response to the NRC report. One of the recommendations from the NRC report was for the ASP to seek another independent evaluation after several years of operation in its new structure. NASA and the ASP leadership thus asked the NRC in 2005 to form an ad hoc committee to assess their approach to extend research results to practical societal applications. In response to this request the NRC established the Committee on Extending Observations and Research Results to Practical Applications. The assessment was designed to focus on ASP's overall approach, including the program's strengths and weaknesses in realizing societal benefits through Earth observations, and the extent and success of ASP's engagement of federal and nonfederal sectors to use NASA data and research in decision-support systems.

The committee consisted of 12 individuals with experience in generating and applying remotely sensed data in decision-support projects, users of decision-support tools, researchers producing results incorporated in decision-support tools, and scientists with experience in determining the types of information and tools that users require (Appendix A). To address its statement of task, the committee reviewed relevant NRC reports and information submitted by external sources, including written data and information requested from ASP (Appendix B; ASP, 2006). Presentations at three open meetings in 2006 (Appendix C) and information from telephone interviews, published reports and other literature, and the committee's own experience were also part of the assessment process. Additional information was requested from several federal agencies subsequent to the committee's three open informational meetings. The committee's final meeting in October 2006 was a closed session in which the committee deliberated the main conclusions and recommendations for the report.

The committee benefited during its writing process from the results of a recent NRC report "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond" (NRC, 2007a), which recommended primary issues NASA should consider during the next decade in applying its Earth data and research to achieve societal benefits. Some of these recommendations have direct relevance for ASP and are examined briefly in this report. Where appropriate, the committee attempted throughout the report to maintain a distinction between which issues were those that could be considered more broadly NASA's responsibilities versus those issues that were specific to ASP.

With a need to address both established, ongoing partnerships and potential partners who had little or no current activity with NASA through the ASP, the committee took a broad approach to its information-gathering and sought expert input from a variety of federal agencies and nongovernmental organizations representative of this range of existing and potential partners and users of NASA products. The committee attempted to gain a similar, representative level of input from all testimony it received through posing a set of questions to all of its external information providers. The committee opted to obtain slightly more detailed responses from a portion of this testimony group. The committee was grateful for a detailed, written response to committee questions from the National Oceanic and Atmospheric Administration (NOAA), provided through the NOAA Research Council (NOAA Research Council, 2006). In the case of the federal agencies, the committee received generally constructive and immediate responses, but did not receive responses to its inquiries from a few agencies with established NASA partnerships, despite several attempts to reach these offices. Lack of response could indicate that the agency had no information to provide, or possibly that the committee might not have contacted the correct persons to respond appropriately. Without resources to provide follow-up in each case of no response, the committee determined that it had obtained adequate responses from a broad enough spectrum of users of NASA products to reach its conclusions and recommendations with confidence.

As a final point, the report contains a historical overview of applied sciences at NASA that was not a specific part of the committee's charge but which the committee felt provided important context for the present ASP structure. Because the committee could identify no official documentation of this history, the information contained in this section of the report represents a summary of the results of telephone discussions with 14 individuals either formerly or currently with NASA or directly involved in NASA projects. Though some subjectivity in the nature of information gathered in this fashion is inevitable, the accuracy of the information was fact-checked with present and former ASP staff and effort was made in writing the text to maintain its overall objectivity.

This report and its recommendations are a result of the consensus of the committee. The recommendations address the statement of task and apply to NASA and ASP, but the needs of other agencies, and nonfederal groups that use or could use NASA data factored into the committee's deliberations and its recommendations. Members of the committee provided keen insights and took part in drafting the report. We were assisted in our efforts by Elizabeth Eide and Paul Cutler, study directors, and Nicholas Rogers, senior program assistant, from the NRC.

Thomas J. Wilbanks
Chair
August 2007

ACKNOWLEDGMENTS

This report was greatly enhanced by input from numerous contributors (Appendix C): Robert Adler, Laurie Ames, Chris Barnard, Ronald Birk, Otis Brown, Pietro Ceccato, Brad Colman, Brad Doorn, Paul Doraiswamy, Marty Frederick, Lawrence Friedl, Teresa Fryberger, Gerald Galloway, Shahid Habib, Robert Harriss, Charles Hutchinson, Anthony Janetos, John Kappenman, Jack Kaye, John LaBrecque, Ricardo Lopez-Torrijos, Alexis Lugo-Fernandez, Nancy Maynard, Ken Miller, John Murray, Scott Pace, Fritz Policelli, Diane Powers, Sethu Raman, Mitch Roffer, Cynthia Rosenzweig, Joseph Russo, Ed Sheffner, Michael Steinberg, J. Marshall Shepherd, Alex Toyahov, Louis Uccellini, Charles Walthall, Mark Weltz, and Dorsey Worthy. These presentations and discussions set the stage for the committee's deliberations in the sessions that followed.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report 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 wish to thank the following individuals for their participation in the review of this report:

Janet Campbell, University of New Hampshire, Durham
Elizabeth A. Chornesky, Independent Consultant, Carmel, California
William B. Gail, Microsoft Corporation, Boulder, Colorado
Jack Harrald, George Washington University, Washington, D.C.
Jerry Hatfield, U.S. Department of Agriculture, Ames, Iowa
Charles Hutchinson, University of Arizona, Tucson
Anthony Janetos, Pacific Northwest National Laboratory, College Park, Maryland
Jeffrey Ritchey, University of Washington, Seattle
William Smith, Hampton University, Hampton, Virginia

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Ruth DeFries, University of Maryland, College Park. Appointed by the NRC, she was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Summary

INTRODUCTION

Remote sensing data and models from the National Aeronautics and Space Administration (NASA) are the basis for a wide spectrum of scientific research endeavors and are key inputs to many public and private services. NASA has decades of experience in applying its Earth observation products to weather forecasting, aviation, climate observations and modeling, famine early warning, monitoring ocean current and surface conditions, agricultural planning, emergency planning and response, and natural hazard monitoring, among others, primarily through partnerships with other federal agencies, academia, or the private sector.

While many NASA programs conduct applied research using Earth observation data, the NASA Applied Sciences Program (ASP) and its precursors have, since the 1970s, been tasked with ensuring the extension of NASA Earth observation data and associated research into practical applications for society through external partnerships. With approximately five years having elapsed under the current ASP structure, and a growing government-wide emphasis on societal benefits in its Earth observing programs, NASA and the ASP leadership asked the National Research Council (NRC) to form an ad hoc committee to assess ASP's approach in extending NASA research results to practical, societal applications.

In response to this request the NRC established the Committee on Extending Observations and Research Results to Practical Applications (Appendix A). This report is the committee's response to that request. In particular, the committee was asked to examine: (1) strengths and weaknesses in NASA's approach to achieve its strategic objectives to realize economic and societal benefits from Earth science, information, and technology; (2) the extent to which the partner agencies and national organizations have found that their collaboration with NASA is helping them carry out their decision-support goals; (3) the extent to which ASP has been able to engage the broader community (for example, the private sector, academia, nongovernmental organizations) in developing improved decision-support tools; and (4) possible issues in ensuring that the extension of NASA's research results into decision-support products maintains the scientific integrity of the data and models. As part of its assessment the committee examined ASP's partnerships, community engagement, processes used to extend research results to partners with decision-support functions, and its means to measure and ensure success in these partnerships.

OVERVIEW

In its examination of ASP the committee found an energetic, structured, and enterprising program enmeshed in complex and changing circumstances related to the emerging federal government commitment to realize societal benefits from Earth observing systems. The systems engineering approach around which the program is organized is a framework for the program to coordinate a range of application areas and various research entities in NASA and across to partners; however, the committee identified several areas where the program could make significant steps to enhance its success in ensuring decision support for societal benefit through both federal and nonfederal partners (Box S.1). The committee recognizes that some of these steps can be enacted by ASP itself but that the success of the program and of the implementation of the recommendations in this report is also contingent on support and specific action from the broader NASA administration, coupled with consistent federal support. The committee also recognizes that addressing the broader NASA actions may require cultural and structural changes at higher levels within the agency, and has drawn these distinctions where appropriate to help ASP establish its role within NASA and toward the external community.

The NRC Decadal Study on Earth science missions (NRC, 2007a) specifically included a panel on applications and societal benefits, recognizing the importance of these issues in the coming decade. Much of this emphasis on societal benefits has emerged in the last 10 years, creating a time for special opportunities for innovative thinking and program refinement with respect to Earth system applications. The committee recognizes the recommendations put forward by this other NRC report and encourages the ASP, with support from NASA, to help implement the recommendations especially in the programs oriented toward Earth-system applications.

Box S.1
Recommendations

RECOMMENDATION 1: ASP should be assigned the responsibility within NASA to review and help establish the requirements and guidelines offered in Chapter 5 of the Decadal Study (NRC, 2007a) for effective extension of data and research to applications that meet societal needs. As part of this action, the committee recommends incorporating an ASP representative on NASA mission design and selection teams to aid ASP in increasing the use and impact of NASA products in the user community.

RECOMMENDATION 2: ASP, in collaboration with other parts of NASA, should help to develop a formal plan and structure for effective transitions from research to operations with direct input from the entire range of users and with support from Congress.

RECOMMENDATION 3: ASP should link NASA data and research to users and beneficiaries through communication in both directions, not simply in one direction that disseminates NASA products without user feedback. Communication between ASP and external users should be enhanced, as should ASP's communications with other groups in NASA that conduct research on Earth-based observations.

RECOMMENDATION 4: ASP should develop processes for sustained interactions with a broader base of users and beneficiaries of NASA observations. ASP should assess user benefits of applications of NASA observations, with public comment and user reviews, in order to evaluate levels of importance to society and to inform the development of outcome metrics. ASP should prioritize intended societal benefits from NASA products and focus efforts on high-priority benefits.

RECOMMENDATION 5: To enhance the program's success in facilitating effective partnerships between NASA and users of NASA products to generate societal benefits, ASP should
1. directly engage with a broader community of users—not just federal agencies;
2. add rigor with respect to performance metrics;
3. evaluate the number and focus of its applications areas;
4. improve the transparency and documentation of the process by which a partner agency engages the broader community, including clarification of the partner agency responsibilities in realizing the shared goal of benefits to society; and
5. clarify and broaden its policies regarding productive relationships and collaborations with the private sector, including but not limited to remote sensing data products.

THE PROGRAM'S APPROACH

The systems engineering approach adopted by the ASP in 2001 provided an operational framework involving evaluation, verification and validation, and benchmarking to focus results from research activities and data collection in various parts of the NASA organization toward applications supported by other federal agencies. The ASP process was oriented toward developing a tighter connection to social benefits with metrics and stronger input from federal users. The program moved away from previous direct partnerships with regional, local, tribal, state, and commercial members of the user community with a goal to clarify the practical benefits of NASA Earth science and reduce perceived and real duplication of effort with other federal agencies. This new approach welcomed nonfederal sectors as participants in discussions for project development, but not as NASA's direct partners. With some exceptions nonfederal partners are supposed to be reached as a third party through the federal agency partnering with NASA. The ASP currently coordinates its efforts over 12 Applications of National Priority: Agricultural Efficiency; Air Quality; Aviation; Carbon Management; Coastal Management; Disaster Management; Ecological Forecasting; Energy Management; Homeland Security; Invasive Species; Public Health; and Water Management.

Once a potential partner agency for use and implementation of NASA data and research is identified, ASP and the partner agency then determine baseline information requirements, assess the potential value and technical feasibility of assimilating NASA information into the decision-support system (DSS), and decide whether future collaboration is useful. If a project is initiated, the verification and validation phase of the systems engineering approach facilitates ASP and the partner agency measuring their performance against requirements and determining if the DSS can achieve the intended outcome. Lastly, the benchmarking phase tests and documents the value of incorporating data or models generated by NASA-sponsored Earth science programs into existing decision-making processes in other federal agencies.

A clear emphasis of ASP's approach is on demonstrating measurable outputs with clients. The importance of documentation in projects is underscored, and benchmarking is one facet of this documentation process. Metrics data collection through a system called the *Metrics Planning and Reporting System (MPAR)* is a formal, distinct facet of project documentation and is used by scientists who receive ASP funding. The committee found areas where both of these systems could be employed in more transparent and useful ways that could enable both NASA and its partners to measure and document the real successes of their partnerships that extend data and research into operations.

ASP'S ENGAGEMENT OF USERS

Federal Partnerships

The ASP has focused on developing partnerships with other federal agencies as the primary method to reach operational and resource management users of NASA products. This approach has generated a number of successes but improvements in establishing and supporting federal partnerships could be made. In the committee's discussions and exchanges with numerous federal agency partners and potential partners, it found that the federal sector has broadly received attention and support from ASP, but that the lack of formal processes to establish requirements, coordinate activities, and extend NASA research to partner operations has affected the overall success of the partnerships in applying DSS for societal benefits. The experiences between NASA ASP and its federal partners have also been very varied. The National Oceanic and Atmospheric Administration (NOAA) and agencies in the Department of Defense, for example, have committed personnel resources to ensure they receive NASA priority support. Others, such as the U.S. Department of Agriculture (USDA) and the Environmental Protection Agency (EPA), have generated programs that help focus NASA efforts to solve their problems. Yet others such as the Department of Homeland Security (DHS), a relatively "young" agency, have had a relatively passive relationship to date in which they are simply recipients of NASA data. NASA's relationship with NOAA is the most mature with respect to weather research and prediction applications, but much room for improvement in extending research to operations still exists.

Generally, the committee found that a systematic feedback mechanism from users to ASP and more broadly, to NASA program planners and decision makers, is lacking. Many federal partners expressed a need for high-resolution multispectral satellite data, for example, but find that neither NASA nor ASP has a formal mechanism to absorb this feedback. In general, federal users have a wide range of needs in terms of satellite data continuity, quality, format, and resolution. They adapt to data formats instituted by NASA, but have limited or no influence over data characteristics. The committee recognizes that some of the issues that hinder more effective partnerships can be addressed directly by ASP and NASA to improve the success of all federal partnerships, but that the different cultures, structural and administrative organization, and approach to applications varies between partner agencies across the federal government, and serves to contribute to the observed variation in the success of the partnerships. A cooperative approach to the partnerships that enhances bidirectional communication is thus of great importance.

Engagement of the Broader Community

NASA's decision to focus ASP primarily on federal agency partners for implementing practical applications of its products carried the expectation that these partners would engage the broader community and would assess the socioeconomic benefits of ASP products. However, the process by which partner agencies engage the broader community lacks transparency and documentation; quantitative metrics that connect the research-to-applications transition of NASA products are also lacking. The committee found that documentation of implementation processes and practices for applying NASA products to societal benefits are largely third-party evaluations, as opposed to evaluations that include input from the direct beneficiaries of the application of NASA products. Key documentation of DSS in the form of benchmark reports, while effective in providing guidance on the application of DSS, lacks critical input from the users of NASA data and models, especially from local governments and the private sector. However, the benchmark reports do provide a critically important database across many application areas for guiding future applications and the direction of the ASP.

ASP's pragmatic decision to focus on the decision-support needs of federal partners has isolated ASP from its ultimate user base and prevents efficient user feedback. ASP's interests are spread over many application areas and will benefit from the ongoing re-examination of the number and scope of the application areas in order to maximize resource use with relation to national programs and priorities.

KEY CONCLUSIONS

In the NASA-wide context, ASP's current role is limited to increasing the use of NASA products from existing missions, whereas ASP could be more effective if it fulfilled a holistic role in which it catalyzes user input from the earliest stages of mission planning. Until the perennial challenge of ensuring the transition of research sensors to operational status is properly addressed, ASP will continue to face an uphill struggle to convince potential users of the operational value of NASA products whose continuity is not guaranteed and whose specifications were not guided by the potential users. The committee reached the following conclusions from which the five recommendations outlined in Box S.1 derive:

Applications of NASA's data and research to societal benefits have historically been limited by questions about NASA's mission and role, and have lacked sustained commitments and program

stability. The historical limitations have included, for example, variations in (1) emphasis on NASA's responsibilities for Earth system programs versus space programs and (2) NASA's responsibilities for directly delivering benefits versus delivering data and models for others to use in the delivery of benefits. NASA's engagement in extending research to operations requires support from top agency officials who, in turn, need congressional support for their actions. The nature of NASA's long-term planning and program implementation activities requires a degree of policy continuity to assure payoffs.

The current U.S. government-wide emphasis on ensuring societal benefits from Earth observing systems is unprecedented, and presents a special opportunity for NASA to enhance its focus on achieving such benefits. The committee views ASP as a key asset for fulfilling the emerging national commitment to societal benefits. However, **NASA does not involve ASP in the initial stages of mission planning in cases when societal benefits are anticipated.** ASP's current role is focused on increasing the use by other agencies of NASA products derived from Earth observing satellites already in orbit. Including ASP as a participant in the initial stages of mission planning and selection would enhance the program's ability to perform its central role in advancing and improving NASA's cooperation with users.

Examination of the NASA research-to-operations transitions indicated minimal direct link with the nonfederal research community, and no active feedback mechanism. Such a mechanism is needed and should be sustained from the initial stages of mission planning onward to ensure that requirements are appropriately considered. **ASP has an opportunity to contribute toward improving the structures that extend research to operations across the federal government**. This potential role for ASP is far more comprehensive than serving merely as a mechanism to move NASA products outward. ASP's networks with partner agencies enable it to serve as a conduit for information from partners about their operational needs and research programs, offering potential to improve the value and relevance of NASA's research contributions to those operations. Support for ASP's role in this process is provided by the fact that **ASP has contributed to notable successes in encouraging and facilitating uses of NASA's data and research for societal benefits.** These successful projects include improved warning, monitoring, and recovery support from national disasters, more timely detection of tropical storms, improved wildfire detection, and improvements in El Niño forecasting for the planning and protection of crops. While these successes are not solely due to ASP's actions—these examples of benefits from NASA programs had their genesis in the basic NASA Research and Analysis program—they do provide a reason to encourage continued and enhanced interaction between NASA and external user communities through a formal program such as ASP. Despite contribution to these successes, **ASP's interactions with federal agencies and other potential users of NASA data and research show wide variations in experiences.** Strengthening and improving NASA's partnerships with users involves not only ASP action, but are also dependent upon organizational issues at the partnering agencies and variations in the motivation of potential partners to use a formal collaboration with NASA to realize social benefits.

ASP currently does not engage the full range of potential users of NASA products to benefit society. Direct relationships with non-federal users are notably missing from ASP's portfolio and their absence limits ASP's potential to be responsive to the full base of potential users of NASA products. The community of users is far broader than other federal agencies alone and encompasses state, tribal, and local governments, the private sector, nongovernmental organizations, and academic researchers. Because these users lie outside the federal system, the present lack of a formal structure that delineates the respective roles of NASA and its nonfederal partners leaves success of eventual partnerships largely to chance.

Finally, **the full potential of social benefits from NASA products will not be realized unless users are involved directly in determining priorities, designing products, and evaluating benefits. ASP also lacks a strong process to guide applications toward achieving societal benefits. ASP will be more effective in its bridging role between NASA and the users if it promotes two-way communication from the mission planning stages through to the incorporation of NASA products in DSS by external partners.** Comprehensive assessments of benefits to society derived from NASA products do not include direct feedback from beneficiaries. Specific weaknesses in communications include: 1) documentation of implementation processes and practices that apply NASA products to achieve societal benefits consist largely of third-party evaluations without direct evaluations from the beneficiaries; 2) iterative, multidirectional communications about applications of NASA products also lack input from users and beneficiaries; and 3) current metrics for evaluating program performance do not meet needs for evaluating and assessing societal benefits of NASA products. The situation is not aided by the distribution of ASP's work across a wide variety of application areas with relatively limited resources.

CLOSING REMARKS

ASP exhibits and communicates a strong commitment to NASA product transfer and decision support. The program displays a sound drive to provide information about research products and to relate those products to decision-support frameworks. The program's commitment, energy, and momentum offer significant potential for further impact. Building on a solid number of successes in helping to apply NASA products to social needs, ASP has embarked on a path since 2001 that adds rigor to its process and aims to enhance the efficiency of its role. By addressing the committee's recommendations on programmatic and broader contextual challenges, ASP can enhance its role in helping NASA to respond to the growing national and international demand for greater social benefit from national observation assets.

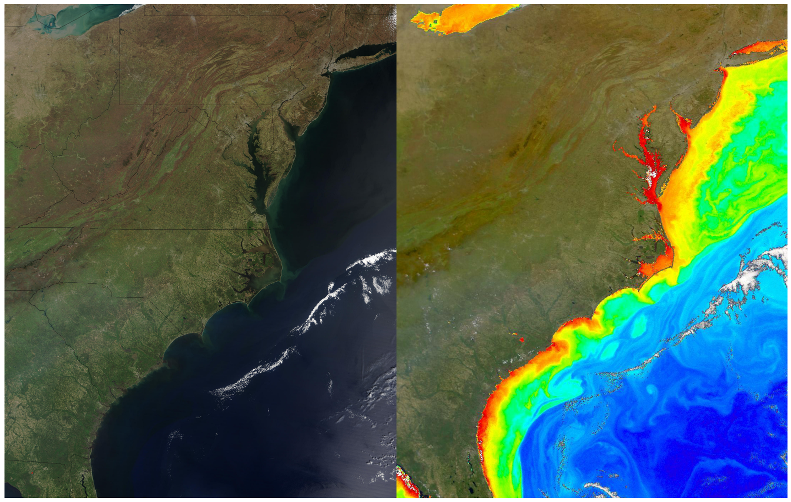
1

NASA and Applied Sciences

INTRODUCTION AND STUDY SCOPE

Images of Earth from space have become globally familiar and have permeated many aspects of daily life, from public school settings, where they are used as educational tools, to Internet map search programs that have become the modern way to locate oneself nearly anywhere on the globe. While numerous public and private space organizations around the world operate satellites that provide these remote sensing images, the National Aeronautics and Space Administration (NASA) was one of the first to collect these images on a regular basis and subsequently make its images generally freely accessible.

While Earth images are visually appealing and relatively easy to interpret at a basic level for the layperson (Figure 1.1a), many people do not realize the existence of a vast amount of important data, research, and models that accompany and underlie these images and are being collected simultaneously from space about Earth's surface, oceans, and atmosphere (Figure 1.1b). These data and associated research provide key inputs to many public and private applications including weather forecasting, aviation, climate observations and modeling, famine early warning, monitoring of ocean current and surface conditions, agricultural planning, emergency planning and response, and natural hazard monitoring. NASA has decades of experience in application of its Earth observation data and research models to societal issues in these and other areas, usually working in conjunction with other federal agencies, academia, or the private sector.



A **B**

FIGURE 1.1 Sample data types collected with different NASA satellite sensors over the eastern seaboard of North America. (A) "True color" image of data collected on April 13, 2003 with the MODIS (Moderate Resolution Imaging Spectroradiometer) instrument on the Terra satellite launched in 1999. (B) Phytoplankton pigment concentration data collected with the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). This instrument captured the biological signature of the dynamic ocean surface conditions along the same part of the eastern coast of the United States as that in (A) also on Sunday, 13 April 2003. Both images are based on visible radiance (color) measurements collected in multiple bands with each sensor, but processed in different ways. The MODIS image combined three bands (red, green, and blue) so that the green vegetation of the Carolinas becomes apparent, while the Appalachian Mountains appear brown. The ocean in the SeaWiFS image was constructed using ratios between blue and green bands; this ratio becomes smaller with higher concentrations of marine phytoplankton or of colored riverine discharge in coastal zones. High biomass is indicated by reds and yellows, while greens and blues show lower biomass. Both sensors measured sunlight reflected from the Earth after being absorbed and scattered by the land or the ocean. SOURCE: (A) NASA Visible Earth–http://visibleearth.nasa.gov/view_rec.php?id=5292 (B) NASA Ocean Color Archive–http://oceancolor.gsfc.nasa.gov/cgi/image_archive.cgi?c=CHLOROPHYLL

While many portions of the NASA organization conduct applied research using Earth observation data, a specified unit within NASA has, since the 1970s, been tasked with ensuring the transfer of NASA Earth observation data and associated research into practical applications for society through external private and federal partnerships. The NASA Applied Sciences Program (ASP) currently fulfills this bridging role between NASA data and observations and external partners who apply those data. The ASP has operated in its present structure since 2001. Table 1.1 lists the historical predecessors to the current program. NASA's draft plan for ASP was reviewed by the National Research Council (NRC, 2002a), and NASA refined its draft plan in response to the NRC report (NASA, 2004). This Earth Science Applications Plan firmly established the background, structure, and goals of the program. One of the recommendations from the NRC (2002a) report was to allow the ASP several years to establish itself and allow projects to come to fruition before further external evaluation was undertaken. With a number of years having elapsed with the current ASP structure in place, and a growing, government-wide emphasis on societal benefits in its Earth-observing system programs, NASA and ASP leadership asked the NRC in 2005 to form an ad hoc committee to assess their approach to extending research results to practical, societal applications (Box 1.1). In response to this request the NRC established the Committee on Extending Observations and Research Results to Practical Applications (Appendix A). This report is the committee's response to that request. The committee's process and report structure are described at the close of this chapter.

The committee notes two important distinctions regarding "basic" and "applied" research at NASA. Basic remote sensing research develops and uses NASA remote sensing data to obtain new knowledge about how to do something; for example, in an attempt to link vegetation to the climate and weather in an area, recognition of the regional changes in leaves and foliation might be important. Basic research at NASA might focus on how to design a satellite sensor that measures the appropriate indices of leaves to differentiate various characteristics of the vegetation that may not be obvious from standard visual photograph. Applied remote sensing research uses remote sensing data, such as the results from the basic research project on foliation, to provide information that is valuable for a specific task like predicting agricultural crop production or drought early warning. Because NASA's mandate does not usually allow it to put its research results or data directly into practice, applied remote sensing usually requires NASA to partner with another federal agency or nongovernment entity to use the NASA observations for these practical applications. While basic and applied research occur throughout the NASA organization and often in conjunction with each other, the distinction between the two is important to understanding how NASA engages partners to employ its Earth data and results in societal applications.

BOX 1.1
Statement of Task

The Committee will examine NASA's Applied Sciences Program and

1. Identify strengths and weaknesses in NASA's approach to achieve its strategic objectives to realize economic and societal benefits from Earth science, information, and technology.
2. Determine the extent to which the partner agencies and national organizations (e.g., Climate Change Science Program) have found that their collaboration with NASA is helping them carry out their decision-support goals.
3. Evaluate the extent to which the program has been able to engage the broader community (e.g., private sector, academia, nongovernmental organizations) in developing improved decision-support tools.
4. Assess possible issues in assuring that the transfer of NASA's research results into decision support products maintains the scientific integrity of the data and models.

The review will focus on NASA's overall approach at the level of the Applied Sciences Program, not on the many specific projects within the program.

CONTEMPORARY GOVERNMENTWIDE EMPHASES AFFECTING NASA'S APPROACH TO APPLICATIONS

The Executive Branch under President George W. Bush has strongly emphasized decision support in its science and technology (S&T) programs, in general, and environmental programs, in particular. This focus is on assuring and documenting benefits for society from investments of taxpayer dollars in public science and technology programs. "Benefits" are interpreted to represent a value in terms of better policy and decision making, associated not only with federal agencies but also with U.S. society, more broadly.

Since 2001 this emphasis has been expressed very clearly in the Administration's two main environmental programs:

1. The U.S. Group on Earth Observations (US GEO [*http://usgeo.gov/*]) is an interagency working group with participation from 15 member agencies, including NASA (and ASP), and three White House offices. US GEO is associated with the international agreement to support a Global Earth Observing System of Systems (GEOSS). The U.S. contribution to GEOSS is the Integrated Earth Observation System (IEOS). GEOSS aims to deliver global social benefits in nine subject areas (*http://www.earthobservations.org/progress/societal_benefits/societal_benefits.html*).

2. The interagency Climate Change Science Program (CCSP), pursuant to the Global Change Research Act of 1990, which has defined five goals, one of which is decision support (*http://www.climatescience.gov/*). CCSP focused its 2005 national workshop on the issue of climate science for decision support.

This emphasis became clear a few years ago when NASA assumed an active role in these interagency programs for two reasons:

1. Since its infancy in the 1950s NASA has focused its organizational practices on applying S&T to meet mission agency needs. Its space programs are one of the nation's best examples of applying S&T to support specific decisions and implementing them successfully.

2. Partly because of its organizational history, which has been more focused on tangible outcomes, NASA has developed an organizational style that is mission oriented and decisive. As a result, while other agencies were trying to ascertain what decision support means and how seriously it should be taken, NASA established a top-down definition of needs rooted in a culture of aerospace engineering, with elaborate road mapping of goals and implementation strategies.

NASA's dominant paradigm has thus been embodied in strategy documents for both US GEO and CCSP. This deep integration in these large programs is somewhat at odds with policy constraints that seem to limit NASA to providing data, technology, and models to other agencies (other users) that are responsible for operational aspects of remote sensing systems and are also the direct providers of decision support (see, for example, U.S. National Space Policy, August 2006, http://www.ostp.gov/html/US%20National%20Space%20Policy.pdf). If NASA is limited to providing products rather than directly assuring outcomes, it not only is kept at a distance from desirable outcomes, for which others can obtain most of the credit, but its social value depends on the performance of others. A recent NRC report (NRC, 2007a), henceforth called the "Decadal Study", was prepared by the Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future. The Decadal Study (NRC, 2007a) recommended the primary issues that NASA should consider during the next decade in applying its Earth data and research to achieve societal benefits. Some of these recommendations have direct relevance for ASP; these are examined briefly in this chapter.

RECENT NRC FEEDBACK TO NASA ON EARTH SCIENCE AND APPLICATIONS FROM SPACE

The Decadal Study (NRC, 2007a) contains visions, discussion, and recommendations that will influence the context and nature of ASP operations. "Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important challenges for society as it seeks to achieve prosperity, health, and sustainability" (NRC, 2007a, p. 1). These declarations are the foundation of the report's "Decadal Vision" of a program of Earth science research and applications in support of society, a vision that includes advances in fundamental understanding of Earth and increased application of this understanding to serve the nation and the world. The declarations call for a renewal of the national commitment to a program of Earth observations from space in which practical benefits to humankind play an equal role with the quest to acquire new knowledge about Earth. The Decadal Study supports its discussion by connecting some of its recommended Earth science missions to societal benefits in areas like human health, extreme event warnings, earthquake early warnings, improved weather prediction, sea level rise, climate prediction, freshwater availability, ecosystem services, and air quality.

To fulfill its Decadal Vision the report recommends that "the United States government, working in concert with the private sector, academia, the public, and our international partners, should renew its investment in Earth observing systems and restore its leadership in Earth science and applications." (NRC, 2007a, p. 3) The report further states that "a fundamental challenge for the coming decade is to ensure that established societal needs help guide scientific priorities more effectively, and that emerging scientific knowledge is actively applied to obtain societal benefits. New observations, analyses, better interpretive understanding, enhanced predictive models, broadened community participation, and improved means for information dissemination and use are all required" (NRC, 2007a, p. 4).

One Decadal Study panel identified potentially useful actions for realizing societal benefits from Earth observations through scientific research and application development (Chapter 5, NRC, 2007a). These actions include incorporating the applications community in planning phases of space missions, directly incorporating social scientists and studies from the social science literature in all phases of the mission planning cycle, developing better relationships between the basic and applied sciences communities, facilitating better community access to NASA data and products, and enhancing education and training of potential users of Earth data and information.

The panel also identified a desire for a greater number of successful applications to arise by design rather than serendipity. They noted particularly that lack of knowledge or experience in understanding the needs, organizational structures, and abilities of potential users inhibits the design of successful applications. Part of the process to involve the nonfederal community in agency planning cycles for applications and to ensure that the needs or requirements of user communities are met is to establish more comprehensive and formalized communication and feedback between the communities and federal agencies, including NASA. The panel recognizes that "an overall Earth science strategy that merges scientific research and societal application must acknowledge that different research and operational applications will require different approaches to measurement, and provide a means of optimizing potential benefits against available resources for the total observing system." Statements of this nature have direct relevance for the ASP and its activities.

HISTORICAL CONTEXT

A chronology of applied sciences at NASA covers nearly 50 years and is important to understanding applied sciences at NASA, generally, and the ASP, today (Table 1.1). Applications at NASA have manifested themselves through multiple administrations and programs, some of which were explicitly aimed at applications, while others were not. NASA's applications programs since the late 1950s developed during five relatively distinct eras (Table 1.1).

NASA's Charge to Extend the Benefits of Space to the Community: 1958

The enabling NASA applications or applied science legislation emerged in 1958 when language was crafted to "extend benefits of space to the community" (http://www.nasa.gov/offices/ogc/about/space_act1.html). Applications to benefit the community are implicit in this language even though NASA is an organization responsible for space and aeronautics research, technology development, and associated data collection and is not tasked to conduct operations and decision-support functions.

Table 1.1 NASA Earth Science Applications from 1958 to 2007

Year	Era	Details
1958	Beginning of Applied Science at NASA	Legislation passed that enabled NASA to "extend benefits of space to the community."
1960-1971	Suborbital Earth Remote Sensing	Applied research mainly in academia and focused on suborbital applications.
1972-1982	Earth Resources Technology Satellite (later Landsat)	A NASA technology transfer program that focused on transferring Landsat-related remote sensing technology to users at the local, state, regional, and national level, under the supervision of NASA regional centers. NASA's Office of University Affairs played a significant role in promoting remote sensing earth resource applications.
1982-1994	Limited Applications Research	NASA-supported applied research during this period fluctuated. NASA decided to focus on trying to understand or measure biophysical phenomena rather than make data useful for specific applications.
1994-2001	Mission to Planet Earth and Earth Science Enterprise	Applied sciences in a programmatic format similar to today's stem from this era. Initially called Earth Applications in the Mission to Planet Earth Program. Scientists could obtain funding through NASA headquarters with ad hoc applications or a few open national solicitations. Stennis Space Center developed an applied Commercial Remote Sensing Program to help university scientists work with the commercial sector to use remote sensing-data (hopefully of NASA origin) in commercial products. Applications and the commercial program came together in 1997 under the Applications, Commercial, and Education Division, one of four divisions in the Earth Science Enterprise that replaced Mission to Planet Earth.
2001-present	Systems Approach and Decision-Support System Era	NASA decided to reorient the Applied Sciences Program toward the use by other federal agencies of NASA data and models to help these agencies make better decisions using their own decision-support systems. In doing so, the program moved away from funding remote sensing in the public and private sectors. The program follows a systems engineering approach involving evaluation, verification, validation, and benchmarking.

NOTE: The chronology of events in this table and this section of the report were derived from telephone discussion with 14 individuals with previous or current connections to applied sciences at NASA. The "Era" designations were defined by the committee for the purpose of this study and do not necessarily represent official NASA nomenclature.

Suborbital Earth Remote Sensing Applications Era: 1960-1971

NASA-funded applied research on suborbital Earth remote sensing research in this period was conducted primarily at academic research centers (for example, Laboratory for Applications of Remote Sensing at Purdue University; the Willow Run Laboratory at the Environmental Research Institute of Michigan; the Forestry Department at the University of California, Berkeley and other centers at the University of California, Davis, Riverside, and Santa Barbara (Estes and Jensen, 1998)). Scientists at these laboratories worked closely with national, regional, and local government agencies. Initially they worked with high spatial resolution multispectral data from aircraft-mounted sensors and developed digital image processing algorithms to extract useful information. Progress on this research prompted the U.S. Geological Survey (USGS) and NASA to develop a satellite remote sensing system that could be used for Earth resource applications: the Earth Resource Technology Satellite (ERTS).

Earth Resource Technology Satellite (Landsat) Transfer Era: 1972-1982

The launch of the ERTS (later renamed "Landsat") in 1972 provided the greatest impetus for applied remote sensing research in the 20th century. Its launch was followed by additional Landsat launches through 1999. Landsat satellites were launched in 1975, 1978, 1982 (Landsat 4 Thematic Mapper [TM]), 1984 (Landsat 5 TM), 1993 (Landsat 6, which did not achieve orbit), and 1999 (Landsat 7 ETM+). Some of the most important NASA-sponsored applied remote sensing demonstration projects were conducted over the first decade after Landsat's initial launch (Box 1.2), and this period generated significant grassroots interest in and excitement about remote sensing technology. In 1977, for example, the NASA Ames Western Regional Applications Program developed a mobile laboratory that traveled throughout the United States demonstrating remote sensing (especially Landsat) applications to state and local agencies. Owing at least in part to this initial introduction to remote sensing and similar contributions from programs in NASA's Office of University Affairs, the universities and some regional users in Arizona, California, Georgia, Nevada, South Carolina, Utah, Indiana, Kansas, and South Dakota became robust users of remote sensor data, and had an encouraging effect on their state governments to begin employing remote sensor data with more regularity.

BOX 1.2
Large Area Crop Inventory Experiment (LACIE)

The LACIE was a NASA-U.S. Department of Agriculture (USDA) partnership established to use Landsat data to conduct foreign crop inventories. It was initiated in 1974 after a poor grain harvest in the Soviet Union. The United States had been unaware of the Soviet harvest problem, and was unprepared for the Soviet purchase of surplus wheat, which significantly affected the global wheat price and the accessibility of this primary crop. Remotely sensed data collected on global crop inventories was subsequently used to assess future markets and trading, functions which are today manifested in the activities of the USDA's Foreign Agricultural Service (*http://www.fas.usda.gov/*).

Technology transfer was the theme of two programmatic emphases during this period: (1) Beginning in 1973 NASA and the National Oceanic and Atmospheric Administration (NOAA) partnered on the Operational Satellite Improvement Program (OSIP) in which NASA developed prototype sensors, flew them on aircraft, transferred them to research spacecraft for evaluation, and then provided successful instruments to NOAA for transition to operational status (NRC, 2003). (2) The second program was directed to university applications and was initiated in 1971, prior to Landsat's launch. Using Landsat data, this program engaged university centers in research projects with state and local governments. NASA's Office of University Affairs (OUA) played a significant role in promoting Earth resource applications at this time. From 1975 to 1978 OUA operated four programs oriented toward applications with: (1) state and local governments (for example, departments of natural resources and environment), (2) federal departments (for example, USDA and the Department of the Interior), (3) the private sector (for example, forestry, oil and gas, utilities), and (4) international partners.

In 1978 these four programs were reorganized and redefined into four new programs: University Applications, User Requirements and Awareness, Application System Verification and Transfer, and Regional Applications (Box 1.3). These programs operated until 1982 when applied science as a distinct program or concept at NASA was largely phased out. OSIP was also cancelled in 1982 because of NASA budget pressures and a desire on the part of the Office of Management and Budget to offload "routine" functions from NASA (NRC, 2003) (see also Chapter 3).

BOX 1.3
Programs at NASA's Office of University Affairs Between 1978 and 1982

University Applications. NASA established grants with 30 to 50 universities nationwide to support university remote-sensing research and infuse university research programs with NASA technology. The research grants allowed students to learn about remote sensing technology and contribute to remote sensing science. Many of these students are now major influences in the remote sensing field.

User Requirements and Awareness. Cognizant that its technology was not reaching the broader community, NASA reached out to the community to understand its needs. In parallel NASA used many avenues to improve public awareness of its science through brochures, letters, county associations, the National Governors Association, and the media, among many approaches.

Application System Verification and Transfer. This program matched NASA technology to applications and verified the success through use by federal and nonfederal users. In addition to direct investment NASA headquarters funded applications projects with the Environmental Protection Agency and the Department of the Interior, for example.

Regional Applications. This program was oriented toward state and local governments and was conducted through the regional NASA centers (Ames, Marshall, Goddard, and Stennis).

Era of Limited Applications Research: 1982-1994

University Applications was the only program element (Box 1.3) that continued through this period. The program element remains today, having survived all subsequent manifestations and reorganizations of applied sciences. NASA did not pursue partnerships with federal, state, or local government agencies again until 1992.

In general, NASA support for applied remote sensing research fluctuated from 1982 to 1994, and NASA management migrated to a philosophy of trying to understand or measure biophysical phenomena rather than focus on data collection and research for specific societal applications. NASA headquarters promoted a basic research program in which global Earth science proposals were driven by NASA employees. Applications typically had an engineering focus and often were not sustained after transfer to users, in part because NASA's unique level of engineering expertise could not be carried over to other partners or users.

Mission to Planet Earth and Earth Science Enterprise Era: 1994-2001

Applied Sciences in a programmatic format similar to today's approach is about a decade old. Applications during this era slowly revitalized through NASA's university program, which worked with nonfederal as well as federal partners. The philosophy of the program was to build a bridge between NASA and research community partners. The main links to state and local users were established through regional associations rather than individual states or local groups.

Starting in the mid-1990s scientists could also obtain applied remote sensing science funding through the Mission to Planet Earth Program from NASA headquarters—primarily through ad hoc application or through a few national solicitations. The balance of applied versus basic funding from Congress gradually increased from pre-1994 levels. Congress in this period was interested in obtaining nearer-term results that could more readily be tied to local needs.

During this era, and separate from the main applications program, scientists at Stennis Space Center in Mississippi developed an applied Commercial Remote Sensing Program Office (CRSPO) (Davis and Macaulay, 2000) (Box 1.4). The goal of the program was to help university scientists to work with the commercial sector to use remote sensing-data (hopefully of NASA origin) in commercial products. The program led to the incorporation of remote sensing data in many companies product lines (for example, Fluor Daniel, Bell South, Westvaco Paper Co., Westinghouse, International Paper Company, Sun Microsystems, Norfolk Southern).

In 1997 CRSPO and the applications program were merged under a new Applications, Commercial, and Education (ACE) Division. This was one of four divisions in the newly created Earth Science Enterprise (ESE) that replaced the Mission to Planet Earth. Another division in ESE—the Research Division—also funded applications. ACE partnered with this and other NASA divisions and centers on projects of mutual interest.

BOX 1.4
NASA's Commercial Remote Sensing Program

With funding from NASA headquarters and congressional earmarks, the Commercial Remote Sensing Program Office (CRSPO) at Stennis Space Center focused on developing a working relationship among academic institutions (referred to as NASA Affiliate Research Centers), NASA centers, and commercial firms. In addition, CRSPO administered a $50 million congressionally directed program to purchase commercial Earth science data to support and accelerate progress in Earth research applications (NASA, 1999). A further $20 million was dedicated to evaluation of various types of NASA scientific data. NASA scientists were encouraged to use commercial data for research, and they continue to do so today.

To determine its high-priority themes, ACE relied heavily on an advisory committee (the Applications Steering Committee), the National Academies, and input from a broad-ranging user community. Feedback was a key element of the communication between NASA and the nonfederal sector at this time. NASA focused on community meetings (for example, regional and local workshops, town hall meetings) where state and local participants, regional associations, and the private sector could present their issues, needs, and ideas, and NASA managers and scientists could develop solutions with these groups. This process gave participants the opportunity to become stakeholders with a direct interest in the future of the program. Community meetings with state and local participants in the late 1990s and early 2000s provided the initial ideas for what are now the "12 Applications of National Priority" for ASP. Examples of these approaches are presented at: *http://geospatial.arid.arizona.edu/slg/* and *http://www.state.hi.us/dbedt/gis/nasa.htm*. The 12 applications areas are discussed in Chapter 2.

Applications-related projects at NASA in this period were perceived by some as very successful in reaching the general public through regional and local projects with good feedback from this community. NASA's implementation of its applications program at this point has been characterized as using a bottom-up, or demand-driven, approach (NRC, 1995), in contrast with the concurrent, centralized Earth Observing System Data and Information System data distribution model. Despite the apparent successes of aspects of this demand-driven approach, the applied sciences at NASA were viewed by a number of people, internal and external to NASA, as a collection of projects distributed throughout NASA without a clear focus or direct connections to NASA's basic research programs. The absence of an official structure at the national level to coordinate and communicate with operational agencies also was criticized, particularly as concerns arose over potential duplication of efforts by several agencies.

The new approach with the ASP adopted by NASA in 2001 could arguably be described as being closer to a supply-driven, or top-down, model. With this new approach to applied sciences, NASA sought to clarify the practical benefits of NASA Earth science and reduce perceived and real duplication of effort with other federal agencies. Under the new approach regional programs were phased out and state and local entities, while not excluded, were not explicitly included in project development or implementation. In addition, the emphasis of the ASP moved from university partnerships to partnerships with federal agency programs. The new approach of ASP is described in the next chapter.

COMMITTEE APPROACH AND REPORT ROADMAP

The committee consisted of 12 individuals with diverse backgrounds and expertise in generating and applying remote sensing data in decision-support projects, with a balance of end users of decision-support tools and products, researchers producing results incorporated in the decision-making tools, and scientists with experience in determining the types of information and tools that end users need. Committee member backgrounds included geography, sustainable development, energy and environmental policy, population and community ecology, meteorology, risk assessment and engineering design, remote sensing and spatial information, cryospheric observations and climate change, marine sciences, statistics, resource management, and population health (Appendix A). To address the statement of task, the committee reviewed relevant NRC reports and information submitted by external sources, including presentations at open meetings, published reports and other literature, and information from the committee's own experience. NASA ASP was also asked to provide specific types of data and information to the committee and complied with the committee's request (Appendix B).

The committee held four meetings in Washington, D.C., in 2006 (Appendix C) and completed its report in 2007. Its first three meetings focused on gathering information. At the first meeting, in January 2006, the committee heard from the study sponsor and representatives from the user community. At the second meeting in April 2006, the one-day panel discussed the NASA-NOAA partnership and academic and private-sector perspectives on use of NASA data for decision support in aviation, weather, and oceans. The final open meeting, in July 2006, extended the panel discussions to a broad spectrum of users of NASA data, with contributions from five federal agencies and five nonfederal user groups. At its closed meeting, in October 2006, the committee shaped its recommendations and the report.

This chapter has summarized the background to the study by placing the NASA ASP in context of the broader federal and NASA framework within which ASP operates, the important national programs that are current drivers of applications beneficial to society, and the historical development of applied sciences at NASA. Chapter 2 examines the approach used by ASP to extend data into operations and decision support (item 1 of this committee's task). Chapter 3 describes ASP's partnerships with federal agencies (item 2 of this committee's task). Chapter 4 discusses ASP's interactions with nonfederal users (item 3 of this committee's task). Chapter 5 presents issues in achieving ASP's objectives (and examines item 4 of the committee's task, as well as portions of the other three tasks). Chapter 6 presents the committee's conclusions and recommendations.

This report is intended primarily for the sponsor of the study, NASA and the ASP, to provide constructive evaluation of ASP's approach to extending NASA Earth data and research to decision-support systems with societal applications. However, open communication between providers of Earth data, operators of decision-support tools that employ the data, and eventual recipients of the results from these tools is an implicit part of achieving societal benefits. Thus, this report is also written to be accessible to the broad community of decision makers, remotely sensed data users, and regional and local users who help stimulate new ideas for research in practical applications of Earth data.

2

The Current NASA Applied Sciences Program

The strategic objective of the National Aeronautics and Space Administration's (NASA's) Applied Sciences Program (ASP) is to expand and accelerate the realization of economic and societal benefits from Earth science, information, and technology (NASA, 2004). This chapter describes and assesses strengths and weaknesses of ASP's current approach to achieving this objective. This assessment provides the foundation upon which later chapters examine relationships between ASP and users of NASA data and research.

This chapter has two parts. First, it presents details of ASP's overall approach, including its areas of focus, and the way the program is administered and assessed. The second section examines the strengths and weaknesses of this approach.

DETAILS OF THE CURRENT PROGRAM

The ASP is a component of NASA's Earth Science Division—one of five divisions of the Science Mission Directorate (Figure 2.1). In 2001, ASP was instructed by NASA management to refocus applications toward the federal agencies and away from local, state, academic, and commercial applied remote sensing research (see Chapter 1 for a history of applications at NASA). The intent of the new focus was to support defined public goods in federal agencies that were already structured and mandated to provide these goods and services. This new approach welcomed academia and the commercial, state, and local sectors as participants in discussions for project development, but not as

NASA's direct partners. With some few exceptions (for example, *http://halvas.spacescience.org/broker/bess/archive/040404.htm* and *http://aiwg.gsfc.nasa.gov/esappdocs/crosscut/DEVELOPProjPlan.doc*), nonfederal partners were supposed to be reached in a third-party manner through the federal agency partnering with NASA. Such an approach was supported by NRC (2002a, p. 5): "the process of interacting with other federal agencies to reach a broad group of users is a viable and appropriate avenue to pursue."

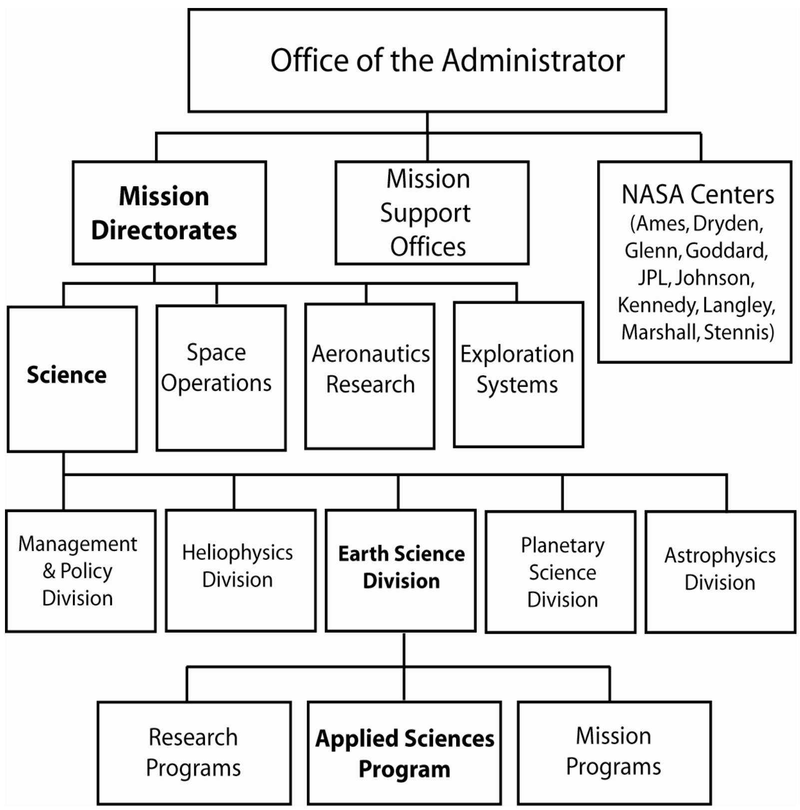


FIGURE 2.1 The Applied Sciences Program in the current NASA organization structure. In 2001 the Earth Science Enterprise and ASP together with it were transferred into the Sun-Earth System Division. This division was subsequently moved into the current Science Mission Directorate.

With this new model NASA sought to clarify the practical benefits of NASA Earth science, reduce perceived and real duplication of effort with other federal agencies, and focus its applications activities in a structured manner. NASA, as a research and development agency, was to extend the observations, model predictions, and computational techniques from its Earth science research to support its (primarily federal) partners. Partner agencies, in turn, would continue to develop and operate decision-support systems (DSS) to analyze scenarios, identify alternatives, and assess risks (Figure 2.2). The DSS are information-processing tools that allow authorities to make informed decisions. The tools are interactive computer systems that provide methods to retrieve information, analyze alternatives, and evaluate scenarios to gain insight into critical factors, sensitivities, and possible consequences of potential decisions. Although providing data for DSS is definitely not the only use for remote sensing data, NASA's philosophy is that NASA-derived remote sensing data and information best fulfill their potential when incorporated into DSS. The Integrated System Solutions Architecture (ISSA) employed by ASP to partner with these agencies (Figure 2.2) embodies a linear transfer of data and research from NASA to its partners with the decision-support tools. In this representation, the ISSA constitutes an "open loop" system without any prescribed feedback mechanism from the partners to NASA for improving earth science models, earth observations, and/or decision support tools.

A representative example of a DSS is the Famine Early Warning System (FEWS) operated by the U.S. Agency for International Development (under contract to Chemonics International) in cooperation with African, south Asian, and Latin American countries. The U.S. Geological Survey provides technical support to FEWS. FEWS uses NASA-derived data to predict famine every year in the Sahel region of Africa. With ASP's current approach NASA does not conduct research to develop the DSS. Developing the DSS is the responsibility of the user. Instead, NASA focuses on ensuring that DSS incorporate remote sensing products to best result.

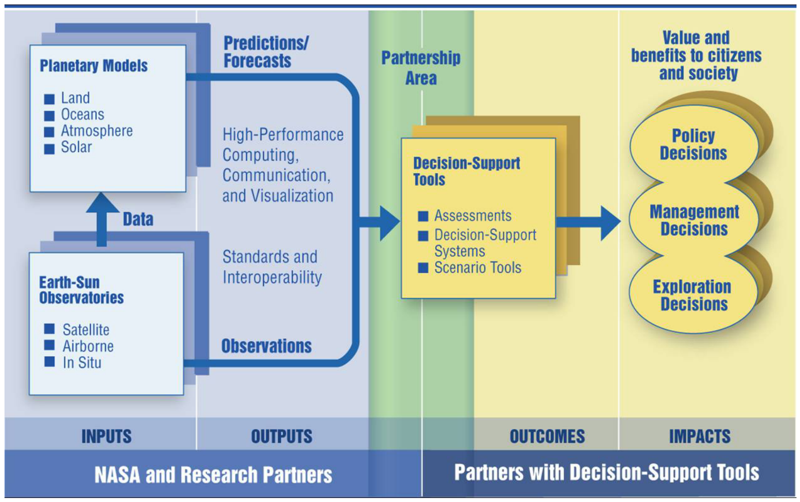


FIGURE 2.2 The NASA Applied Sciences Program approach based on the use of partner agency decision-support systems. SOURCE: NASA, 2004.

With this focus on applications for decision support, ASP's director, in 2002, promoted a systems engineering process around which the program would be organized. The systems engineering process was used to define an approach to extend NASA data and products into DSS operated by other agencies. Systems engineering is a systematic, formulaic approach with which NASA has significant expertise. This approach was viewed as a way to decrease the tendency for NASA technology to be "pushed" out to the community and instead to allow the community to "pull" the technology toward it with a bridging function and funding through ASP. As stated by NASA (2004), "The purposes of this rigorous approach are to identify and resolve data exchange problems, build partners' confidence and reduce risk in adopting Earth science products, and strengthen partners' abilities to use the data and predictions in their decision-support tools." The next section describes the systems engineering process and subsequent sections present other contextual information on ASP's approach.

Systems Engineering Process

The systems engineering process has three phases: evaluation, verification and validation, and benchmarking (NASA, 2004). To initiate the process NASA develops partnerships with organizations that it believes can use NASA satellite data. During this evaluation phase NASA signs a memorandum of agreement with partner agencies and identifies DSS that could benefit from NASA products. While providing data for DSS is not the only use for remote sensing data, NASA and ASP have identified DSS as a key focus for input of NASA data and research. ASP and the partner agency then determine baseline data requirements, assess the potential value and technical feasibility of assimilating NASA data into the DSS, and decide whether to pursue further collaboration on the project. During the verification and validation phase ASP and the partner agency measure performance against requirements and determine if the DSS can achieve the intended outcome. In the benchmarking phase (Box 2.1) the value of incorporating data or models generated by NASA-sponsored Earth science programs into the decision making of other federal agencies is tested and documented.

BOX 2.1
Benchmarking

Benchmarking is one of the primary objectives of ASP's systems engineering process. ASP indicates that "benchmarking refers to the task of measuring the performance of a product or service according to specified standards and reference points in order to compare performance, document value, and identify areas for improvements." Part of NASA's definition of a benchmark is "how the Decision Support System that assimilated NASA measurements compared in its operation, function, and performance to the earlier version."

NASA considers benchmarks an important measure of program quality and claims that "the benchmarking process (1) lowers perceived risk to adopting other Earth science data and technology, (2) provides metrics to report to agency sponsors and inform other users, (3) enables cooperation and builds trust between the agencies, and (4) develops success stories leading to more efforts between the agencies."

One part of the benchmarking phase is to measure and quantify the impact of NASA input to DSS output. According to NASA, the measurements can include the time to produce results; the accuracy, quality, and reproducibility of DSS results; and the enhanced ability of a DSS to fill a previously unmet need.
SOURCE: http://science.hq.nasa.gov/earth-sun/applications/benchmark2.html

Applications of National Priority

The ASP applies the systems engineering process in 12 *Applications of National Priority*: Agricultural Efficiency, Air Quality, Aviation, Carbon Management, Coastal Management, Disaster Management, Ecological Forecasting, Energy Management, Homeland Security, Invasive Species, Public Health, and Water Management. These 12 areas, expanded from seven at the inception of the program in 2002, had their origins in suggestions made by state and local participants in community meetings in the late 1990s (see also Chapter 1). NASA managers stated that they used certain criteria in developing the current set of 12 applications areas that considered: socioeconomic return, application feasibility, whether or not the area was appropriate for NASA, and partnership opportunities. The evolution from seven to 12 application areas was influenced by program personnel identifying gaps in the list, by the identification of new, potential decision-support tools or opportunities in other agencies, interest expressed in the program by managers in partnering agencies, and key national interests. With respect to national interests, areas identified in strategic plans of other agencies (e.g., NOAA) and national and international programs (the U.S. Climate Change Science Program, U.S. Climate Change Technology Program, Global Earth Observation initiative, Geospatial One Stop, or World Summit on Sustainable Development) (Birk, 2006) factored into guiding the application area definitions and scope. The relationship between the 12 ASP application areas and NASA's six Earth Science Focus areas is shown in Table 1.2 of the web site http://science.hq.nasa.gov/strategy/AppPlan.pdf. The committee supports the fact that ASP is presently evaluating the 12 application areas to determine if they require modification in number or scope.

The 12 Applications of National Priority are administered by seven program managers who serve as points of contact (POCs) for each application area. These POCs are responsible for identifying appropriate data for their application area(s) and developing portfolios for partner agencies. POCs allocate ASP resources through open solicitations that undergo peer review (Box 2.2). These solicitations often request user proposals that target specific satellite remote sensing systems.

In addition to open solicitations, ASP funds rapid prototyping capacity projects that can forgo peer review. ASP managers identify research that is approaching readiness, or is ready, for application and provide funding to accelerate the application process. Funding for rapid prototyping is intended to complement existing support and to solve problems that lead to modification or transfer of a product or model rapidly to an operational entity. NASA has, for example, funded rapid prototyping work in coral reef research with the intent of complementing NOAA research and monitoring of coral reef bleaching. Likewise, NASA has funded modification of the Moderate Resolution Imaging Spectroradiometer (MODIS) direct broadcast satellite data products to augment weather forecast operations.

A third portion of ASP's budget goes to funded and unfunded earmarks that may or may not undergo peer review. In both fiscal years (FY) 2005 and 2006 ASP's budget allocation from Congress was approximately $50 million (Birk, 2006). Out of this total approximately $15 million was directed to congressionally earmarked projects. Of the 147 projects supported by ASP during FY 2002 to FY 2006, approximately half were the result of research solicitations. The other projects were either internally directed (circa 37 percent) or directed by Congress (circa 19 percent). Furthermore, eight of the solicited projects were funded as a result of a congressionally directed FY 2005 earmark to Stennis Space Center for a special solicitation through the Mississippi Research Consortium. Fewer than half of all ASP-supported projects from FY 2002 to FY 2006 resulted from an open solicitation.

BOX 2.2
Types of ASP Open Solicitations

ASP open solicitations have included those for the Research, Education and Applications Solution Network (REASoN) and Research Opportunities in Space and Earth Sciences (ROSES). The REASoN solicitations, managed solely by ASP, were first funded in 2002 and concluded in 2005. The FY 2005 REASoN solicitation on "decision support from Earth science results" attracted more than 250 responses. The NASA ROSES solicitation is not limited to ASP. In 2005 it attracted more than 100 responses. Researchers who apply for grants must develop a client in a federal agency other than NASA. The proposal must demonstrate how the client will use NASA products to improve its decision making. This forms the basis of benchmarking (Box 2.1). A new ROSES 2007 solicitation announcement was issued as this report was being finalized, and ASP has one element in that solicitation (Decision Support Through Earth Science Research Results); proposals will be reviewed during the summer of 2007.

Each solicitation is managed with the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES). Proposals are submitted electronically to NSPIRES and subsequently ranked by managers based on input from peer review. For additional information, see *http://science.hq.nasa.gov/earth-sun/applications/sol_current.html* and *http://nspires.nasaprs.com/external/index.do/*.

Metrics

In the context of the current Administration, one clear emphasis of ASP's approach is for clients to demonstrate measurable outputs. The importance of project documentation is underscored and benchmarking, as described previously, is a part of this documentation. Another part is the formal metrics data collection system called the *Metrics Planning and Reporting System* (MPAR). This system is used by all scientists who receive ASP funding and is administered by the University of Maryland Global Land Cover Facility (see *http://glfc.umiacs.umd.edu/index.shtml*). For example, recipients of NASA REASoN applied science funding are required to record their performance metrics monthly.

In developing this metrics system an MPAR working group was charged with reviewing and recommending program-level performance metrics and collection tools to measure how well each activity supports NASA Earth Science Enterprise science, *application* [italics added] and education programs (Rampriyan, 2006). This working group provides ongoing MPAR review, evaluation, recommendations, and metrics development. In addition, it recommends additions, deletions, or modifications to standardized sets of metrics.

The MPAR working group's initial set of core (baseline) program-level metrics consisted of 10 items (Table 2.1, left-hand column). These metrics fall into three groups: a measure of the activity's user community (metrics 1 and 2), a measure of the activity's production and distribution of products and services (metrics 3, 4, 5, 6, and 7), and a measure of the activity's support for ESE science, applications, and/or educational objectives (metrics 8, 9, and 10). The metrics provided by a research activity are assessed in the context of the project's mission statement or program role. For example, a science activity might have no role in applications or education, and metrics 9 and 10 would not apply to it, or an activity might have a role in applications and education, and metric 8 would not apply to it. Similarly, the measure of an activity's production and distribution is evaluated in the light of its role and the resources it uses. The magnitudes of the metrics that would indicate success for an activity vary widely across the set of activities, and all of these measures are not applicable to every activity.

STRENGHS AND WEAKNESSES OF ASP's APPROACH

Building on the descriptions of key facets of ASP's approach in the previous section, this section presents the strengths and weaknesses of ASP's approach. In particular, this section conveys findings on the benchmarking process, the 12 Applications of National Priority, solicitations, metrics, and budget. Detailed discussion of the merits and drawbacks of ASP's federal focus is postponed to later chapters (particularly Chapter 4). One outcome of ASP's federal focus is that the work of ASP is insufficiently informed by the needs of the many users of its products and is not connected strongly enough to the final applications of NASA's data and research. This lack of information from users is also carried to communication of user needs in mission planning. The Decadal Study (NRC, 2007a) emphasized user-defined requirements that maximize societal benefits; thus, this lack of direct connection and communication between ASP and many of its users or potential users is of major concern. One notable effort by ASP to generate a communication template with potential partners consists of a single catalog (http://www.asd.ssc.nasa.gov/m2m/coin_chart.aspx; see also Appendix E), or "coin chart" of the enormous variety of NASA products. This chart is an attempt to consolidate all the Earth Observation sources, physical parameters measured, models and analysis systems, model outputs/predictions, and decision support tools in NASA's portfolio for access by the community interested in using NASA data and research for DSS. The chart is underused and indicates continued need for a more inclusive and holistic ASP role within NASA and with the stakeholder community. The perspectives presented in the remainder of this chapter are considered in the context of this broader ASP role.

Benchmarking

ASP's benchmarked products have resulted in important benefits and lessons learned. Although the products themselves had their genesis in other NASA programs, and the "success" of the products is not solely due to ASP's involvement in the products' extension to partners' DSS, the benefits of these products include (1) improved recovery support from national disasters such as hurricanes and floods; (2) more timely detection of tropical storms resulting in much improved evacuation decisions and (3) improvements in El Niño forecasting for the planning and protection of crops. Among the lessons learned are: (1) interaction and timely feedback from the customer is essential for project success; (2) success sometimes requires use of multiple sources of data and sensors;

TABLE 2.1 Program-level Metrics and Purpose Statements Associated with the *Metrics Planning and Reporting System* (MPAR).

	Metric	Definition and Implementation	Purpose Statement
1	Number of Distinct Users	Number of distinct individual users (based on nonduplicated internet protocol addresses) who request and/or receive products, services, and/or other information during the reporting period.	To measure the size of the project's user community assessed in the context of its ESE role.
2	Characterization of Distinct Users Requesting Products and Information (by Internet domain)	Classes of users who obtain products and services from the project. The metric reveals the relative proportion of users accessing data and services from (1) first-tier domains: .com, .edu, .gov, .net, .mil, .org, foreign countries, and unresolved, and (2) second-tier domains, such as "nasa.gov"and "unm.edu."	To measure the types of users served by the activity assessed in the context of its ESE role.
3	Number of Products Delivered to Users	Number of separately cataloged and ordered data or information products delivered to users during the reporting period (by project-defined product identification). A product may consist of a number of items or files that make up a single item in a product catalog or inventory.	To measure the data and information produced and distributed by the activity assessed in the context of its ESE role. The count of products delivered is a useful measure given the user-oriented definition of a product that is independent of how the product is constituted or how large it is.
4	Number of Distinct Product Types Produced and Maintained by Project	A product type is a collection of products of the same type such as sea surface temperature products. The project may add many or few product types through time but these should be tracked independent of the number of products delivered.	The count of product types produced is a useful measure because of the effort by the activity required to develop and support each of its product types.
5	Volume of Data Distributed	The volume of data and/or data products distributed to users during the reporting period (in gigabytes[GB] or terabytes[TB]).	Volume distributed is a useful measure but one that depends heavily on the particular types of data an activity produces and distributes and must be assessed in the context of the activity's ESE role and data it works with.
6	Total Volume of Data Available for Research and Other Uses	Total cumulative volume of data and products held by the project and available to researchers and other users (GB or TB). This number can include data that is not online but is available through other means.	The cumulative volume available for users provides a measure of the total resource for users that the activity creates.

7	Delivery Time of Products to Users	Response time for filling user requests during the reporting period. Averaged and standard deviation summary times are collected for electronic and hard media transfers.	The delivery time for electronic or media transfers to users is a measure of the effectiveness of the activity's service.
8	Support for the ESE Science Focus Areas (when applicable)	REASoN projects include a quantitative summary of data products supporting one or more of NASA's science focus areas, and report any changes at the next monthly metrics submission. The focus areas are weather, climate change and variability, atmospheric composition, water and energy cycle, Earth surface and interior, and carbon cycle and ecosystems.	To enable the ESE program office to determine which ESE science goals are supported by the activity, and to assess how the data products provided by the activity relate to that support.
9	Support for the ESE Applications of National Importance (when applicable)	REASoN projects include a quantitative summary of the data products supporting one or more of NASA's Applications and report any changes at the next monthly metrics submission.	To enable the ESE program office to determine which ESE applications goals are supported by the activity, and to assess how the data products provided by the activity relate to that support.
10	Support for ESE Education Initiatives (when applicable)	In partnership with the study manager the REASoN projects submit data pertaining to the adoption and use of educational products by audience categories. These groups can include higher education, K-12, museums, and informal education.	To enable the ESE program office to assess support provided by the activity to ESE education initiatives, by indicating use by education user groups of the activity's products and services.

SOURCE: Rampriyan, 2006

(3) advanced planning and agreement between NASA and partner agencies on required metrics is important; (4) community-accepted metrics are the most meaningful; and (5) real-time information is highly desired by users.

Weaknesses of the benchmarking process are:

1. inconsistency in the benchmarking process across applications;
2. unclear demonstration that an ASP product improves the decision-making capability of a partner agency;
3. lack of a standard reference point for benchmarking;
4. inconsistency in the application of metrics; and
5. stretching or broadening the meaning of benchmarking.

These weaknesses are related to the way ASP conducts its activities and communicates with partners, and to the nature of its organizational position within NASA.

1. Inconsistency in the benchmarking process. NASA references two documents as guides for benchmarking and preparation of benchmark reports: *Benchmarking Process Guide* and a *Proposed Guideline for Benchmarking Report Content*. The guideline identifies six benchmarking activities:

1. planning and design;
2. description of methods and metrics used;
3. preparatory activities;
4. data collection/user feedback;
5. analysis of findings; and
6. lessons learned.

A note to the guideline indicates that "quantitative assessments should be emphasized in the benchmarking phase to the greatest extent practicable" (NASA, 2007). A review of several ASP benchmark reports indicated considerable diversity in the approaches. The program element and project applications teams made up of NASA and partner agency personnel determined the form and structure of the benchmarking process and the content of the benchmark report. It is apparent that the benchmarking is driven more by the characteristics of specific applications and the tools and procedures of the partner agencies than by any standard format.

2. Unclear demonstration of impact. Major parts of the benchmarking are the comparisons made by the applications teams of (1) the decision-support tools that use the Earth science observations and models; and (2) the partners' existing tools and procedures. A desired outcome of ASP is for the partner agencies to adopt the use of NASA Earth science products. Thus, a second major activity of the benchmarking is that the applications teams develop proper documentation of procedures and guidelines to describe the steps to access and assimilate the Earth science observations and products. An issue of concern is how to demonstrate in a balanced manner that the ASP product improves the decision-making capability of the partner agency and results in benefits to society.

3. Lack of standardization. While the intent of benchmarking is, among other things, to permit comparison of different products in terms of benefits, there are many cases where a standard reference point does not exist and the benchmarking team has to create its own standard. In addition, cases exist where the benchmarking simply takes the form of enhancements of a previous DSS.

4. Inconsistent application of metrics. The metrics ASP uses for measuring the effectiveness of its products in improving user decision-making capability and assessing the ultimate benefits received are not always suited to the products' goals or purposes. A major challenge in benchmarking is identifying metrics that have the necessary status to be recognizable standards or figures of merit for making the desired comparisons. For ASP these metrics are often only developed following the completion of a project and the ensuing effort to carry out the benchmarking. The application of metrics lacks consistency in terms of recognizable standards or reference points. The general absence of a more prescriptive and quantitative process for measuring product success compromises in-depth comparisons of product benefits. In the private sector the metrics for benchmarking products are usually clear. They include the quantification of such performance indicators as product quality, ease of application, ability to meet customer schedules, time from product development to application, customer response, and the ability to meet goals or product targets.

5. Stretching or broadening the meaning of benchmarking. The meaning of the benchmarking process is stretched where suitable standards cannot be developed, as in compromising the product comparative basis of a standard by employing an application-specific measure or developing improvements in a DSS without making any comparisons.

The weaknesses of the benchmarking process and the lessons learned point to opportunities for improving this process. These include:

- **Identification of principles applicable to all benchmarking efforts so that consistency and integration can be achieved.** A desired outcome would be a concept that facilitates comparisons and the assessment of the relative value of products and services.

- **Greater involvement of third-party users (the broader community)**. The ASP has the opportunity to greatly enhance the benefits of NASA applied science products and services to society. While the links between NASA and partner agencies are somewhat clear, the links between the partner agencies and the broader community and between ASP and the broader community are insufficiently informed. The result is a major barrier in assessing the real and long-term benefits to society.
- **Limiting benchmarking to meaningful standards and metrics**. Some of the benchmarks have to be stretched to meet the intent of a national or international benchmark. Benchmarking products for DSS ought to be based on distinguishable reference points or standards.
- **A comprehensive review of benchmarks and benchmark reports to develop an improved set of metrics**. Little evidence exists of attempting to refine the benchmarking process across all program elements. The current state of benchmarking is very much an ad hoc process. The database that now exists in the form of many benchmark reports appears to be adequate for developing a systematic basis for streamlining the benchmarking process and developing a set of metrics more suitable to quantification.

ASP benchmarking fails to take account of the end use. It is assumed that ASP intends its benchmarking to account for this. An alternative is that ASP intends to leave that aspect to the agency partner and merely wishes to ensure that ASP is doing its part in the partnership. This may be a subtle distinction, but it reflects the difference between criticizing ASP for not fulfilling its mission and then criticizing its mission for being too constrained by the boundaries placed around it by others. An understanding of partner requirements is needed in order to allow benchmarking to function effectively and take into account the "end uses" of NASA products. Some changes to the documentation and reporting requirements of the partners and the greater use of external review groups would aid in making the needs of end users more transparent to ASP. These issues are addressed in more detail in Chapter 4.

Applications of National Priority

Agency personnel and others expressed interest and concern about the 12 Applications of National Priority. Their concerns were grouped as follows: (1) whether ASP is the appropriate NASA lead in certain application areas; (2) the extent to which connections to user agencies have developed for key national applications; and (3) the mismatch between the number of applications and ASP staffing levels.

1. ASP as appropriate NASA lead. In some applications areas other agencies are providing significantly more funding than is ASP. For example, ASP is not the only agency engaged in carbon management; ASP spending in the Carbon Management application is less than that of the Department of Energy's Terrestrial Carbon Program and the National Science Foundation's special carbon cycle solicitations. The Department of Energy also has interests in energy management. Careful evaluation of ASP's involvement in various applications where other agencies have strong and well-funded programs may assist ASP in setting its priorities in balance with its resources and in being most effective in partnerships with federal agencies and the broader community. The idea is not to infer an exclusive correlation between level of funding and benefits achieved, but rather to determine where ASP can be most effective in taking leading roles and establishing partnerships.

2. Extent of connections developed to partner agencies for key applications. The Homeland Security, Disaster Management, Energy Management, and Carbon Management application areas each have natural partnering agencies with whom to establish dialogue and projects. For example, the Department of Homeland Security (DHS) recognizes that remote sensing products are critical to homeland security yet little interaction with NASA regarding applied research has been initiated (Barnard, 2006). In addition, the Federal Emergency Management Agency (FEMA), responsible for national emergency preparedness and response in DHS, has had little to do with the ASP's Disaster Management application area. The Minerals Management Service, a potential partner with Energy Management, noted that improved remote sensing products are needed immediately for support of management of oil, gas, sand, gravel, and other extractive activities in the Gulf of Mexico, but no discussions have been opened with ASP (Lugo-Fernandez, 2006). The weaknesses in some of these potential partnerships are not solely a function of ASP's actions or organization but result from organizational, managerial, and resource issues at partnering agencies as well. Some of these relationships are discussed in more detail in Chapter 3.

3. Staffing levels. Concern was expressed that the 12 application areas cannot be appropriately administered by the small ASP staff. It is difficult for the seven managers to be knowledgeable about the information content in all 12 application areas where the managers are required to both establish relationships with new partners and maintain existing relationships with established partners.

Given ASP's ongoing examination of its application areas, an opportunity exists for adaptation based on the committee's findings and other feedback. Dialog with partner agencies in NASA and with the broader user community will undoubtedly be central to informing ASP's decisions. With respect to the staffing issue in particular, one possible approach could incorporate open solicitations and peer review of some application areas to be led and conducted by scientists at a NASA center (e.g., Ames, Marshall, Goddard, Stennis) while still being coordinated by an ASP program manager. There is considerable expertise at the NASA centers, and each has special areas of applications expertise.

Solicitations

Solicitation issues fall into two categories: the focus of some solicitations and the way solicitations are managed.

1. Solicitation focus. The aim of focused solicitations targeting remote-sensing systems is to stimulate demand for products that require data from those systems. Thus, it is possible for NASA to build a system that has little demand and ASP could then be directed to initiate a solicitation to generate interest in the data stream to support the sensor's existence. An example of such an open solicitation is the one that encouraged those submitting proposals to incorporate little used Gravity Recovery and Climate Experiment (GRACE) data instead of MODIS data. Approximately 80 percent of the proposals ignored this emphasis and focused instead on the familiar MODIS data (Birk, 2006). Uncertainty on data continuity is likely a significant factor in discouraging users from proposing to work with data from some sensors. For example, NASA's highest spatial resolution remote-sensing system (Landsat-7 Enhanced Thematic Mapper + (L7/ETM+), which has significantly exceeded its predicted lifetime, has no approved follow-on programs that will provide data continuity. Users are understandably reluctant to propose applications based on these data streams.

2. Solicitation management. The largest drawbacks evident to the committee in ASP's management of the solicitation process were complications created by regular, significant, and sometimes hard-to-find changes in the program documentation which has made the proposal process difficult or discouraging for potential partners. In addition, the expectation for independent (nonfederal) applicants to establish federal partnerships in advance of some proposal submittal deadlines created additional, unrealistic, tasks for the applicants, and potentially discouraged viable and interesting proposals from being submitted to the applicant pool. A constructive step in the direction of better management of the solicitation process was implemented in the recent solicitation announcement for ROSES 2007 (see also Box 2.2). For this solicitation NASA offered a conference call to explain the ROSES 2007 announcement to all interested parties, and provided Internet presentations on the process for those who wanted further information.

These challenges point to opportunities for improving ASP's approach to solicitations. Improvements in the solicitation process could encourage submission of more high-quality and innovative project applications, thereby improving the opportunity for greater success in fulfilling the application of NASA data to a variety of projects with societal benefits. ASP could streamline the solicitation process somewhat, for example, by facilitating communications between independent (nonfederal) applicants and federal partners. Other improvements to the focus of some of the solicitations require NASA, outside of ASP, to be active in engaging ASP early in the mission development process. Similarly, NASA could rely on ASP to extract information and communicate with the user community to obtain their input as to user needs for data and research. ASP could then be in a position to generate stronger proposal solicitation programs that represented data streams that are both available and desirable.

Metrics Planning and Reporting System

NASA's *Metrics Planning and Reporting System* (MPAR) would be a good tool for establishing a system of accountability and measurement of project progress and success. However, MPAR appears to collect metrics as if most of the users were NASA Distributed Active Archive Centers (DAACs) rather than NASA-sponsored application projects. DAAC metrics include information on the number of hits on a website and the volume of data distributed; these types of metrics are not entirely suitable to gauge the progress of projects coordinated by agencies, institutes, or groups that do not serve an archiving function. Other valuable applied remote sensing metrics include publication of results in refereed journals, masters and doctoral dissertations completed as a result of the applied research, presentation of applied results at meetings of learned societies or in public forums, and documentation of the use of NASA-derived data or models in the user's DSS. Fortunately, recent improvements in the *Metrics Planning and Reporting System* allow the incorporation of impact metrics. The Decadal Study (NRC, 2007a, p. 146) also commented on this topic:

> Systems of program review and evaluation will need to be revamped to make our vision of concurrently delivering societal benefits and scientific discovery come into being. Numbers of published papers, or scientific citation indices, or even professional acclamation from scientific peers will not be enough… The degree to which human welfare has been improved, the enhancement of public understanding of and appreciation for human interaction with and impacts on Earth processes, and the effectiveness of protecting property and saving lives will additionally become important criteria for a successful Earth science and observations program.

The private sector (see also Chapter 4) has generated successful commercial applications employing NASA data and research. A mechanism to engage the private sector and include appropriate metrics would give ASP a new and potentially beneficial way to perform its bridging role. Chapter 5 builds on this discussion of metrics and proposes solutions.

Budgeting and Accounting

The committee commented on two aspects of ASP's budgeting and accounting: (1) the negative impact of earmarks on ASP's ability to manage its portfolio, and (2) challenges created by research grants having to cover costs of obtaining commercial imagery. The topics of budgeting and accounting differ from the others in this section because they are externally driven. Furthermore, the committee was not tasked to make recommendations on such matters. Nonetheless, these topics provide insights into some of the constraints under which ASP managers operate and both NASA and Congress might consider their impact on the program.

1. Earmarks. In addition to raising issues of lack of peer review and occasionally being unfunded, earmarks present a management challenge to ASP staff. These issues often emerge late in the fiscal year with the requirement that they must allocate part of their budget to earmarked projects.

2. Commercial imagery. Covering commercial imagery costs in research grants is currently a required part of research proposals. This procedure has resulted in elevated project costs that decrease the practicality of conducting, for example, any type of research on changes in the natural environment. This type of research often incorporates frequent snapshots over extended periods of time over large geographic areas and the costs of such coverage using commercial imagery may be prohibitive.

Developing partnerships among the government, private industry, and the academic community to facilitate feedback between research and operational processes of the nation will require investment of ASP resources. Because ASP does not completely control its own budget, the program may experience difficulties in enacting strong strategic changes to its operations, and in supporting its generally rigorous open competition and peer review.

SUMMARY

1. Since 2001 ASP's approach to reaching users has been primarily through other federal agencies. Despite practical advantages, this approach has restricted ASP's relationship with end users, resulting in less inclusion of user needs in mission planning.
2. The program is organized into 12 Applications of National Priority. The committee heard opposing arguments in support of either more or fewer application areas. The need for greater depth in key partnerships was also emphasized. ASP's openness toward adapting this applications list and the nature of its partnerships in some areas is well timed.
3. The program is underpinned by a systems engineering process that provides a framework to transition NASA products into decision-support systems operated by other agencies. Benchmarking is a central activity in this process, but it has yet to arrive at a level of consistency and clarity to serve the needs of the program.
4. ASP supports research through three mechanisms: open solicitations, which are peer reviewed; rapid prototyping activities, which are not peer reviewed but allow greater responsiveness to new opportunities; and earmarks, which may or may not be peer reviewed and add to the challenges of developing a focused program. From FY 2005 to FY 2006, funded earmarks accounted for roughly one-third of the total ASP budget. Fewer than half of all ASP-supported projects from FY 2002 to FY 2006 resulted from an open solicitation. Despite ASP's attempt to steer proposals to certain data streams, submissions tend to gravitate to familiar sensors. Uncertainty over the continuity of remote sensing data beyond the NASA research and development phase is a perennial, unsolved challenge faced by ASP. The absence of effective user feedback in the ISSA

makes it difficult for ASP to build bridges between NASA and partner agencies and larger user communities, and to develop effective mission plans.

3

Partnerships with Federal Agencies

The Applied Sciences Program (ASP) uses partnerships with other federal agencies to apply National Aeronautics and Space Administration (NASA) research products in operational decision making. Such partnerships are ASP's primary conduit to end users. Fourteen federal agencies are involved in these partnerships (Table 3.1), which accounted for roughly half of the projects (75 out of 141) funded through ASP in fiscal year (FY) 2006. This chapter lays the foundation for examining the extent to which the partner agencies and organizations have found that their collaboration with NASA through the ASP is helping them carry out their decision-support goals. The discussion continues in Chapter 5.

This chapter has three parts. First, it presents examples of ASP's engagement with federal partners. These examples provide a cross section of agency experience and include the U.S. Department of Agriculture (USDA) and Environmental Protection Agency (EPA)—as two of ASP's longer-term partners—and the National Geospatial-intelligence Agency (NGA), Department of Homeland Security (DHS), and Minerals Management Service (MMS)—as agencies with less mature partnerships. In general, there is great variety in the strength and maturity of federal partnerships (Box 3.1). The second part of the chapter examines the complex relationship between NASA and the National Oceanic and Atmospheric Administration (NOAA). NOAA plays a dual role as an operational home for research sensors developed by NASA and as a user of NASA products. The third part summarizes common challenges encountered by federal agencies in achieving research-to-operations transitions with NASA and identifies aspects of NASA's process that could be improved.

To produce this chapter, the committee drew on presentations and written input from agency representatives. In addition, the committee presented questions to ASP (Appendix B; ASP, 2006). The committee received ample information from some agencies, particularly NOAA (NOAA Research Council, 2006), either through meeting presentations or material submitted in response to committee questions. Not all ASP partnerships with other agencies were as readily documented.

THE PROCESS OF ENGAGEMENT

A variety of constraints influence ASP's collaboration with federal partners and its processes to promote collaboration. The committee examined several federal partnerships to understand common elements and areas for improvement. Each of the five examples below describes partner agencies' requirements, mechanisms used in collaboration with ASP to enhance the partnership process, and the results. The examples begin with the most mature partnerships.

BOX 3.1
Unevenness in NASA's Relationships with Federal Partners

NRC (2007a) observed that "new measurements for applications in weather forecasting can be evaluated within the existing structures of NASA and NOAA because those agencies have for the most part worked out the processes by which the importance of such measurements can be evaluated, notwithstanding the known difficulties of transitioning new measurements to operations. However, new measurements for land-cover, geological hazards, or water resources, to mention just a few, do not have existing relationships between client agencies and the space agencies that naturally lead to evaluation of their potential for applications. New measurements that would be relevant to such critical issues as deforestation and the loss of biological diversity or interruption of ecosystem services essentially have no client agency, and must rely on individual university researchers or staff in non-governmental organizations to lobby the space agencies, without benefit of strong institutional ties to those agencies."

Table 3.1 NASA Partnerships with Other Federal Agencies in Each of the 12 Application Areas

National Application	Partner Agencies	NASA Contributions	Partner Agencies Decision-Support Tools	Decadal Outcomes of Agencies' Use of NASA Data and Information
Energy Management	DOE, EPA	Extended weather forecasts, seasonal climate prediction, and distribution of incoming solar radiation via Terra, Aqua, SORCE (Solar Radiation and Climate Experiment), CloudSAT, NPP (NPOESS Preparatory Project), GPM (Global Precipitation Measurement)	RETScreen Natural Resources Canada (NRCan)	Energy management sources and integration into the power grid through use of RETScreen Location of energy management facilities Biomass crop selection and maintenance strategies
Agricultural Efficiency	USDA, EPA	Seasonal temperature and precipitation, extended weather forecasts, and soil moisture via GPM, Aqua, Terra, NPP, Landsat, Aquarius, suborbital	Crop Assessment Data Retrieval and Evaluation (CADRE)	Improved crop production assessments Increased agricultural productivity and reliability
Carbon Management	USDA, EPA, DOE, USGS, USAID	Measurement of carbonaceous gases and aerosols, terrestrial biomass and marine productivity via Terra, Aqua, Aura, NPP, OCO, and suborbital	CQUEST tools developed to implement Section 1065(B) of Energy Act of 1992 (EA92) voluntary sequestration of greenhouse gases	Operational decision-support system (DSS) with improved assessment of carbon sources and sinks for a carbon-trading regime
Aviation	DOT/FAA	Improving weather nowcasting, monitoring of volcanic aerosols via Terra, Aqua, NPP-Bridge, GPM, and suborbital, improving cockpit capabilities via: • Aviation Weather Information • Synthetic Vision System (SVS)	National Aerospace System (NAS) Controller/pilot decision aids Runway incursion prevention	Enhanced National Airspace System, AWIN (Aviation Weather Information Project), and SVS that reduce the aviation fatal accident rate by a factor of 10 by 2022

Table 3.1 Cont'd NASA Partnerships with Other Federal Agencies in Each of the 12 Application Areas

National Application	Partner Agencies	NASA Contributions	Partner Agencies Decision-Support Tools	Decadal Outcomes of Agencies' Use of NASA Data and Information
Homeland Security	DHS, NIMA, USDA, USGS, NOAA, DOD	Observation and modeling of atmospheric chemical transport and precipitation via Terra, Aqua, NPP, GMP, and suborbital	Department of Homeland Security (DHS) situation control	Improved capabilities of homeland security officials to prepare, warn, and response to homeland security threats, especially air and water exposure
Ecological Forecasting	USGS, USDA, USAID	Observation of land cover change, vegetation structure, and biomass and use in ecosystem in models via Landsat, NPP, and suborbital	Models of habitat change Impacts of El Niño	Enhancing ecosystem sustainability as economics and populations shift and grow
Disaster Management	FEMA, USGS, NOAA, USDA	Observations of topographic change and crustal strain and motions, extended weather forecasts via Aqua, SeaWinds, SRTM (Shuttle Radar Topography Mission), Landsat, GPM, and suborbital	HAZUS (Hazard U.S.) risk Prediction Carrier for Integration of Natural Disaster Information (CINDI)	Enhanced risk assessment, warning and response for hurricanes, tornadoes, flooding, earthquakes, and landslides
Public Health	CDC, DOD NIH, EPA, USGS, NOAA	Observations and modeling of weather, climate, and other environmental factors influencing disease vectors and air quality via Aura, NPP, Jason, GPM	Environmental Public Health Tracking Network (EPHTN) Arbovirus Surveillance Network (Arbonet) Malaria Modeling and Surveillance (MMS)	Improved a surveillance systems (Arbonet) Integrated environmental factors into EPHTN Improved accuracy and precision of disease predictions with a corresponding increase in warning time
Coastal Management	NOAA, EPA	Measurement and modeling of ocean temperatures, winds, color, and salinity associated with harmful algae blooms via Terra, NPP, SeaWinds, Landsat, Jason	Harmful Algal Bloom Mapping System/Bulletin (HABMap/Bulletin)	Improved capability of DSS to forecast HAB initiation, transport, toxic severity, landfall, and demise

Invasive Species	USGS, USDA	Observations and modeling of land cover change, biomass, and climate influencing species proliferation in areas where newly introduced, via Terra, Aqua, NPP, Landsat	Invasive Species Forecasting System (ISFS)	Operational, robust, and early detection and monitoring of plant invasions to protect natural and managed ecosystems
Water Management	USBoR, EPA, USDA, USGS	Improved models of water transport, storage, and quality using observations of snow cover, soil moisture, and topography via Aqua, NPP, GRACE, GPM, Landsat, and suborbital	RiverWare Better Assessment Science Integrating Point and Nonpoint Source (BASINS) Agricultural Water Resources and Decision Support (AWARDS)	Improved water quality and quantity assessments Forecasts of precipitation and daily crop water use toward reduction of real irrigation Seasonal predictions for optimum vegetation selection and improved water use efficiency
Air Quality	EPA, NOAA, USDA, FAA	Measurements of aerosols, ozone, emissions, and modeling of aerosol and chemical atmospheric transport via Terra, NPP, Aura, Glory, and suborbital	Community Multiscale Air Quality (CMAQ) modeling system AIRNow and Air Quality Index	Multiple-day air quality forecasts and robust emissions control planning

NOTE: See Appendix D for Abbreviations and Acronyms List
SOURCE: NASA, 2004, p 47-48.

Department of Agriculture

The mission of the USDA is to provide "leadership on food, agriculture, natural resources, and related issues based on sound public policy, the best available science, and efficient management." The USDA has a long history of partnering with NASA. The relationship began in the 1970s with the NASA-initiated Large Area Crop Inventory Program (LACIE, Box 1.1) and continued into the 1980s with the USDA-initiated Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) Program. Those programs led to the operational use of remote sensing data by the Agricultural Research Service, Forest Service, and Foreign Agricultural Service (Box 3.2), among others.

Examples of requirements

USDA has wide-ranging requirements for remote sensing data. These requirements are driven by the need to analyze the health and quantity of trees and crops and the natural resources (water, air, soil) that support agriculture. Such requirements can be grouped under eight themes that align with focus area working groups (FAWGs) set up by USDA and NASA. The NASA/USDA FAWGs are agriculture efficiency, air quality management, carbon management, disaster management, homeland security, invasive species, resource inventory and monitoring, and water management. The FAWG on air quality focuses on a number of new NASA data sources for supplementing ambient air quality measurements of ozone, aerosols, ammonia, and volatile organic compounds. For example, a strong need exists, particularly in USDA's Forest Service, to measure emission sources of ozone and particulates, because burning on agricultural and forest lands affects regional haze and ambient air quality. USDA activities relating to another FAWG—agricultural efficiency—require higher spatial resolution than is available from NASA. In addition, they need user-friendly data formats and more rapid access to NASA data than is currently available. Activities under the disaster management theme require hyperspectral data, a continuous Landsat data series, and expertise in unmanned aerial vehicles (UAVs). Activities under the water management and conservation theme that already use NASA tools and resources in conjunction with USDA in situ data to forecast water availability have unmet needs for high-resolution hyperspectral data for water quality assessment.

Box 3.2
Use of NASA Data by the Foreign Agricultural Service

USDA's Foreign Agricultural Service (FAS) partners with NASA through its Production Estimates and Crop Assessment Division (PECAD) (Doorn, 2006). PECAD's Crop Explorer (see *http://www.pecad.fas.usda.gov/cropexplorer/*) has tools for assessing crop production worldwide using various NASA data sources, including MODIS, Advanced Microwave Scanning Radiometer (AMSR-E), and Tropical Rainfall Measuring Mission (TRMM). Landsat has been a key data source for FAS, and the NASA/USDA Global Reservoir and Lake Monitor Project uses lake and reservoir levels from NASA's Jason-1 satellite every seven to ten days for estimates of lake and reservoir height to develop estimates of irrigation potential.

Process

Given the long history of USDA-NASA collaboration, this discussion focuses only on partnership processes established under the present iteration of ASP. A USDA-NASA Memorandum of Understanding (MOU) in 2003 established a Federal Interagency Working Group on Earth Science Applications (IWGESA) with a joint funding Announcement of Opportunity through ROSES (Chapter 2). USDA has subsequently supported several projects through ROSES. This ASP-coordinated NASA-USDA collaboration led to formation of the aforementioned FAWGs. The FAWGs are tasked to identify projects for collaborative development by USDA and NASA and to develop prospectuses for these new projects. USDA provides feedback to NASA through these working groups and through publications and reports on activities that use NASA data. In addition, NASA and USDA have held two interagency workshops to fuel collaboration. At the first workshop, held in Denver in 2003, IWGESA initiated several research proposals. The follow-up meeting, in 2005 in New Orleans, assessed progress on proposed collaborations and attracted a wider range of USDA participants.

Results

USDA needs a wide range of data and models to support its diverse applications. The NASA-USDA partnership has supported a subset of these needs. For example, NASA has provided new tools that are particularly useful in the areas of air quality, precipitation, soil moisture, and water resource monitoring. There are unmet needs in applications that involve high-spatial-resolution and hyperspectral remote sensing data, particularly for assessment of disasters and agricultural efficiency. USDA also has requirements for high-frequency, high-resolution multispectral satellite data, but no formal process exists for expressing scale and resolution requirements for such data. Issues of data continuity—particularly with respect to Landsat—are of growing concern to USDA agencies such as FAS. While this issue is one of policy with respect to the continuity of the Landsat project and not under ASP's mission, the importance of this project and other data continuity issues to ASP and its partners is clear. ASP's voice, for its activities and as a representative for federal partners in this larger policy issue, is an important one for NASA to consider.

Environmental Protection Agency

EPA's mission is to protect human health and the environment. The agency has worked closely with NASA for two decades. In the early 1990s, land cover issues were at the forefront of their interaction. EPA scientists developed remote sensing applications together with NASA scientists at Langley and Ames Research centers. More recently EPA has worked directly with ASP and has tried to provide feedback to NASA through this program.

Examples of Requirements

EPA requires predominantly high-spatial-resolution multispectral data to aid in its decision making. Because of the regulatory nature of EPA and the need for data to withstand judicial scrutiny, the quality and reliability of these data are more important than developing new research applications (Worthy, 2006).

In the federal government only the U.S. Geological Survey's Earth Resources Observation Systems Data Center (USGS EDC) provides such data—from Landsat. Images can cost $400 to $700, although with any image quality problems the imagery may be provided at a lower cost. In addition, many images are free to the public domain outside EDC. EPA does not routinely use commercial satellite data for its operational environmental monitoring because these data are not designed with science quality in mind, they are costly, and the options for data sharing may be controlled by a license agreement.

Process

EPA's partnership with ASP is focused on application of low-spatial-resolution data. Between 1998 and 2004 EPA used SeaWiFS data in some of its programs. These data were acquired through the NASA data buy (Chapter 1). EPA now uses NASA MODIS data, which are free and provide frequent revisits over the same location. NASA and EPA have used several MOUs or Memoranda of Agreement (MOAs) to define the formal mechanisms of their partnerships. EPA has implemented these partnerships with an employee dedicated to developing tools with NASA.

Results

Formal arrangements and a direct liaison working with NASA have helped facilitate the partnership process and created the potential for establishing EPA's requirements. Unfortunately, NASA and ASP have had difficulties dedicating staff to these interactions. In addition, NASA's competitive process for funding projects has slowed some project development. It is possible for EPA to pay for internal projects through base funding, and EPA believes direct funding to some collaborative projects may expedite the process of transferring research to operations. Additional resources as well as greater continuity in formal partnership mechanisms may also strengthen the feedback loop from the EPA user community to NASA.

National Geospatial-Intelligence Agency

The NGA has had a relationship with NASA since 2003. Its mission to supply geospatial information to the defense complex and to society requires multiscale, multiresolution data with global coverage. In addition to supporting military operations, these data are used in such applications as environmental assessments, ground planning, and disaster support. Where possible the agency uses unclassified data and fuses these data in-house with classified images (Powers, 2006).

Examples of Requirements

NGA routinely uses NASA data (e.g., from MODIS) though they also require higher-spatial-resolution multispectral data than are available from NASA. While some NASA data formats require extra processing for use by NGA (for example, the MODIS data), NASA data quality is considered good for NGA applications. Because open use of the Internet compromises NGA's network security, one common additional requirement is a direct data feed through nonpublic channels.

Process

NGA demonstrated its commitment to use of NASA products by appointing a full-time liaison at NASA in 2003. The liaison facilitates communication of needs and requirements. There are, however, no other formal arrangements that could provide a complete cycle of requirements establishment, feedback, and transition of NASA research to operations.

Results

NGA acknowledges that NASA has always been responsive to its needs but has not requested feedback. In addition, NGA notes that a NASA help desk would be useful. With respect to assisting with NGA's data needs in the long term, there is no NASA-NGA mechanism to develop new technologies to support pressing NGA requirements for high-frequency, high-resolution multispectral satellite data. In general, under the current arrangement NGA uses what it can obtain from NASA until the source is either put into operation by another agency or is discontinued.

Department of Homeland Security

The NASA-DHS relationship is young, evolving, and has yet to be formalized. DHS is involved in all phases of disaster management and is responsible for providing data to a multitude of users, from policy- and decision makers to field workers across a wide range of agencies. DHS is primarily a data user, not a producer, and works closely with NGA, NOAA, and USGS to acquire data. DHS also uses data that originate at NASA (from orbital and suborbital sources) and the USDA National Agricultural Imagery Program, among a number of freely available sources. From the standpoint of DHS, the focus of use for remote sensing data is toward emergency or disaster response, recovery and mitigation. Examples of applications include oil seepage detection, detection and scope of metropolitan power outages, natural disaster response (tornadoes, hurricanes, floods, and wildfires) (Barnard, 2006).

Examples of Requirements

Many of the DHS agencies require frequent high-spatial-resolution multispectral, multiplatform data, and on occasion live and dynamic data feeds. In addition, DHS wants unclassified data that are available to responders on the Internet for the most rapid dissemination.

Process

In DHS one person at FEMA coordinates GIS and remote sensing with all relevant agencies and directs selection of the appropriate remote sensing data for a given situation. DHS consults with the U.S. Army Corps of Engineers (USACE) on data interpretation. Amongst the 12 spectral satellite systems available and appropriate for use by DHS in 2006, four of the systems were NASA's.

Results

Currently, DHS is a consumer of NASA products, and no formal mechanism exists for ASP to help develop new technologies to support DHS requirements. Placement of a NASA employee with remote sensing expertise on detail at DHS occurred for a brief period and was deemed successful in encouraging initial interactions between DHS and NASA through ASP (see Section 3.3.2 for these itemized formal agreements). Otherwise, DHS has relied primarily on other federal agencies to provide processed NASA data to meet their decision-support needs and to speak to NASA about its data requirements. A primary issue for a relatively new agency like DHS has been to establish its own requirements, prior to making direct communications about these requirements to agencies like NASA (Barnard, 2006). As DHS' requirements crystallize, identification of specific persons within DHS to serve as contacts with NASA and ASP was suggested as an additional practical step for DHS to follow to foster better communication with NASA.

Minerals Management Service

The Minerals Management Service (MMS) of the Department of the Interior manages the nation's oil, gas, sand, gravel, and other mineral resources on the seafloor in the U.S. Exclusive Economic Zone (EEZ). The MMS has increasing responsibilities for managing and leasing of outer continental shelf (OCS) areas for activities related to offshore wind energy, wave energy, ocean current energy, offshore solar energy and hydrogen generation, and programmatic environmental impact statements (EISs). The MMS's geographic focus is the Gulf of Mexico, which is home to over 95 percent of U.S. offshore oil and gas production, although there is still some offshore production in Southern California and limited leasing and exploration in federal waters off Alaska (Lugo-Fernandez, 2006). MMS relies on accurate oceanographic and weather forecasts to make decisions that impact the nation's energy and offshore mining processes.

Examples of Requirements

NASA satellite images provide a unique means to observe and monitor the EEZ frequently, repeatedly, and in a synoptic manner. Using these images, MMS works with industry to monitor and understand oceanographic conditions such as eddies and currents. Such water motions are of particular interest because they affect drilling operations and dispersal of spills. Eddies can result in shutdown of drilling operations, and strong ocean currents and winds (Figure 3.1) can damage equipment and cause substantial economic losses.

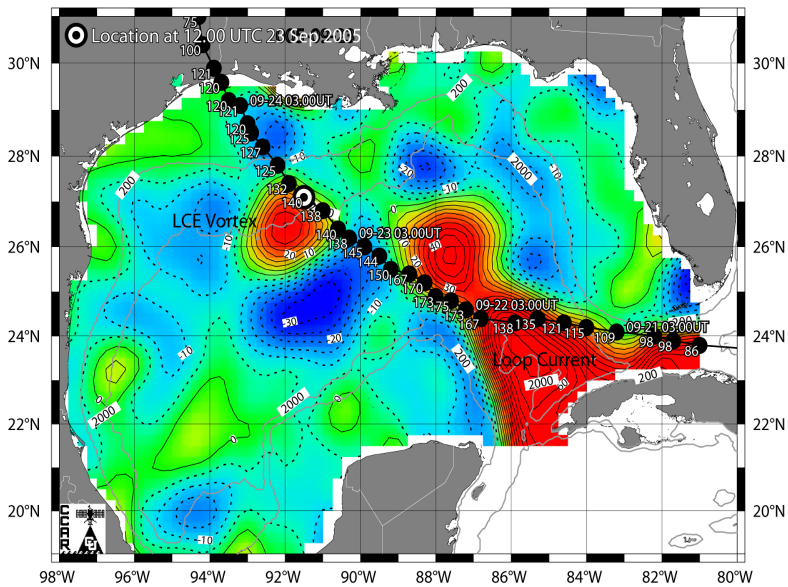


FIGURE 3.1 Path of Hurricane Rita over the Loop Current and Loop Current eddy "Vortex" in the Gulf of Mexico. Image shows color map of sea surface height overlaid with the National Weather Service observed and predicted path and maximum sustained wind speed for the hurricane from the 7 am CDT forecast on September 23, 2005. High sea surface height (red) is associated with very deep and warm waters of Caribbean origin. Altimeter data from the NASA/CNES Jason-1 and T/P, ESA Envisat, and U. S. Navy Geosat Follow-on altimeter satellites were used to map the height field. Hurricane Rita passed over the main concentration of U.S. outer continental shelf oil and gas drilling operations in the Gulf. SOURCE: Courtesy of Dr. Robert Leben of University of Colorado

Process

MMS has no formal mechanisms for dialogue with NASA. Nonetheless, MMS uses NASA data and, mostly over the last decade, has awarded contracts (including those for 43 oceanographic projects) for environmental research and monitoring.

Results

The MMS-NASA relationship is an example of an agency's reliance on NASA data without a formal partnership that includes official contacts or a means to impact sensor specifications by communicating observational requirements.

NASA's RELATIONSHIP WITH NOAA

NASA's relationship with NOAA is different from those described above because NOAA is both a user of NASA products and a conduit for extending NASA products into an operational setting (Box 3.3). This section covers both facets of this relationship. The first element of discussion in this section is NOAA's operational use of NASA data. This is followed by discussion of the research-to-operations transition. NOAA, through its Research Council, was particularly responsive to the committee's questions (NOAA Research Council, 2006). Quotes from the council's response are used throughout this section.

Box 3.3
Example of the Complexity of the NASA-NOAA Relationship

NOAA's National Environmental Satellite, Data and Information Service's (NESDIS's) Center for Satellite Applications and Research (STAR) has extensive interactions with NASA in (1) remote sensing instrument development, (2) remote sensing research, (3) calibration/validation of new instruments and products, and (4) real-time use of experimental satellite products.

Several staff members of STAR were on the Atmospheric Infrared Sounder (AIRS) and MODIS science teams and provided science and guidance, from an operational perspective, for the development and use of those instruments. STAR provided the routine ground truth buoy data (Marine Optical Buoy, MOBY) for calibrating the MODIS ocean color bands and products; STAR scientists on the AIRS science team contributed atmospheric profile retrieval algorithms and methodology to test the usefulness of AIRS data for numerical weather prediction.

MODIS data are used operationally by NOAA to derive wind vectors over the polar regions. These polar winds have had a measurable impact on the accuracy of numerical weather forecasts. The AIRS is proving to be an excellent test instrument for future operational hyperspectral atmospheric sounders such as the Infrared Atmospheric Sounding Interferometer (IASI) and Cross-track Infrared Sounder (CrIS).

SOURCE: NOAA Research Council (2006).

NOAA as a User of NASA Products

The National Center for Environmental Prediction (NCEP) is a major operational processing center in NOAA's National Weather Service (NWS). The NOAA Coastal Services Center (CSC), part of the National Ocean Service, supports decisions on coastal management, recreation, and hazards. Both NOAA centers use NASA data.

National Center for Environmental Prediction

NCEP produces weather and climate analyses and forecasts derived from NOAA, NASA, and other data sources (e.g., radiosonde networks, radar networks, surface stations) to NWS field offices, the public and private sector, and academia. NCEP, or its equivalent predecessor, has used NASA data since the early 1960s.

Examples of Requirements

NCEP relies heavily on a range of models and satellite and surface weather observations to complete its mission. In addition to relying on NOAA's operational data sources, NCEP draws on many NASA satellites (e.g., MODIS, Box 3.3; TRMM [NRC, 2005a]; and TOPEX, JASON, Box 3.4). NCEP operationally uses models and methodologies developed by NASA (e.g., Box 3.4).

Box 3.4
NOAA Application of NASA Data and Models

The NOAA Research Council presented the following as examples of successful applications of NASA data and models in NOAA:

- The NASA Coupled Climate Forecast Model will be one member of the NOAA multi-model ensemble forecast system for operational climate forecasts.
- NASA tools such as the Observing System Simulation Experiment (OSSE) methodology, the Finite Volume Global Circulation Model, and the Goddard Cumulus Ensemble Model have been used by NOAA.
- NOAA's operational seasonal climate forecasts, which use altimetry data from NASA's/Centre National d'Etudes Spatiales's (France) TOPEX and JASON satellites to forecast the impacts of such phenomena as the El Niño/Southern Oscillation, have provided enormous economic benefits.

SOURCE: NOAA Research Council (2006).

Process

Despite a long history of NCEP use of NASA data and models, there is no formal mechanism to transmit, review, revise, and develop requirements. One source of optimism is the Joint Center for Satellite Data Assimilation (JCSDA) (NRC, 2007b), whose participating members include the Department of Defense (DoD), NASA, and NOAA. The participants' shared goal is to accelerate the use of satellite data in numerical weather prediction. The center provides resources and scientific interactions that facilitate timely use of NASA experimental satellite data in operational models.

Results

NOAA's input to the committee underscored the cultural differences between agencies with research and operational missions. NCEP emphasized that its requirements are not well understood or appreciated by NASA. The stringent steps required for operational assessment, acceptance, and implementation require careful and continuous coordination by agency managers to ensure that the academic community is provided with a clear set of requirements to focus the research, and that the results of the research are then implemented. The NOAA response to the committee stated,

> Yet, the difficulties involved with the transition from research to operations are still not fully appreciated by either the research community, the operational community and especially the policy and budget community: From a sociological point of view, the stringent steps required to modify operational systems and related software (that assures operational product delivery) are viewed by the research community as a roadblock. From a budgetary point of view, the resources required to assess and implement new procedures and related IT [information technology] infrastructure are underfunded by both sides, and no one really wants to assume these costs. NOAA Research Council (2006).

In the past, a program called OSIP facilitated the transition from research to operations. To further quote the NCEP response to the committee:

> One bright spot in the transition process involved the satellite community. In the beginning of the satellite era in the 60's and early 70's, NASA and NOAA worked through the 'Operational Satellite Improvement Program' (OSIP) in true partnership to test

> satellites, assess the data and validate the instruments (NASA lead), before deploying and sustaining an operational satellite network (NOAA). The rapid spin up of the GOES [Geostationary Operational Environmental Satellites] program came out of this effort (among other success stories). OSIP was halted in the 1980s by a mutual agreement between NASA and NOAA. With the demise of the OSIP went the strong inter-agency support for the satellite R2O [research to operations] transition process, and here we are today.

According to the NOAA Research Council the process for stating requirements is informal, with NASA making the final decision on research projects they fund. JCSDA has identified a need for high-frequency, high-resolution multispectral satellite data from NASA. Yet, even with NASA's involvement in the JCSDA, there is no mechanism to influence new research on space technologies that would lead to future satellites and products designed to address requirements not satisfied with existing NASA data. Since the demise of OSIP, no formal program exists for NASA to develop and test new space observation systems that would make the transition into NOAA operations. Furthermore, NASA no longer necessarily accepts the responsibility to develop and space test future satellite systems needed by NOAA to improve operational weather forecasting. The Geostationary Imaging Fourier Transform Spectrometer (GIFTS), which is capable of enabling revolutionary improvements in hurricane and severe convective storm (including tornado) predictions, is an example of a new system not being space demonstrated by NASA for NOAA. NASA did fund the development of a highly successful GIFTS Engineering Demonstration Unit. The space demonstration of GIFTS by NASA and NOAA was recommended in the Decadal Survey (NRC, 2007a) report. This is one example of the "disconnect" in the space system responsibilities shared by these two agencies, and underscores the sense that broader issues than just those under ASP's purview require resolution in order for ASP to be as effective as expected in its "bridging" role.

In general, there is no clear sense at NCEP of which programs need mutual support by NOAA and NASA. Success depends on the overall investment and balance of investment among observations, computational power, and research and transition support. On the observational side, airborne and surface systems receive fewer resources than space systems (Box 3.5) even though the former could contribute to high-resolution data needs of the community. Support for computational power and research and transition support is also inadequate. This has, for example, caused a multiyear backlog of new satellite products waiting at JCSDA to be tested before they can be used operationally (NOAA Research Council, 2006).

Coastal Services Center

The Coastal Services Center (CSC) has attempted to integrate NASA data into its work since the mid-1990s.

Examples of Requirements

CSC uses remote sensing data to achieve performance goals relating to (1) build regional capacity to address coastal hazards and other weather and water conditions, (2) adequately characterize coastal and marine areas for management, and (3) improve ecosystem management through tools, technologies, and information services used by NOAA partners and customers. Operational data are required for several applications to implement decision-support tools. CSC performance is gauged by the number of such tools generated and their usability.

CSC customers and partners work on topics that generally require higher spatial resolution multispectral data than are available from NASA. In many cases customers also require a higher temporal and spectral resolution. Consequently, CSC often turns to private sector vendors to collect and process data for decision-support tools. Where requirements are less restrictive, CSC works with NASA and the private sector on data and tools development (Box 3.6).

Process

Collaboration between NOAA/CSC and NASA is informal—through in-kind contributions in the case of the Harmful Algal Bloom (HAB Forecasting System. There is no formal mechanism for communicating data needs and results back to NASA, and there is little funding from CSC for the NASA science community or interaction between the two groups.

BOX 3.5
Insufficient Resources for Airborne and Surface Systems

"There are insufficient resources being allocated to airborne and surface systems, which can be more responsive and produce higher data quality than space systems for high-resolution requirements. Current surface, in situ, and seafloor instruments are insufficient to provide the spatial coverage and integrated knowledge necessary to ground-truth and calibrate space and airborne imaging systems."
SOURCE: NOAA Research Council (2006).

BOX 3.6
Coastal Services Center Partnership with NASA and the Private Sector

The NOAA Harmful Algal Bloom (HAB) Forecasting System team has been working with Applied Coherent Technologies (ACT) to develop the Rapid Environmental Assessment and Composition Tool (REACT) that may use NASA data (e.g., from MODIS) and other data (e.g., SeaWiFS and OrbView-2 data from GeoEye) for HAB forecasting. ACT is funded by a NASA REASoN grant (Chapter 2). A formal Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Oceans and Human Health is preparing the five reports required by the Harmful Algal Bloom and Hypoxia Amendments Act of 2004 (HABHRCA). The NOAA National Centers for Coastal Ocean Science's Center for Sponsored Coastal Ocean Research (CSCOR) has the interagency lead for preparing those reports. CSCOR also interacts less formally with NASA via interagency peer-review panels for projects such as the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB). National Ocean Service scientists are also asked to review proposals for NASA.

Under an informal collaboration with NASA (through Goddard Space Flight Center and the Jet Propulsion Laboratory), NOAA (NOS and NESDIS) has purchased high-resolution SeaWiFS data for continental U.S. research applications and the NASA Ocean Color Program provides in-kind support by distributing the data to CSC's research community using the same standards as earlier NASA-purchased data.

SOURCE: NOAA Research Council (2006).

Results

Although the NASA science community develops and tests the SeaWiFS algorithms that contribute to the GeoEye product used in the HAB Forecasting System (Box 3.6), there are no formal NOAA-NASA partnership mechanisms to support the NASA science community. Most research results are published in peer-reviewed journals. NOAA members of NASA science teams report quarterly on progress during formal science team meetings, but NOAA has no formal mechanism for communicating back to NASA, although informal communication has occurred through the NASA Goddard Space Flight Center and the NASA Jet Propulsion Laboratory.

Extending NASA Research to NOAA Operations

Because NASA is a research and development agency, the long-term benefits of its contributions to operational decision support hinge on effective processes for transferring sensors to operational entities such as NOAA. NOAA has dual responsibilities in this regard: ensuring that it carries NASA sensor systems into full operation and that its requirements for NASA products are conveyed to and considered by NASA and its science community. The research-to-operations transition between NASA and NOAA has a long history, particularly with respect to weather monitoring and prediction. Despite some successes the overall NASA-NOAA relationship is mixed (Boxes 3.7 and 3.8).

BOX 3.7
Operational Satellite Improvement Program

The Operational Satellite Improvement Program (OSIP), which operated between 1973 and 1982, aimed to facilitate the transition of NASA research to NOAA operations. Several groups who addressed the committee hailed OSIP as a success in coordinating budgets and programs to achieve this goal. NASA-NOAA cooperation was guided by a formal 1973 agreement that was funded at about $15 million per year. The budgets for NASA and NOAA (and its predecessor) reflected this agreement. NASA used its funding to develop prototype sensors, fly them on high-altitude aircraft, and transfer them to research spacecraft for evaluation. Successful instruments were then provided to NOAA for transition to operational status. The program fell victim to NASA budget pressures and a desire on the part of the Office of Management and Budget (OMB) to offload "routine" functions from NASA, and was cancelled in 1982 (OTA, 1993; NRC, 2003).

BOX 3.8
Key Recommendations from *Satellite Observations of the Earth's Environment: Accelerating the Transition of Research to Operations*

NRC (2003) observed that there are examples of successful transition from research to operations but that the process was largely ad hoc. In addition, it noted that for every successful transition there were many more that were not successful, and there was no mechanism to ensure the process was efficient and effective. The report's main recommendations were that:

- A high-level joint planning and coordination office should be established to focus on the transition process.
- A strong and effective Interagency Transition Office (ITO) for planning and coordination of activities of NASA and NOAA in support of transitioning research to operations should be established by and should report to the highest levels of NASA and NOAA.

In addition to these primary recommendations, others include:

- NOAA and NASA should improve and formalize the process of developing and communicating operational requirements and priorities.
- All NASA Earth science satellite missions should be formally evaluated in the early stages of the mission planning process for potential applications to operations in the short, medium, or long term, and resources should be planned for and secured to support appropriate mission transition activities.
- NASA and NOAA should jointly work toward and should budget for an adaptive and flexible operational system in order to support the rapid infusion of new satellite observational technologies, the validation of new capabilities, and the implementation of new operational applications.

SOURCE: NRC (2003).

The 2003 NRC report (Box 3.8) was generally well received by NOAA but less so by NASA. There were several reasons for this disparity, and they highlight the cultural and perceptual problems in trying to bring about change in federal organizational relationships. In particular, NASA was a reluctant sponsor of the study, which was initiated by NOAA/NESDIS. NASA believed the existing ad hoc system was working well and did not need to be formalized. NASA was concerned about focusing too much on the NOAA customer and that other customers would be left behind. NASA also did not want to contribute manpower to an effort it believed was unnecessary. Lastly, NASA believed the formal process would slow progress and negatively impact their budget.

Little has changed since the 2003 NRC report, as summarized in NRC (2007a) (Box 3.9). NASA and NOAA have grappled with how to better coordinate their programs but other priorities have intervened. As an indication of the uncertainty in developing lasting agency formal relationships, a draft transition plan was presented but then withdrawn as this committee was beginning its work. The NOAA Research Council's feedback to the committee gives further insights into where the relationship could be improved (Box 3.10).

The research-to-operations processes between NOAA and NASA's Earth Science Division are currently termed "research *and* operations" (R&O) by NASA. To the Earth Science Division, R&O means making the transition from NASA-developed research-grade sensors and sensor-level components into NOAA operations and to assess NOAA operational measurements that can satisfy NASA Earth science research needs (e.g., developing long-term climate data records). Missing in this definition is a clear path to inform NASA-supported scientists of NOAA requirements, a mechanism for NOAA to help participate in supporting this research, and a formal mechanism to develop such technologies aimed to make the transition to operations for purposes of data continuity.

In summary, neither NASA nor the ASP has a formal mechanism to plan missions that support NOAA's operational activities, or to transfer sensor-level components directly to users in these areas. Past successes in cooperative programming and budgeting under OSIP provide a model for NASA and NOAA to address this need. There is no doubt that some significant successes in research-to-operations transitions have occurred in spite of the lack of overarching formal arrangements, of requirement-generation processes, and of dedicated funding. Personal relationships and hard work of individuals on science teams and joint working groups have provided the foundation to overcome some of these issues and have led to the successes of this partnership. However, the informal background to the successes is problematic in that it causes peaks and valleys in the achievement curve and greatly affects the confidence of users and the rest of the community in the continuity and strength of individual programs. Given ASP's focus, it clearly has a central role in advancing and improving NASA's cooperation with NOAA.

BOX 3.9
The State of the Research-to-Operations Transition

Several Quotes from NRC (2007a) provide a sense of the current state of the research-to-operations transition.

"An efficient and effective Earth observation system requires an ongoing interagency evaluation of the capabilities and potential applications of numerous current and planned missions for transition of fundamental science missions into operational observation programs. *The committee is particularly concerned with the lack of clear agency responsibility for sustained research programs and the transitioning of proof-of-concept measurements into sustained measurement systems.* To address societal and research needs, both the quality and the continuity of the measurement record must be assured through the transition of short-term, exploratory capabilities into sustained observing systems. Transition failures have been exhaustively described in previous reports and the committee endorses the recommendations in these studies."

"The committee is concerned that the nation's institutions involved in civil space (including NASA, NOAA, and USGS) are not adequately prepared to meet society's rapidly evolving Earth information needs. These institutions have responsibilities that are in many cases mismatched with their authorities and resources: institutional mandates are inconsistent with agency charters, budgets are not well matched to emerging needs, and shared responsibilities are supported inconsistently by mechanisms for cooperation."

"Recommendation: U.S. civil space agencies should . . . plan for transitions to continue demonstrably useful research observations on a sustained, or operational, basis and foster innovative new space-based concepts. In particular, NOAA should increase investment in identifying and facilitating the transition of demonstrably useful research observations to operational use."

"Because no one space agency or its partners can hope to encompass the full range of the measurements to applications chain, interagency coordination will certainly be required to enable the larger effort to 'exceed the sum of its parts' in fully realizing benefits. There are likely to be needs for interactions among staff with different types of backgrounds and training that are difficult to foresee now but that will demand new interdisciplinary relationships to be built."

SOURCE: NRC (2007a).

BOX 3.10
Feeding NOAA Requirements into NASA Mission Planning

"NASA requests requirements from NOAA, but only as broad enquiries that lump operational needs with the requirements of the research community and the NASA research program. While it is recognized that NASA does not have operational responsibilities, the direction taken by research and experimental missions is driven by the requirements NASA identifies. The use of NOAA requirements information we have developed for NOAA customers and partners would allow NASA to develop instrumentation that would meet those requirements."

SOURCE: NOAA Research Council (2006).

IMPROVING THE EFFICIENCY OF NASA'S FEDERAL RELATIONSHIPS

Three common themes emerged from the committee's discussions with federal agency representatives that affect the effectiveness of ASP's processes: (1) more formal arrangements are needed to ensure systematic transfer of data or knowledge from NASA to partner agencies; (2) there is no effective feedback mechanism to collect requirements or coordinate joint funding from other agencies so that NASA can initiate research and engineering programs to develop the most appropriate technologies, products, and decision-support system (DSS) components to address the nation's needs; and (3) support provided by ASP is always short-term—from rapid prototyping funds lasting a few months to three years at most—and there is no vision (or provision) for long-term continuity of partnerships or the research underpinning them. Of the many facets of the partnership process that could be strengthened to address these challenges, three stand out: (1) the feedback loop between NASA and its partners, (2) the formality of agency partnerships with NASA, and (3) the role of joint, or interagency, working groups.

The Feedback Mechanism

NASA and NOAA worked jointly to develop a conceptual model for the NASA-NOAA research-to-operations transition (Figure 3.2). The model has no direct link with the extra-governmental research community, and there is no active feedback mechanism. Such a mechanism is needed from the initial stages of mission planning onward to ensure that requirements are appropriately considered. A feedback mechanism needs to be sustained, even as sensors and models move to operations, to ensure science-based support, data quality, and a path for developing new and creative management solutions.

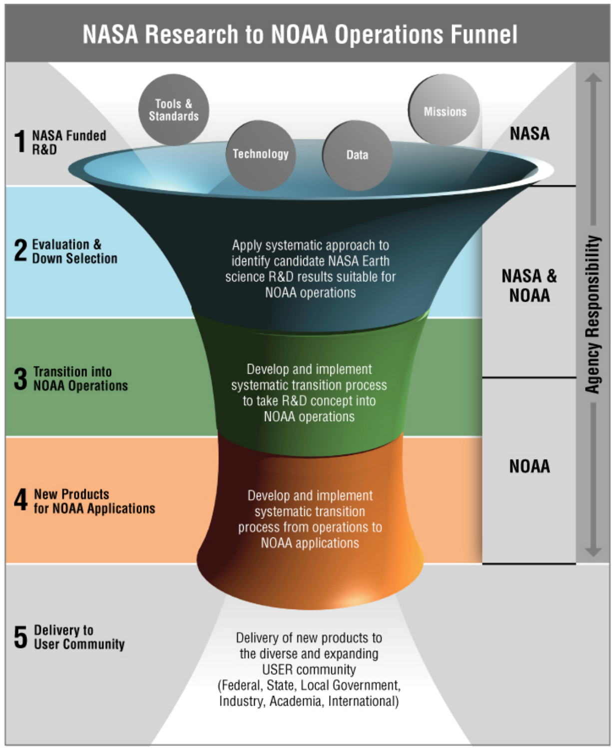


FIGURE 3.2 NASA and NOAA's conceptualization of the NASA-NOAA Research-to-Operations Funnel. SOURCE: Uccellini (2006).

Formal Agreements

Although NASA has developed a number of formal partnership agreements (e.g., Table 3.2), NASA and its partners would benefit from more. NOAA, for example, desires more formal arrangements such as MOUs for transfer of resources from NASA to NOAA once an operational capability has been demonstrated (NOAA Research Council, 2006). One challenge is that no mechanisms have been identified to transfer capabilities, especially without negative impacts on budgets at NASA.

In general, such formal agreements can (1) establish requirements that lead to prioritization of NASA research based on greatest need and benefit, (2) guide the transition of research to operations and commitments by participating parties to achieve common goals, and (3) clarify (for key groups such as Congress, for example) the common interests of partner agencies. As the NOAA Research Council (2006) recognizes, MOUs (as well as MOAs) could be the basis for these arrangements. They do not have the force of law or necessarily the backing of Congress or the OMB, but they could point the way to more formal agreements that might have this backing.

Interagency Working Groups

Climate change has recently become a high-priority issue for the Executive Office and Congress, and NASA's role as a provider of long-term data records that document various aspects of climate change have been highlighted in these discussions (see Chapter 1). Interagency coordination is desirable on such multidisciplinary topics as climate change and can potentially be achieved through the structure of interagency working groups (IWG). The Climate Change Science Program (CCSP) (Box 3.11) and the Earth Observing System (EOS) have used this approach. EOS produced the NASA Terra and Aqua satellite programs that have provided significant support to federal and private entities concerned with global synoptic datasets and climate change. Some data streams from the Terra and Aqua programs have also been incorporated into program planning within several interagency working groups under the aegis of CCSP (Box 3.11). Detailed examination of the CCSP will be reported in a forthcoming study by the NRC titled "Strategic Advice on the U.S. Climate Change Science Program" (*http://www8.nationalacademies.org/cp/projectview.aspx?key=209*); our review of ASP's interactions with this group was based on information that could be derived from public sources.

The bridging function of ASP is particularly suited to the IWG function of linking NASA research to other federal agencies responsible for climate change DSS. ASP's defined mission casts itself directly over CCSP's four core approaches: scientific research, observations, decision support, and communications. Support at NASA and from ASP for the CCSP is demonstrated in part by the active role the ASP has taken in several CCSP working groups, including co-chairing the subgroup on Decision Support Resource Development and Human Contributions and Responses [to climate change] (for information on the working group's goals, see *http://www.usgcrp.gov/usgcrp/Library/ocp2007/ocp2007-hi-decisionsupport.htm*).

The committee found it difficult to extract from public sources any neutral information about the direct impact of NASA and ASP on achieving CCSP's goals. NASA contributions are noted on the CCSP website, but whether these contributions are tied directly to the actions of ASP, a NASA center, or other scientific team at NASA is not easily assessed. The relatively early phases of some of the CCSP working group projects may also preclude a detailed evaluation of the success of data transfers to DSS under the CCSP umbrella that might be attributed to ASP.

The committee also recognizes that the effectiveness of the working group approach requires interagency coordination and significant startup time to establish common goals and operating procedures. Successes (or failures) to date in implementing some of the goals of the working groups under CCSP may simply not be attributable to the actions of one or another agency within the group. Regardless, ASP is authorized and in a position to take a strong contributing role in establishing productive exchanges of information and facilitating data and research transfers in CCSP.

BOX 3.11
Climate Change Science Program

CCSP was launched in February 2002 as a collaborative interagency program under a new cabinet-level organization (Figure 3.3) designed to improve the government-wide management of climate science and climate-related technology development. The program aims to provide a scientific basis for evaluating contributions to climate change to aid policy makers. CCSP incorporates and integrates the U.S. Global Change Research Program (USGCRP) with the Administration's Climate Change Research Initiative (CCRI).

CCSP includes a number of working groups with interests in satellite observations and improving DSS. Among many CCSP interagency working groups, three have specific interests in improving DSS. These are the groups focused on Climate Variability and Change (CVC), Climate Variability and Predictability (CLIVAR), and Decision Support Resource Development and Human Contributions and Responses.

Table 3.2 NASA Agreements with Federal Agencies and Nonfederal Organizations

Earth Science and Applied Sciences Program				
Agreement Type	**NASA Signatory**	**Partner(s)**	**Title/Purpose**	**Enacted**
MOU	Administrator	USDA	Cooperation and Coordination in Science and Technology Research, Development, Transfer, Utilization, and Commercialization	Apr. 1998
Basic Agreement	Administrator	DoC	Collaborative programs, especially in area of satellite programs, data systems, research and analysis, and other areas	June 1998
MOU	Administrator	DOT	Cooperation on the Remote Sensing Technology Application in Transportation	Sep. 1999
MOU	ESE (Earth Science Enterprise)	USGS	Collaborative programs. Purpose is to facilitate the conduct of scientific research and long-range technology development	Jan. 2000
MOU	Administrator	Western Governor s' Association (WGA)	Concentration in the application of remote sensing data and technology in development of environmental policy	Aug. 2000
MOU	Administrator	FEMA	Alignment of NASA's Natural Hazards research and applications development and adoption of science and space technologies by FEMA	Dec. 2000
LOA (Letter of Agreement)	ESE	Association of American State Geologists (AASG)	LOA describes the support and cooperation that will be provided by NASA and AASG to advance mutual objectives	Jan. 2001
LOA	ESE	USAID	Research, development, and application of remote sensing technology to monitor environmental aspects of economic aspects of economic development activities that impact the carbon cycle	May 2001
MOU	ESE	International City/County Management Association (ICMA)	Promote cooperation between NASA and ICMA in order to disseminate geographic information technology	Sep. 2001
MOU	ESE	Multiple Agencies	Interior, Defense, Agriculture, NASA: MOU among federal agencies responsible for data related to the criteria and indicators for sustainable forest management in the United States. Initial MOU in Oct. 2000; NASA joined Sep. 2001	Sep. 2001

Agreement	SMD	National Association for Search and Rescue	Technology Solutions to Search and Rescue Applications	Nov. 2001
Strategic Partnership	ESE	DHS - FEMA	Formal working relationship in the development and enhancement of FEMA's HAZUS Decision-Support System	c. 2002
MOU	ASP	DOE/NREL	Apply NASA Earth Science data and model products to enhance the nation's ability to expand the use of renewable energy technologies in a number of end-user applications	Feb. 2003
MOU	Administrator	USDA	Cooperation in Earth science. Framework to facilitate science and technology research, development, transfer, utilization, and commercialization effort in the area of Earth remote sensing	May 2003
MOU	ESE	EPA Office of Water	Cooperation in Water, Coastal and Earth Science	c. 2003
MOU	ESE	DHHS – CDC	Applications of Earth Science Research and Development for Environmental Public Health with NCEH and ATSOR	Feb. 2004
MOU	SMD	DOI/National Park Service	MOA between NASA and the National Park Service. Purpose: Use Earth Science imagery and NASA exploration and science programs for the preservation, enhancement, and interpretation of the natural resources of the United States	Jan. 2005
MOU	SMD	Multiple Agencies	DHS, NOAA, DoD, EPA, NRC, NASA – Interagency Modeling and Atmospheric Assessment Center	Apr. 2005
MOU	Administrator	FAA	Support the FAA/NASA Executive Research Steering Committee in oversight of the FAA and NASA join aviation and space transportation research and development efforts	May 2005
Interagency Agreement	Center	USFS	Collaborative Research and Applications in Support of Disaster Management and Natural Resource Studies	Oct. 2005
MOU	SMD	DHS	Agreement for temporary (one-year) assignment of NASA employee	Dec. 2005
MOU	SMD	DHS	MOU between NASA and Department of Homeland Security	Dec. 2005
MOA	Administrator	EPA	Cooperation in Environmental and Earth Science and Applications	Dec. 2005
MOU	SMD (Science Mission Directorate)	Bureau of Reclamation	Cooperation in water resource management	Pending in 2006

SOURCE: ASP (2006).

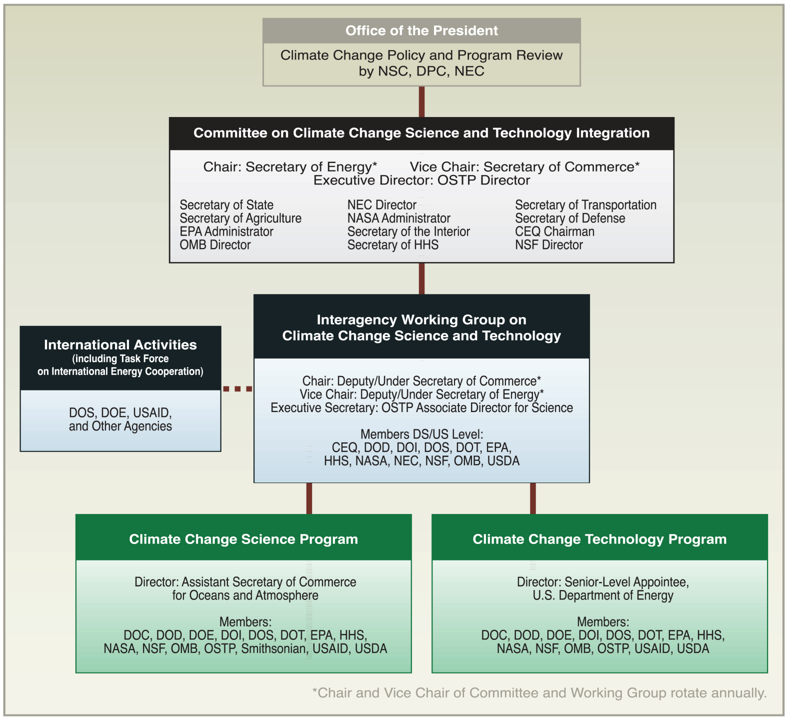


FIGURE 3.3. Organizational context for the Climate Change Science Program. SOURCE: CCSP (2003).

In addition to CCSP, which clearly has some current public attention through ongoing climate change discussions, ASP participates in 11 other domestic interagency organizations (Table 3.3) and numerous national subcommittees and task forces. Representation in these groups may be either through a representative of the ASP or through the Earth Science Division or other unit within NASA. As of August 2006 ASP was also involved in 10 international committees or working groups, including the Intergovernmental Panel on Climate Change, the World Meteorological Organization, the United Nations Educational, Scientific and Cultural Organization, and the Central American Commission for Environment and Development. The committee recognizes the relevance of these organizations and ASP's effort to participate in their activities. However, similar to CCSP, determining the direct involvement of ASP in the organizations' activities as opposed, or in addition, to the involvement of NASA generally was difficult either through public references for these organizations or through NASA's and ASP's web pages.

Table 3.3 Domestic Interagency Organizations in which ASP Participated in 2006

Organization	Participants	Focus
Climate Change Science Program	Federal agencies	Climate change
Climate Change Technology Program	Federal agencies	Energy Research and Development Portfolios
United States Group on Earth Observations	Federal agencies	Earth observation systems
Commercial Remote Sensing Space Policy	Federal agencies	Commercial remote sensing
ederal Geographic Data Committee	Federal agencies, state agencies	Standards for geospatial data
Geospatial One Stop	Federal agencies	Portals for geospatial data
U.S. Weather Research Program	Federal agencies	Weather research
Committee on Environment and Natural Resources Subcommittees	Federal agencies	Coordination of interagency science and technology programs
Civil Applications Committee	Civil agencies; intelligence community	Coordination of Civil agency use of national assets
Joint Planning and Development Office	Federal agencies	Aviation issues
Ocean US	Federal agencies	Coordination of Oceans Research and Resources
Subcommittee on Integrated Management of Ocean Resources	Federal agencies	Coordination of Management of Ocean Resources

SOURCE: ASP (2006).

SUMMARY

The ASP has focused on supporting other federal agencies as the primary method of reaching operational and resource management users. ASP has identified some specific successes in achieving societal benefits through transfer of NASA products to external applications and these include: (1) improved warning, monitoring, and recovery support from national disasters, such as hurricanes and floods; (2) more timely detection of tropical storms, resulting in much improved evacuation decisions; (3) improved wildfire detection; and (4) improvements in El Niño forecasting for the planning and protection of crops. The successful outcomes of use of NASA data in these types of projects are not solely attributable to ASP's activities in facilitating partnerships, as many projects have had their genesis in other units within NASA where partnerships with external users were already established. The committee was challenged by the need to try to differentiate between what ASP could consider "their" successes and those successes that had input from other NASA units. The suggestion is therefore made that the requirement to document "successes" as measures of performance should be viewed and used as a means to encourage communication within NASA and not to obscure the intended collaborative nature of the relationship ASP has with its internal NASA colleagues, or the intended external partnerships between NASA and user communities.

While successful transfers of research to operation and DSS are documented, the committee identified room for improvement. In particular, the committee concludes that:

1. The lack of formal processes to establish requirements, coordinate activities, and make the transition from NASA research to partner operations affects ASP's overall effectiveness.

2. Federal partners have received a broad range of attention and support from ASP. NOAA and agencies in DoD have committed dedicated personnel resources to ensure they receive NASA priority support. Others, such as USDA and EPA, have generated specific programs that help focus NASA efforts to solve their problems. Yet others, such as DHS, have a relatively passive relationship in which they have been simply recipients of NASA data. As an area in which to concentrate federal partnership development with "younger" agencies, disaster and risk management, in particular, may be one of the most obvious to provide direct and immediate societal benefit through application of remotely sensed data.

NASA's relationship with NOAA is the most mature with respect to weather research and prediction applications but there is much room for improvement in the research-to-operations transition process.

3. A systematic feedback mechanism from end users to NASA program planners and decision makers is lacking. Many federal partners have expressed a requirement for high-resolution multispectral satellite data, for example, but indicate that they do not find an effective mechanism at NASA to absorb this feedback. In general, federal users have a wide range of needs in terms of satellite data continuity, quality, format, and resolution. They often adapt to data formats provided by NASA, but express that they have limited or no influence over data characteristics (see also Chapter 5, section 5.1.2).

The committee concludes that the most successful federal partnerships could include an explicit link to the partner federal agency's user community and a plan for continuation after ASP funding ended.

4

Beyond Federal Partnerships: Engagement with the Broader Community of Users

This chapter examines the extent to which the National Aeronautics and Space Administration's (NASA's) Applied Sciences Program (ASP) engages the broader community of users in researching, developing, and validating the scientific basis and applications of NASA products. "Broader community" means organizations that are not federal agencies, but are currently benefiting from collaborations with NASA or have the potential to do so. Examples of members of the broader community are academia and academic research institutions; state and local governments; tribal nations; and the private sector, including manufacturing, processing, and service entities; nongovernmental nonprofit organizations; and international organizations.

These communities have many diverse interests. Academia generally is interested in advancing knowledge through creative research and education programs; state and local governments want products that enhance their decision-making capabilities that allow them to improve their services, including emergency response and resource management. The private sector wants data to improve their products and services, and hence their competitive position. Nonprofit organizations provide services for a specific issue, and the tribal nations seek information and products for the general betterment of their people. These diverse interests complicate the assessment of how much society is benefiting from ASP's work. The committee chose to examine ASP's process of engagement, the products involved, and its current practices in engaging the broader community.

Before addressing the process and practices involved in ASP's engagement of the broader community, it is important to recall what the ASP mission entails and how it is supposed to benefit society. NASA has a research program that puts instruments into space to produce observations of Earth processes such as climate change, agriculture and food supply, air pollution, water resources, land dynamics, natural disasters, aviation safety, and weather forecasting. The remotely sensed observations are used for analysis of resource changes and to develop models for predicting future conditions, such as crop production, El Niño forecasts, and propagation of invasive species. The analyses and models are then used as supporting evidence for decision making on such matters as the pricing of agricultural products, disaster management, water management, and resource conservation. A part of the process is benchmarking the value of the results or models generated and making them a part of decision making. Through application, decision-support systems (DSS) emerge that can be provided to and applied by organizations. The desired result is to benefit society through better management of resources and disasters, weather forecasting, food supply, and transportation safety, among others. One question this committee has been asked to address is how well the broader community is being engaged in this important endeavor and whether the experience of this community is being incorporated into the feedback process to decision making about the future direction of the ASP.

THE PROCESS OF ENGAGEMENT

The process of engagement by ASP is the pursuit of partnerships with organizations for the development of DSS that benefit society. NASA relies heavily on federal agencies as its partners to develop decision tools for implementation (Chapter 3). NASA's partnering primarily with federal agencies inevitably leads to such agencies having a major influence on the development of decision-support tools possibly at the expense of other sources, especially the private sector. NASA works with the partners through ASP to validate and incorporate Earth science data into tools to enhance established relationships that the partner agencies have with other organizations, which mostly by serendipity, include some members of the broader community. The engagement process has many facets, among which are internal NASA operations that can affect implementation of ASP activities. The ASP operates through the NASA field centers, Earth science laboratories, and the Distributed Active Archive Centers. These organizations identify Earth science results, design products, and provide information to partners.

ASSESSMENT OF ENGAGEMENT ACTIVITIES

NASA puts into place agreements and initiatives to collaborate with other organizations in the application of NASA technologies (Table 3.2). Examples are the large number of agreements with interagency and nonfederal organizations and U.S. and international committees relating to NASA Earth science. Even though the NASA agreements include nonfederal organizations, an examination of the participants in the ASP reveals essentially no direct engagement of the broader community. Rather, the nonfederal participants are such national and regional organizations as the Association of American State Geologists, the International City/County Management Association, the National Association for Search and Rescue, and the Western Governors' Association. There is limited evidence that these national organizations have strong ties with many key members of the broader community, especially the private sector. Academic institutions have been able to partner with local constituents in certain of the Applications of National Priority, such as agricultural efficiency, ecological forecasting related to fire dynamics, water quality monitoring, and carbon management; several institutions located near NASA centers appear to have garnered a disproportionate amount of attention and resources. The international committees in which NASA is involved have a similar government and institutional framework with no direct evidence of any strong links with the broader community. Should ASP consider the establishment of direct links with such users as the private sector and other nongovernment organizations as too much of a burden for the program, alternative solutions should be considered, some of which are discussed later.

The extent to which ASP has focused its partnering efforts on federal agencies and encouraged them to take on the task of engaging the broader community can be seen in the list of ASP-funded projects in FY 2006 (Table 4.1). As noted in Chapter 3, over half of the funded projects (75 of 141) were with federal agencies. An additional 48 funded projects were based at academic institutions, which have the goal of developing application products targeted to 11 of the 12 Applications of National Priority (energy management did not have an academic partner). A limited number (8) of nonprofit organizations were funded and only three for-profit enterprises were funded. State and local partners were also poorly represented, with just seven receiving funding. The data in Table 4.1 show a lack of ASP direct partnerships with such broader community entities as nonprofit, private, state, and local organizations. The data in Table 4.1 do not show unfunded activities associated with use of NASA products, as the unfunded usage was not possible to track given the data available to the committee.

Table 4.1 ASP-Funded Projects

Application Areas	Federal	Academic	Non-profit	Private	State	Local
Agricultural Efficiency	3	5	1		1	
Air Quality	9	4		2		
Aviation	6	4			1	
Carbon Management	5	5				
Coastal Management	5	2			1	
Disaster Management	3	4	1			3
Ecological Forecasting	4	3	4			
Energy Management	5					
Homeland Security	3	3				
Invasive Species	3	5	1			
Public Health	4	3				
Water Management	5	3		1		
Cross Cutting	20	7	1		1	
Total	75	48	8	3	4	3

SOURCE: ASP (2006).

ASP's focus on federal agency partners is also reflected in usage statistics for the various websites and gateways serving as programmatic reference sites. For example, from January through August 2006, 48.1 percent of the hits on NASA's Application Implementation Working Group (AIWG) website were from users with the .gov domain extension (Table 4.2), 4.3 percent were from U.S. academic users (.edu), 4.8 percent commercial users (.com), and only 3.0 percent from nonprofit organizations (.org). The distribution of hits was similar in 2005 and 2004.

Table 4.2 Domain Names of Visitors to the AIWG Website, By Year

		2006[a]		2005		2004[b]	
Domain/Country	Domain Extensions	Number of Hits	Percent of Hits	Number of Hits	Percent of Hits	Number of Hits	Percent of Hits
U.S. Government	.gov	27,130	48.1	50,242	52.9	9,570	42.4
Unknown	.ip	15,734	27.9	22,742	24.0	6,089	27.0
Commercial	.com	2,707	4.8	7,662	8.1	1,532	6.8
Network	.net	5,812	10.3	6,349	6.7	2188	9.7
U.S. Educational	.edu	2,400	4.3	4,630	4.9	2309	10.2
NonProfit Organizations	.org	1,718	3.0	564	0.6	365	1.6
USA Military	.mil	450	0.8	486	0.5	135	0.6
Germany	.de	174	0.3				
China	.cn	96	0.2				
United States	.us	203	0.4				
Italy	.it			521	0.5		
Canada	.ca			141	0.1		
Australia	.au					31	0.1
Unknown				87	0.1	197	0.9
Other				1,506	1.6		

[a] Statistics from January through August of 2006
[b] Statistics from September through December of 2004
SOURCE: http://aiwg.gsfc.nasa.gov/stats/.

Usage data from NASA's Earth Science Gateway shows a similar bias towards government-based domains of users during FY06 (Table 4.3):

Table 4.3 Domains of Users of NASA's Earth Science Gateway in Fiscal Year 2006

Domain	Percentage
.gov	70
.com	6
.edu	2
.net	8
.ca	3
.uk	1
Unknown	7
Other	3

SOURCE: http://aiwg.gsfc.nasa.gov/stats/.

The decision by NASA leadership in 2001 to focus on partnering with federal agencies to facilitate and enhance the development of DSS has had the predictable effect of limiting the involvement of other members of the broader community of users in developing models and applications. While it appears to have been NASA's belief that it was the role of the partner federal agencies to advance the development of DSS among the broader community, the lack of a formal structure that delineates the roles of NASA and its partners leaves success largely to chance. Examples of successful development and employment of DSS by nonfederal entities certainly exist, and the projects competitively funded by the ASP include such grantees. However, the generally ad hoc nature of the relationship between the ASP and potential nonfederal users of DSS suggests that maximum benefit is not being realized.

An example of NASA's failure to engage the broader community is in the area of high-resolution satellite imaging systems, which is discussed more in Chapter 5. In particular, significant requirements exist for radiometrically calibrated, frequent, synoptic products at spatial resolutions that range from 0.25 to 100 meters, with a spectral resolution sufficient to accommodate between 6 and 20 visible spectral bands (color), and temporal resolution ranging from twice daily to two-week revisit cycles. Although spatial resolution and temporal frequency are generally tradeoffs, commercial providers do not meet the requirement for science-quality, high-spatial, spectral, and temporal resolution data. These requirements are shared by a large number of entities in the broader community, including those with national security, emergency management, resource management, enforcement, and research responsibilities, and include tribal, state, and local urban planners (Jensen and Cowen, 1999), terrestrial resource managers and researchers focused on land processes (NSGIC, 2006), coastal managers and scientists (Carder, et al., 1993), and a wide range of users of satellite imagery at the global, continental, or coastal zone scale (NRC, 2002b). This class of data has the largest group of users, and yet they have the greatest lack of response from NASA in addressing their need for high-resolution data. NASA's addressing these requirements would satisfy a large cross-section of the broader community and would also address critical requirements of several federal operational (FEMA, DHS, NOAA, EPA, DOI, DOE) and research agencies (NSF, USGS, NASA) (Chapter 3), likely facilitating some additional interest from the community to engage NASA through ASP, and vice versa.

One overarching issue in attempting to assess ASP's engagement with the broader community (and for its engagement with federal agencies [Chapter 3]) is the lack of a prescribed feedback system from users. ASP's Integrated System Solutions Architecture (Figure 2.2) refers to a model of moving data inputs to outputs to outcomes and finally to impacts (NASA, 2004). This system envisions data accessed from satellite, airborne, and in situ platforms being incorporated into Earth science models that, in turn, produce predictions that become incorporated into decision-support tools. Ultimately, these decision-support tools should inform policy and management decisions. ASP sees this overall process as moving research to applications, with various partners playing a fundamental role in developing and applying DSS. With the partners having the primary burden of making the transitions from research missions and observations to applications, it appears that ASP has become almost *disengaged* from the broader community. In addition, the committee found a lack of supporting evidence that the federal partners are successfully engaging the end users. As a result the process is largely a unidirectional one as opposed to being applications driven. From the view of the end users, there are several limitations of this one-way flow model. The lack of feedback loops from partners (federal agencies, state agencies, non-government organizations) who develop and employ DSS to the developers and maintainers of sensory platforms (and, to some extent, model developers) leads to three missed connections:

1. Users of NASA's products are frustrated with a number of technical issues associated with aging NASA platforms and sensory arrays. The committee could not identify a mechanism for end users to communicate effectively with NASA through ASP about these shortcomings. While NASA may be prohibited from getting directly involved with DSS, this does not preclude an agency or ASP from building conduits for timely feedback from partners. The issue of missing operational support, and whose responsibility it is to provide such support, arose frequently in the briefings the committee received from users and potential users of NASA products.

2. Frustrations also arise because NASA is a research and development organization and the continuity of data from a NASA sensor is not assured in the long term even if the data have useful applications. Interestingly, the success and longevity of NASA missions such as Landsat and NOAA's Advanced Very High Resolution Radiometer (AVHRR) have created a user community that is dependent on older-generation sensors. And while many of these users have made a transition to MODIS products in place of AVHRR, it is unclear what will happen in three to five years when this platform retires and National Polar-orbiting Operational Environmental Satellite System does not possess the same capability.

3. A process for selection of sensors for operational transition is also lacking. Such a process seems to be nonexistent or infrequent at the design stage of new sensors and platforms (or at least when decisions are made as to which sensors will be placed on a new platform). Evidence of this lack of communication is the number of orphaned sensors that do not appear to be used by any partners.

The lack of a feedback loop suggests that the role of the broader community has not been made sufficiently transparent in ASP to support a comprehensive assessment of benefits to society. Users of NASA products may not know that NASA (or ASP) was even involved in the production of the information they rely upon in their decision making, compounding the difficulty of engaging the broader user community. It is a problem of too many "unconnected dots" in the path from research to operations.

Among the reasons given by ASP for not having more direct involvement with the broader community is the view shared by some government entities such as the Office of Management and Budget that NASA is a research agency and applications development is not a primary part of the NASA mission. These same entities point out that many federal agencies have science application responsibilities and that engaging NASA in the applications and implementation business would be duplicating such responsibilities. Partnering primarily with federal agencies to assess the potential for ASP products to improve the partner's decision-support tools is apparently the adopted strategy. Meanwhile, the partner agency is tasked with engaging the broader community in the application of ASP products. This strategy constrains the transfer of information and technical knowledge between the applications and the user community, because a partner agency may not have sufficient knowledge of the NASA product or may not know how these products could be modified to meet user needs. Benchmark reports are supposed to help, but they often come late and sometimes not at all.

In spite of ASP's disproportionate engagement of federal agency partners and users, examples of research transfer to application products can be found in a range of ASP-funded projects encompassing a range of user groups (Box 4.1). Other NASA programs have successfully engaged the broader community in applications development without ASP involvement (Box 4.2); while this type of success is commendable and should be encouraged, it may also show the potential for enhanced communication and engagement within NASA, and specifically between ASP and other NASA units or programs where research with "applications potential" is being conducted. ASP's role in bridging the transfer of such research and data to external partners and users could be more effectively incorporated through solid internal communications at NASA, and could potentially increase the rate and number of successful transfers to the private sector.

BOX 4.1
Examples of Transfer of Research to Applications in the Broader User Community

The Institute for Technology Development—a nonprofit organization established to facilitate hyperspectral application development for industrial and public service usage in areas of earth resources, forensics, and biomedical applications of remote sensing—has developed partnerships with the National Corn Growers Association, the National Cotton Council, the United Soybean Board, and the National Association of Wheat Growers. These partnerships define the transfer of NASA remotely sensed information to the targeted commodity groups.

The Yellowstone Ecological Research Center, another nonprofit organization, has been funded to develop remotely sensed data products to assist in regional conservation efforts, river management, and land use management in the Great Yellowstone region.

A program that has received periodic attention from NASA Earth Science and Space Grant has been the establishment of the Geospatial Extension Specialist (GES) Program as part of Cooperative Extension in the Land Grant University system (http://www.geospatialextension.org/). It began in 2000 with 3 state pilot projects (Arizona, Mississippi, Utah) and has grown since to 14 states without continuing NASA support and only sporadic attention (some with Space Grant, some that have partnered with USDA). In the initial model, NASA offered 3 years of support with the understanding that, at the end of that period, a tenure-track extension position would be created to sustain the program (different models have been used in different states). Recently, some interest in the GES Program has resurfaced in ASP, and discussions between NASA, NOAA, USDA and USGS have occurred over the past year to look into the program and potentially move it forward again in a more substantive way (see also Box 5.3).

Similar examples can be found in the air quality and weather forecasting applications. Sonoma Technology Inc. and Baron Advanced Meteorological Systems (BAMS) have been active in using NASA's satellite data on optical density to provide air quality products to state and local governments and to industrial clients. BAMS has also developed weather forecasting products that are being used by local government for disaster planning associated with storms along the coastline of North Carolina.

BOX 4.2
Technology Transfer to the Private Sector Without ASP Involvement

NASA's Goddard Space Flight Center and Jet Propulsion Laboratory (JPL) have developed prototypes of LIght Detection and Ranging (lidar) and InterFerometric Synthetic Aperture Radar (IFSAR) technology with the goal of technology transfer to the private sector. EarthData Inc. uses the IFSAR technology (renamed GEOSAR) developed in conjunction with JPL (see *http://www.earthdata.com/.*). NASA's Solid Earth Program in the Earth Science Division was involved in the IFSAR and lidar work and has successfully engaged the private sector on technology development and transfer of differential GPS and the International GPS Service.
SOURCE: John LaBrecque, personal communication (2006).

There are opportunities for ASP to engage the broader community. Many of the federal agencies have strong ties with academia, the private sector, and the tribal nations. Some academic institutions prefer joint NASA and other federal agency cooperative institute personnel to be located on campus for effective engagement. One clear example of a successful engagement activity is the Environmental Protection Agency (EPA) and its relationships with state and regional agencies on air quality, water management, and public health. Other agencies or entities in the agencies that have strong ties with members of the broader community include the National Weather Service (NWS) and the Departments of Agriculture, Transportation, and Energy. There are however, sometimes barriers to such agencies' engaging the broader community. For example, EPA is a regulatory agency, which by law must keep an appropriate distance from those they regulate. The difficulty is that many regulated organizations are important members of the broader community. In addition, agencies that are not in the regulatory business have their own interests to protect and it is not always best from their perspective to reach out more than they are specifically required to do. They, too, are competing for funds, research, and recognition, and agencies tend to do what is specifically required. The result is that it is almost impossible to get a good indication of the benefits to society of NASA products, because those in the best position to measure the benefits are at the end of the applications pipeline and are not involved in a major way.

Little direct evidence from the NASA partners documenting their direct engagement of the broader community suggests that what is left to assess is how well ASP packages NASA products for their partners to apply, implement, and distribute to society. Of course, this is more of an activity of the application teams (made up of NASA and partner personnel), which further complicates any assessment of ASP's explicit performance. However, at a qualitative level the achievements of ASP's program elements and focus areas cut across an impressive list of applications for the betterment of society. There is no doubt that considerable analysis and innovation have gone into the selection of projects.

A review of NASA documents reveals many references to ASP projects that benefit society. For example, consider the DSS for the program element, Agricultural Efficiencies. NASA indicates that data emerging from this program element serve not only the federal government but also a large community of other users, such as commodity trading companies, farmers, relief agencies, and anyone with an interest in global crop production. However, searches for supporting evidence of the engagement process with such members of the broader community as farmers, trading companies, relief agencies, and the many private sector organizations providing products and services to the agricultural community do not produce documentation that can be tied back to direct input and communication with NASA or the ASP (e.g., Russo, 2006). Nevertheless, evaluation of the many precursor activities, such as the nature of the products and the tools of their implementation, can yield some proxy assessment of the degree to which NASA's and ASP's engagement in the process influence the projects' successes in the broader community.

METRICS, DOCUMENTATION, REQUIREMENTS, AND ACCOUNTABILITY

Applied science performance metrics associated with ASP do not seem to exist. The goals and objectives of the program are qualitative—with descriptors such as "improving our understanding" and "expand and accelerate societal benefits." Metrics based on principles that provide both quantitative and qualitative measures can have many benefits, including improved program management, greater accountability to Congress and the public, and a roadmap for interacting with stakeholders. Guidance on a metrics model for ASP to consider is provided in NRC (2005b), a report that examined metrics for the Climate Change Science Program (Chapter 5).

ASP performance evaluations also lack assessments by the beneficiaries of the applied science products, something that could be overcome with a well-designed metrics program that included user feedback and a formal peer-review process. As best can be determined by the committee, ASP managers do the actual performance evaluations. Little evidence was found of any significant engagement of the broader community in this process. On the contrary, the discussions of detailed performance data usually begin with reference to working with federal agency partners, with no mention of any member of the broader community. An example is the following quotation from the 2004 ASP performance and accountability report (*http://aiwg.gsfc.nasa.gov/esappdocs/PAR_ESA_FY04.pdf*; p. 1):

> By working with Federal agency partners, NASA improves essential public services like tracking hurricanes, assessing crop health and productivity, evaluating forest fire risks, ensuring aviation safety, improving energy forecasts, and determining the potential for the climate-driven spread of infectious disease. NASA's Earth observing systems and Earth science models advance researchers' ability to understand and protect Earth, its resources, and its diverse and precious life.

These are important activities with far-reaching potential; however, the performance and accountability reports provide little documentation on which to assess the extent of engagement of the broader community. On occasion there is reference in NASA's reports to involving and benefiting the private sector, but little actual performance information is presented.

NASA takes the position that their partners, the federal agencies and national organizations employ their directives and networks to engage such members of the broader community as local governments (state, county, city) and the private sector. As previously noted (Chapter 3), examples of partner agencies that have a legacy of strong ties with members of the broader community are EPA, USDA, and NOAA, the latter especially through the NWS. EPA has relationships with state and regional agencies on air quality, water management, and public health. NASA indicates that EPA works with such organizations on tools to support their activities. What is missing is direct evidence from organizations like the state and regional agencies, and the private organizations supporting them, about the benefits they derive from NASA products.

There are no formal or quantitative procedures, standards, or methods for measuring federal agency use of NASA data, much less their use by members of the broader community. ASP has in the past taken the position that the partners and others must take the initiative to make outcomes to improve decision support. As ASP writes, "The outcomes and impacts largely lie with our partner organizations." ASP indicates that they are constrained on such activities by "personnel commitments" and time management.

Progress and activity reports are provided by funding recipients at weekly, monthly, annual intervals and constitute ASP's only documentation of its products. Some broader community exposure is provided through published journal articles and special conferences and presentations where benchmarks, benchmark reports, and other ASP products are referenced and are part of the source material. The benchmark reports are considered the best source of information on the quality of the decision-support capabilities. A major activity of the benchmarking is that of the ASP applications teams' development of proper documentation of procedures and guidelines to describe the steps to access and assimilate the Earth science observations and products. Assessment of socioeconomic benefits is generally left to the partners to conduct informally.

In the absence of direct feedback from users and beneficiaries (society in general) of ASP products, the benchmark reports are probably the best metric for assessing programmatic benefits to society. This is because the benchmark reports are intended to measure the performance of a product "according to specified standards and reference points." Based on the 2005 ASP Annual Report, three benchmark reports were published among the 12 Applications of National Priority (NASA, 2005). Two of the reports were by the Air Quality application team and one by the Water Management application team. An additional nine reports were published in 2006 (in Agricultural Efficiency [1], Aviation [3], Disaster Management [4], and Invasive Species [1]). The committee did not see an integrated and comprehensive review of the disposition of the benchmark reports in terms of their effectiveness in engaging the broader community and obtaining feedback from the beneficiaries of NASA products (Chapter 2). A question as to the validity of the benchmarking process also arises, given that little to no input from the end users of the NASA products is incorporated in them. In many cases the end users will be those in the private sector who are often in the best position to apply the test of practicality to technological products. The private sector and local governments have extensive and direct involvement with the true beneficiaries of the NASA products, namely the public at large.

It is clear that interactions with the broader community are left up to the partner agencies and national organizations. This arrangement often provides little impetus for the partners to engage members of the broader community since partners generally have their own research and operations priorities. Since government agencies, including NASA, respond best to specific requirements, it would seem that having the broader community receive benefit from partnering with NASA through ASP will require the establishment of new program requirements and perhaps legislative action. The issue of the benefits to society of government research activities extends beyond NASA, and legislation that addresses this issue for NASA should be directed at government research in general.

The performance and accountability evaluation process of ASP appears to be more promotional than a clinical and critical process of quantifying performance on the basis of feedback from the user groups. The committee could find little to no evidence of input from the broader community on the evaluation of the societal benefits of ASP's work, thereby limiting the credibility of any such assessment. The most meaningful measure of performance in the name of benefiting society comes from the beneficiaries of the services and products provided.

INVOLVEMENT OF THE BROADER COMMUNITY IN APPLICATIONS OF NATIONAL PRIORITY

The Applied Sciences Program defined 12 Applications of National Priority to focus the partnerships implemented primarily with federal agencies (Table 2.1). The initial community workshops that NASA conducted in the late 1990s to discuss the priority areas (see also Chapter 2) were explicitly intended to gather general requirements from state, local, and tribal governments. The private sector and academia were involved as resources, to help explain what was available to these governments. Since then, the influence of these nonfederal groups has been largely absent and ASP's strategic planning process does not match outcomes and impacts with specific community goals making efficient prioritization of its activities and resources difficult. The partnerships, have been focused, controlled, and largely kept within the federal government.

ASP has identified several societal benefits across the 12 application areas: data and decision-support tools that supported the September 11 recovery operations, Hurricane Andrew, the Montana wildfires, location of lost aircraft, and flood recovery activities along the Mississippi River. They are proud that NASA data (from the Tropical Rainfall Measuring Mission) have shortened warning time for tropical depressions and hurricanes and thus put the process of emergency evacuations on a much more scientific basis. NASA indicates that ASP funding to enhance DSS has resulted in hundreds of millions of dollars saved as a result of much improved El Niño forecasts. An impact of great national significance is the improvement in weather forecasting, in general, as a result of implementing NASA products. The questions are whether the present paradigm of the ASP has an adequate cost-benefit ratio, and whether opportunities for improvement can be identified.

Of the 14 federal agencies involved in ASP partnerships, USDA, USGS, EPA, and NOAA dominate. Drawing in part from the FY 2005 annual report (NASA, 2005) as well as from the NASA Applications Implementation Working Group website (*http://aiwg.gsfc.nasa.gov/*) and testimony presented to the committee, the most active programs in terms of publications and conferences appear to be Agricultural Efficiency, Air Quality, Ecological Forecasting, and Public Health. In terms of available benchmark reports, Agricultural Efficiency, Air Quality, and Water Management have the lead. Lagging in benchmarking activity are the application areas of Disaster Management, Public Health, and Water Management. The Agricultural Efficiency Program element is one of the strongest application programs, with Air Quality, Disaster Management, Public Health, and Water Management having considerable potential. These elements are also active at the international level. The trade-offs ASP might have to consider as a result of an international versus domestic emphasis are difficult to assess. The program elements Energy Management, Carbon Management, and Homeland Security do not appear as strong in their activities as the other programs at this time.

Disaster Management is an ideal program element for involving many sectors of the broader community, such as local government organizations (the first responders), the private sector (the owner of most physical assets), the service industry (operators of our infrastructure), and the engineering and construction industries (the designers, constructors, and recovery organizations). The committee could not find any direct involvement of first responders (local organizations) and infrastructure providers. Incorporating some of these broader community user groups might allow ASP to realize the potential of this application area more quickly and directly.

Ecological Forecasting is another program element where the committee found little evidence for an integrated approach to account for community and public interests. Realistic ecological forecasting is best done by spanning political jurisdictions and defining geographical boundaries based on scientific knowledge. Policy decisions must balance community development programs with impact of activities from industries that may include transportation, resource extraction and use, and manufacturing on land, in the ocean, or the atmosphere. In addition to industry and community input, scientific data like that provided by NASA plays a balancing role to weigh various policy options offers another opportunity for ASP to establish direct communication between NASA and these broader community sectors. Establishing the Ecological Forecasting Program element in place of the previous Community Growth Program element is an example of an action that could distance NASA from the broader community. Ecological forecasting without the engagement of local organizations further increases the danger of setting restrictive boundaries on the activity.

Another example of strong interest by the broader community is in Water Management. This is one of the most important issues facing local governments in the western states and in Florida, among others, but the committee again found little evidence of ASP seeking involvement in regional water management or hydrological planning programs.

Most of the ASP program elements involve activities associated with climate and weather. Considering that the NWS has a long tradition of interacting with the private sector, the opportunity exists to establish a framework for partner agencies to engage the broader community, especially the private sector. USDA has a similar long-term relationship with nonfederal agencies and could contribute to such a framework. EPA and DOE also have a legacy of extensive interaction with nonfederal organizations. The opportunity exists to develop a model for the ASP to extend NASA products to nonfederal entities in the private sector.

Overall, the committee did not identify much documentation of direct interaction between NASA and the broader community among the approximately 147 projects that ASP currently has underway. NASA is relying on its federal partners to engage these groups and be the conduit for societal benefits. However, the lack of information about relationships between such federal agency partners and the broader community makes it difficult to carry out a complete benchmarking process to assess societal benefits; this is a missed opportunity to address ASP's mandate to enhance the benefits to society of NASA's science and technology investments.

BENEFITS OF ENGAGING THE BROADER COMMUNITY

Many benefits could be generated for NASA and society through more direct engagement of the broader community with the ASP. These benefits are noted without full knowledge of the current relationships between the NASA partners and members of the broader community; such relationships are not part of the ASP documentation in any definitive form provided to the committee. The benefits to NASA include attempting to increase the applications of their data and research to the benefit of a much larger segment of society (as exemplified by NASA's Solid Earth Program involvement in the development of IFSAR [Box 4.2]). Such an approach could lead to a greatly expanded resource base to facilitate improvements in sensor technologies and innovative applications.

Establishing feedback mechanisms from the broader community to NASA and ASP is critically important to assure higher payoffs for ASP activities. Feedback of this nature would yield broad-based information for guiding engineering and technology development efforts, among others. A DSS is an information system that accumulates input from a variety of sources. The ASP focus on the federal government severely limits the diffusion of NASA products and technologies. Nonfederal entities also need assistance to develop fully benchmarked and developed DSS, while others, especially the competitive private sector, may only want the raw data for applying their own algorithms and models to develop innovative new product lines, a possible major contributor to the process by which NASA products can benefit greater segments of society through applications.

Involving a broader community and deployment of NASA products among nonfederal users could also contribute to better integration of the nation's capabilities, capacity, and infrastructure. Feedback information on data needs and data sharing could contribute extensively not only to guiding technology development but to the integration process as well.

ENGAGING THE BROADER COMMUNITY

An important question is "what is the best path forward for engaging the broader community?" Two factors compromised the committee's assessment of ASP's engagement of the broader community: (1) NASA does not have the lead in the process; (NASA asks partner federal agencies to assume that role), and (2) the partner agency process for engaging members of the broader community is not clearly defined in the ASP documentation. Much more engagement may exist than is apparent in the documentation provided to the committee. Nevertheless, several factors can greatly improve the involvement of non-federal organizations in ASP. One such factor would be to improve the reporting requirements of the partners on user interfaces and the disposition of information. Another factor would be to make greater use of external review groups that can better identify the full range of users and their present and emerging needs.

Every effort will need to be made to choose partners and establish requirements of the partners that clearly integrate the resources of the nation. The integration process needs to be guided by the scope of ASP to avoid engaging community members not in a position to make a significant contribution. Absent from the ASP engagement process (though not absent from applications development in NASA in general) is the private sector which provides leadership in the development of innovative products that benefit society, and therefore needs to be a major force in testing the practicality of NASA's products. The private sector, for example, is extremely interested in disaster management and application of remotely sensed data to these problems, as they own most of the assets under threat. This area could be fruitful ground for ASP to establish new partnerships between NASA and the private sector. Besides the greater direct involvement of the private sector, all ASP partners will need to document and highlight plans of engaging nonfederal organizations in the implementation of NASA products to the benefit of all.

SUMMARY

1. ASP relies primarily on federal agency partners for implementing practical applications of its products and expects these partners to engage the broader community. Socioeconomic benefits of ASP products are primarily assessed by the federal partner agencies.
2. The process by which partner agencies engage the broader community lacks transparency and documentation.

3. Quantitative metrics that connect the research to applications transition of ASP products are lacking.

4. Comprehensive assessments of benefits to society of ASP products that include feedback from beneficiaries are not performed and documentation of implementation processes and practices of applying ASP products compromise third-party evaluations of benefits.

5. Key documentation of DSS in the form of benchmark reports, while effective in providing guidance on the application of DSS, lacks critical input from the end users and especially local governments and the private sector. The benchmark reports do provide a critically important database across many application areas for guiding future applications and the direction of the ASP.

6. Inefficient transition from research to operations of NASA products impairs the consideration of the applications community to commit to use of science products because of a lack of assurance of product continuity.

7. The performance and accountability evaluation process of ASP does not appear to be a clinical and critical process of quantifying performance on the basis of feedback from the user groups. The committee could find little to no evidence of input from the broader community on the evaluation of the societal benefits of ASP's work, thereby limiting the credibility of any such assessment.

5

Achieving the Objectives of NASA'S Applied Sciences Program

This chapter summarizes the committee's findings with respect to three questions. (1) What are users' expectations about the ability of the data and tools provided through NASA's Applied Sciences Program (ASP) to meet their needs? (2) How appropriate is ASP's Integrated Systems Solution Architecture (ISSA) for describing the transition of NASA products to realized societal benefits? (3) Does ASP's strategic planning process need other mechanisms for coordinating and tracking results? These questions tie together ideas put forth in previous chapters.

USER EXPECTATIONS

What are users' expectations about the ability of the data and tools provided through NASA's ASP to meet their needs? While the committee did not assess user needs, it came away with general observations on users' expectations (Chapters 3 and 4, Appendix B). Data needs (including a mechanism to specify new sensor types that provide useful data) were emphasized by users over the need for new modeling or data analysis tools, and very little discussion was presented of any need for new models. Users tend to employ NASA data in their own models to aid in decision support rather than using NASA models. Users appeared to need better access to (1) NASA data to replace existing field data; (2) improved monitoring and prediction capabilities for management, planning, and regulatory compliance; and (3) a mechanism to provide continuity in sensing technologies. Users generally felt no mechanism existed by which to convey their needs on a routine basis.

The committee's findings are summarized for the following areas:

- data continuity;
- geospatial and temporal resolution;
- data quality;
- format interoperability;
- unused data;
- data on physical characteristics of the environment;
- data latency;
- the Applications Implementation Working Group website; and
- benchmark reports.

All findings in this section point to the general need for enhanced user feedback mechanisms and processes for considering user needs.

Data Continuity

The user community is particularly concerned about data continuity. Older satellite systems and instruments, such as Landsat, offer familiarity to users. Landsat has provided continuous global coverage since 1972 and AVHRR since 1979. While the Land Remote Sensing Policy Act of 1992 identifies a privately funded and managed system as the preferred option for a successor to Landsat, commercial data providers indicate that there is an insufficient market to justify the private investment that would be required to fly a commercial Landsat-like system. Users are reluctant to build practical applications based on NASA remote sensing data streams that may not exist in the near future or that are considered experimental. Operationally it is difficult to take data from Landsat and substitute that for other data and get equivalent results. Because the licensing provisions for commercial companies restrict sharing of information in its original form with other users, commercial vendors are reluctant to build software that will accommodate new instruments that are considered experimental. The issue of continuity transcends the Landsat and AVHRR datasets in that commercial applications depend on reliable data delivery over the long term. If a dataset is not available at a crucial time or is not scheduled for operational delivery, the cost of developing products for these research-level data products is not justified economically.

Geospatial and Temporal Resolution

Numerous user groups indicate that they need data with a spatial resolution better than that offered by Landsat-7 ETM+ (NASA's highest-resolution platforms) to conduct their day-to-day local and regional work (e.g., Barnard, 2006; NSGIC, 2006; Walthall, 2006; Worthy, 2006). Many users said that in order to support their day-to-day remote management and regulatory decisions they need data with spatial resolution higher than 10 meters. However, NASA appears to have decided not to develop measurements smaller than 10 meters, stating that the commercial sector should provide data at this scale. Review of this practice may be necessary if government, in particular, is to be more cost-effective in its data collection efforts and avoid overlap. Where NASA's role in serving the national need for higher-resolution data has been restricted by reluctance to launch the necessary sensors, other federal agencies have partnered with the National States Geographic Information Council to cover this critical need (Box 5.1), although this agency coordination is not a solution to provide frequent, synoptic national or global coverage as is required for many national needs.

BOX 5.1
Imagery for the Nation

The Imagery for the Nation Project is an example of coordination by federal, state, and local government agencies to meet a need for high-resolution digital imagery for a wide range of applications, including natural resource management, agriculture, land use planning, and homeland security. The National States Geographic Information Council (NSGIC) developed the concept for Imagery for the Nation in 2004 and proposed it to the Federal Geographic Data Committee (FGDC) and National Orthophoto Program Committee (NOPC) in 2005. The project will collect and disseminate standardized nationwide aerial color imagery products at 1-meter, 1-foot, and 6-inch spatial resolutions with repeat imagery every one to five years depending on location, population density, and image resolution. The imagery acquired through this project will remain in the public domain and will be archived to ensure its availability for posterity.

No federal funds have been committed to this project but funds have been requested for FY 2009. The projected cost is $111 million per year for the first three years, with a projected cost saving of 25 percent over current, less coordinated data purchases by individual federal, state, and local agencies. Both the U.S. Department of Agriculture and U.S. Geological Survey (USGS) support the concept; if implemented, USGS would manage the program.

SOURCE: *Http://www.nsgic.org/hottopics/iftn/imagery_forthe_nation.pdf* and *Http://www.nsgic.org/hottopics/iftn/briefing_document.pdf*.

Data Quality

NASA data quality was considered excellent by users with whom the committee interacted. In addition, users felt that validation and verification of accuracy and geographic and temporal adjustment were adequate. ASP is concerned about the loss of the scientific integrity of the data and models when a partnering agency assumes responsibility for continued operations without continuing support by ASP. Partnering agencies are concerned that NASA does not provide products of appropriate resolution or format to satisfy their needs and apparently has no mechanism to address these requirements. The National Oceanic and Atmospheric Administration (NOAA) stated, for example, that many NASA global products are reprocessed internally by NOAA to meet spatial, temporal, and format requirements of the National Ocean Service. In some cases NOAA uses NASA global products at existing spatial and temporal scales, although not optimal for NOAA needs, by reformatting data. There appears to be no means for ASP to ensure the integrity of products once responsibility is assumed by a partnering agency, in spite of NOAA having a long history of cooperation with NASA. Concerns over data integrity could be alleviated, in part, if NASA were to provide data at a resolution and in a format needed by end users. Developing feedback mechanisms as outlined in this report might also contribute toward NASA and ASP being more confident that data integrity is maintained after the data have been adopted and incorporated in partners' operations.

Format Interoperability

Progress to provide data in formats that enhance interoperability does not proceed at a speed that many users would prefer. The large size of data holdings for NASA products exacerbates the formatting problem. Achieving a balance between maintaining these large global data products and the needs of local users is challenging, and has not been resolved. NASA's data products can be accessed through eight government Distributed Active Archive Centers (DAAC). The DAACs process, archive, document, and distribute data from Earth Observation System (EOS) satellites and measurement programs. The DAACs tend to distribute products in hierarchical data format (HDF) while the modeling and GIS community tend to use other formats. To convert the files can be tedious and time consuming. Many users indicated that they would like to have NASA data in a format that enhances interoperability with their other non-NASA information products and software.

Unused Data

Large quantities of potentially useful data may go unanalyzed. Causes of this lack of analysis may be related to funding, to the fact that the applications community may not yet have learned how to use the data, or to concerns on the part of the applications community about lack of continuity. In other cases the operational agency's (or other users') requirements may be at odds with NASA's research priorities, or limitations on spatial resolution of NASA instruments may preclude data use. Of data produced by NASA's 17 Earth observing satellites, only those from two satellites—Landsat and Moderate Resolution Imaging Spectroradiometer (MODIS)—are in high demand by the user community. In a recent round of proposals received by ASP 80 percent proposed using MODIS data (Birk, 2006).

Data on Physical Characteristics of the Environment

Among NASA sensors the committee found a range of measurement capabilities for determining physical characteristics of the environment. Remote sensing of land surface and atmospheric characteristics are the most advanced (for example, vegetation condition, fire fuels, pollutant concentrations, weather forecasts). Less advanced are capabilities for measuring coastal and subsurface characteristics (for example, water quantity and quality, levee integrity, and fisheries; Roffer [2006]). Ample opportunity seems to exist for development of new sensors and for applications research to respond to these and other potential markets.

Data Latency

Time lags between data acquisition and processing into products and delivery to users were cited as a problem for some users, particularly in the commercial weather forecasting community. It was unclear which efforts were being considered to speed the transfer of data to the ground-based processing centers. Responsibility to rectify this situation does not rest solely with NASA but may also involve other partners like NOAA.

Applications Implementation Working Group Website

ASP managers stated that the main way users learn about NASA data and tools is by visiting the Applications Implementation Working Group

(AIWG) website. However, committee members and other users found the site confusing and needed NASA staff assistance to find the data they needed. The ASP, through the Geosciences Interoperability Office, is developing the Earth Science Gateway, which is supposed to enable better access to and use of Earth observations and model products. It is currently in beta test phase. Further development of this approach may allow data and visualization tools to be made available through open-standard protocols.

Benchmark Reports

The NASA Research, Education, and Application Solutions Network (REASoN) and Research Opportunities in Space and Earth Sciences (ROSES) research programs funded by ASP are starting to produce benchmark reports. These reports are reviewed by ASP personnel but receive little outside peer review. To date, NASA and ASP have not used a transparent review of the disposition of the few existing benchmark reports in terms of their effectiveness in engaging the broader community. After more benchmark reports are released it would be useful to obtain feedback from the beneficiaries of the NASA products.

NASA'S INTEGRATED SYSTEMS SOLUTION ARCHITECTURE

How appropriate is the ISSA (Figure 2.2) for describing the transitioning of NASA products to realized societal benefits? This architecture characterizes an integrated system that connects basic scientific observations through a number of intermediary analytic steps to outputs directly relevant to decision makers. In this framework, Earth observations are inputs to models that simulate the dynamic processes of Earth. These models produce outputs that predict and forecast to inform decision-support tools, typically computer models assess events (e.g., forest fires, hurricanes), relationships among environmental conditions and other scientific metrics (e.g., epidemiological data), or resource availability. Outcomes are decisions about policy or management issues like food supply or natural disasters.

Many of the outputs are not being used by the intended users. These models are typically developed by software engineers based on what they think the end user wants. An opportunity exists for ASP to bring together software engineers and end users to ensure that what NASA is developing assists the users in making their decisions. Two-way dialogue ought to be incorporated in this process (see Boxes 5.2, 5.3, 5.4).

BOX 5.2
Avoiding the Risk of One-time Experiments

The Decadal Study (NRC, 2007a, p. 141) stated that "unless there is sustained institutional support for interactions between the scientific producers and the applications users of information, there is a risk that even successful examples of Earth science applications become "one-off" experiments that are not repeated over time. Of the examples identified in the previous section [of NRC, 2007a], for example, only those involving weather forecasting had institutional mechanisms designed specifically to foster such two-way interactions. In the other cases, the two-way interactions occurred early in program development through the activities of principal investigators, but there is no clear institutional mechanism to ensure that improvements in observations, methods, or changing needs can propagate through the systems. In sum, to be successful, the use of Earth science data for applications of benefit to society will require research as well as data. Such research will improve our understanding of successful transitions from research data to societal applications, processes of information adoption and use outside the scientific community, and decision-making under uncertainty. It will also require sustained communications with potential users of scientific information."

Program managers can be particularly effective in connecting the main functions of the systems architecture and providing iterative dialogue. In this way, ASP managers serve an important function in understanding and documenting whether all the pieces in the chain leading from inputs to societal benefits exist, whether they are adequately connected, how various organizations at the federal, state, and local levels fit into that system, and who will manage the flow and how. ASP indicated early in this study that their official responsibility was for the left-hand side of Figure 2.2, and that they had little official influence over what occurred on the right-hand side (once the products had been transferred to their partners). ASP's ISSA is not adequate in its present form to effectively transfer from research to applications to the benefit of end users. Much of the approach appeared too linear and unidirectional, where basic research was converted into societal benefits without user feedback. Making the transition from research to societal benefits requires explicit identification of which outcomes and impacts are needed so that activities and resources can be targeted accordingly—a function that the feedback loop will enhance.

BOX 5.3
Forging Stronger Connections to User Requirements

ASP's process may ideally be conceived as including the feedback loop in the research-to-operations transition that bridges the "valley of death" (NRC, 2003) by providing clear channels for agencies to transmit requirements to NASA. USDA sought but could not find such channels. In addition, there are no clear links between ASP and some of the major observing programs (e.g., Oak Ridge Isochronous Observation Network [ORION], National Ecological Observatory Network [NEON], Integrated Ocean Observing System [IOOS]). There is no systematic mechanism for NASA to assess or learn of user needs, including those of the federal agencies.

The following examples illustrate opportunities and models that ASP could follow to forge stronger connections to users and their requirements.

1. There are operational requirements laid out in the various presidential directives issued over the past five years (e.g., U.S. Ocean Action Plan, Climate Change, Exploration) that can be mined. For example, the U.S. Office of Science and Technology Policy/National Space and Technology Council has initiated a long-term process to define an Ocean Research Priorities Plan.

2. Formal structures have been set up to link management and operations with research and education (e.g., the SIMOR Committee of the White House's Committee on Ocean Policy). ASP could represent NASA in this structure.

3. The infrastructure and regional contacts developed over the years by the Space Grant Consortium and the Geospatial Extension Specialist Program (see also Chapter 4) could be used to implement an outreach and extension program similar to that of NOAA's Sea Grant Program and Climate Science Applications Extension Program (see http://cals.arizona.edu/climate/). These types of grant programs could be linked as additional elements of the research-to-operations feedback mechanism serving NASA, NOAA, and other entities.

4. The longtime partnership between the National Weather Service (NWS) and the private sector, which results in both general and tailored weather forecast and warning products that are widely acknowledged as valuable, is a good model upon which to build the user feedback loop. NWS and commercial meteorological products have applications ranging from scientific research to human safety, transportation, agriculture, and daily forecasts.

5. New findings and research results from NASA's basic Earth science research (core funding) are potential candidates for applied remote sensing science. There are currently no formal links between basic Earth science research and ASP through which results obtained during the basic remote sensing science initiatives are communicated to ASP.

BOX 5.4
Developing and Implementing Applications at the U.S. Naval Meteorology and Oceanography Center

The U.S. Naval Meteorology and Oceanography Center (METOC) has developed an effective approach to developing and implementing applications. The model used by METOC involves two major steps.

1. A rigorous process to identify requirements that includes
   - Formal engagement of all stakeholders to obtain input;
   - Establishing a process for feedback and product/application review; and
   - Metrics.
2. A production system organized by capabilities that includes
   - Data acquisition;
   - Aggregation of similar data types into specific products;
   - Fusion of dissimilar but complementary data, which can be "overlaid" onto a four-dimensional model (space/time) after georeferencing;
   - An efficient distribution system that delivers the right product, to the right customer, at the right time, regardless of their location; and
   - A customer service program (help, technical documents, literature, discussion forums).

STRATEGIC PLANNING

Does the strategic planning process need other mechanisms for coordinating and tracking results? ASP's strategic planning process does not include explicit identification of which outcomes and impacts it wants to achieve with which audiences, making effective targeting of activities and resources more difficult. The strategic plan of ASP is a broad document with many goals, not all of which are clear, accompanied by practical steps for implementation.

The committee found that metrics are not currently being collected by ASP to gauge progress toward achieving their goals. Some useful metrics to employ for this purpose would be those that measure the outcomes and impacts actually achieved by NASA products as reported by NASA partners. One of the more difficult problems for ASP would be setting priorities among the 12 application areas in the absence of an overarching national strategy on environmental issues.

Metrics need to assess the process as well as progress in the transition of research to practical applications and demonstration of societal benefit. "Process" refers to the level of planning, type of leadership, availability of resources, and accessibility of information. Metrics used by ASP are currently focused almost exclusively on quantitative measures of website usage and very little on adoption of benchmark reports (Chapter 2).

Performance measures are currently lacking to demonstrate that ASP's decision-support tools are helping decision makers make better choices. Incentive structures enacted by the Government Performance Review Act (GPRA) of 1993 and related policies put into place by the Office of Management and Budget require federal agencies to set strategic goals and to measure program performance against those goals. These policies tend to emphasize, rather than deter, disconnections between outputs and outcomes. GPRA's Program Assessment Rating Tool (PART) evaluations apply only to individual federal agencies. The Act does not apply to multiagency programs such as the Climate Change Science Program (CCSP) to which NASA outputs contribute. This relinquishing of control over achievement of goals in multiagency collaborative efforts is a significant deterrent to collaboration. The NRC report, Thinking Strategically, addresses this explicitly (NRC, 2005b).

Some of ASP's output contributes to interagency activities such as the CCSP. A study of the appropriate use of metrics for the CCSP (NRC, 2005b) recommended a general set of metrics that this committee believes would be useful for ASP to consider as it prioritizes the outcomes and impacts it most wants to achieve:

- Process metrics (measure a course of action taken to achieve a goal);
- Input metrics (measure tangible quantities put into a process to achieve a goal);
- Output metrics (measure the products and services delivered);
- Outcome metrics (measure results that stem from use of the outputs and influence stakeholders outside the program); and
- Impact metrics (measure the long-term societal, economic, or environmental consequences of an outcome).

These performance measures comprise both qualitative (e.g., productivity, research quality, relevance of research to the agency's mission, leadership) and quantitative measures.

Methods for gaining feedback from academics and the user community come almost exclusively from the external peer review of ASP proposals. Review of completed projects takes place exclusively by internal review. The present system has no end-user review of projects. The committee looked for use of other methods through which ASP might have gained information and feedback, but found little evidence that any had been employed. These other methods were:

- *Workshops* for potential users to disseminate the lessons learned from their projects.
- An *advisory committee* with representatives from multiple government levels and the private sector to monitor the program. Such a committee could consult with the interagency committees and industry representatives and organizations.
- *Competitive solicitations* that take a more user-inspired basic research approach as defined together with the user community.
- *Collaborative, user-driven dialogue* to identify what information users need to address a problem, what NASA can offer, and how the needs and possible responses to those needs might converge. The user may leave with a different understanding of what they need and NASA may come to a different understanding of what to offer or how products could be offered.

Such methods would lead to more relevant data streams and research results that would more likely be used. In addition, these methods would improve perceptions of the legitimacy of the process and credibility of the knowledge it produces, given the increased transparency and openness that user engagement requires (NRC, 2006).

The science produced by NASA will be more useful and effective if its products are designed so that they are perceived by multiple stakeholders to be credible, salient, and legitimate. The process for gaining feedback needs to be perceived not only as scientifically credible but also salient to users' concerns and generated through legitimate means. These properties increase the likelihood of ultimate effectiveness. Because different stakeholders will have different standards, a central challenge is the task of getting multiple key actors all to see that a product meets their individual, particular salience, credibility, and legitimacy criteria (NRC, 2007c; Mitchell et al., 2006; Cash et al., 2003)

SUMMARY

1. NASA works from the basis that Earth observation data and tools are intended for scientific research. However, consideration of how additional benefits might accrue from Earth science data products is critical in informing public understanding of investment in these services.

2. For applications the consistency of the information stream can outweigh the gain in information provided by a new research development. Thus, advances in technology for applications or models will need to be significant improvements to overcome the cost of making the transition

to a new product. If the information delivery is erratic or not available when required, the utility of the advanced product will lose its value and will not be incorporated into the application area.

3. The process between the development of model results and other decision-support tools is what matters if expected benefits are to be realized by the end user. Considerably more effort is needed to improve the understanding of all parties involved in the process. This includes the communication between the research community and the ultimate users of the information. A revised strategy that incorporates a feedback mechanism and engages regional, local, and private users as well as other federal agencies is needed if ASP is to better realize the societal benefits resulting from its data and tools. A fundamental issue is the transfer from a research asset to an operational one that provides long-term, consistent information that is useful to a user community. The current structure does not guarantee transition from research to operations. It assumes that once research results have been demonstrated as useful in a benchmark report, a plan will be developed by someone else to transfer the capacity to an operational configuration to serve on a routine basis.

4. A strong need exists for ASP to reach out to users to get a complete understanding of the requirements process. Currently, numerous agencies at multiple levels of government are collecting similar data at different spatial and temporal resolutions while others process the data internally in duplicative fashion, and not always in a validated, scientific manner. Such an approach is neither efficient nor cost-effective. Better access to data to replace existing field data collection methods and to improve monitoring and prediction capabilities for management, planning, and regulatory compliance is also needed. The committee heard little about the need by users for different tools, particularly models, provided by NASA. Furthermore, no formal mechanism exists for agencies or other users to provide specifications or needs to NASA to develop new sensing technologies.

5. ASP's strategic planning process does not incorporate explicit identification of what outcomes and impacts it most wants to achieve, with which audiences—making efficient prioritization of its activities and resources difficult.

6. No clear links appear to exist between ASP and some of the major observing programs, for example, Oak Ridge Isochronous Observation Network (ORION), National Ecological Observatory Network (NEON), and Integrated Ocean Observing System (IOOS).

7. Program managers can be particularly effective in connecting the Earth Science Framework, including providing iterative dialogues. To do so, it is important for ASP managers to understand and document whether all the links in the chain from inputs to impacts exist, whether they are adequately connected, how various organizations at the federal, state, and local levels fit into that system, and who will manage the flow and how.

8. ASP's strategic planning process does not include explicit identification of what outcomes and impacts it most wants to achieve with which audiences, making efficient prioritization of its activities and resources difficult to do. Setting priorities among the 12 applications areas in the absence of an overarching national strategy on environmental issues or a formal mechanism for collaboration across the agencies would be a critical problem.

6

Conclusions and Recommendations

The committee's assignment was to assess the strengths and weaknesses of the approach used by NASA's Applied Science Program (ASP) to promote the use of NASA data and research in decision-support systems (DSS) for the land, ocean, and atmosphere that yield benefits to society. As part of its assessment the committee examined ASP's partnerships and community engagement, the processes used to extend research results to partners with decision-support functions, and the means to measure and ensure success in these partnerships and transfers. In its examination of ASP the committee found an energetic, structured, and enterprising program involved in complex and changing circumstances related to the emerging U.S. government commitment to realize societal benefits from Earth observing systems (for example, *Strategic Plan for the U.S. Integrated Earth Observation System,* CENR/IWGEO [2005]). The ASP, using the organizational system it adopted in 2001, has had some accomplishments and communicates strong commitment to NASA product transfer and decision support; but the program has several challenges to overcome, both within and outside NASA, before it can become more effective in its role.

The committee views ASP as a key asset for fulfilling the national commitment to societal benefits. The systems engineering approach adopted in 2001 provides a framework in which to operate, but the program's potential can be enhanced significantly through adoption of a number of steps. Some of these steps can be taken by ASP itself, but some depend additionally on cooperative actions taken by NASA more broadly, as well as by others whose policies determine missions and constraints for NASA. The committee outlines the main components of these suggested steps through the conclusions and recommendations that follow. The committee supports the key elements of the Decadal Study

(NRC, 2007a) regarding broader NASA approaches to DSS (as outlined in Chapter 1 of this report) but does not repeat those here.

CONCLUSIONS

CONCLUSION 1: Applications of NASA's data and research to societal benefits have historically been limited by questions about NASA's mission and role, and have lacked sustained commitments and program stability.

Historical limitations have included variations in (1) emphasis on NASA's responsibilities for Earth system programs versus space programs, and (2) NASA's responsibilities for delivering benefits versus delivering data and models for others to use in the delivery of benefits. Mandated changes in these roles over time, in addition to perceived interpretations of these roles by NASA, have made ASP's bridging role between NASA and the user community difficult to implement.

The relatively long time periods required to deliver significant societal benefits through applications of NASA's Earth observations and research depend on consistent interest and support from the top levels of the agency and integration with the wider range of NASA programs. Because of the long-term nature of NASA's activities, NASA's successful engagement in extending research to operations also requires policy continuity that is supported by Congress.

CONCLUSION 2: The current U.S. government-wide emphasis on ensuring societal benefits from Earth observing systems is unprecedented, and presents a special opportunity for NASA to enhance its focus on achieving such benefits. The committee views ASP as a key asset for fulfilling the emerging national commitment to societal benefits.

At no time in the history of efforts to relate space-based observations and Earth system models has so much U.S. government-wide emphasis been placed on assuring societal benefits from observing systems. Notable examples include the strategic plans for the Integrated Earth Observing System (IEOS) Program and the Global Earth Observing System of Systems (GEOSS) Program. Moreover, the Decadal Study (NRC, 2007a) specifically included a panel on applications and societal benefits, recognizing the importance of these issues in the coming decade. Much of this kind of emphasis has emerged in the last 10 years, creating a time when special opportunities exist for innovative thinking and program refinement.

CONCLUSION 3: NASA does not involve ASP in the initial stages of mission planning in cases when societal benefits are anticipated.

ASP's current role is focused on increasing the use by other agencies of NASA products from Earth-observing satellites already in orbit. Including ASP as a participant in the initial stages of mission planning and selection would enhance the program's ability to perform its central role in advancing and improving NASA's cooperation with users.

CONCLUSION 4: ASP has an opportunity to contribute toward improving the structures that extend research to operations across the federal government.

This potential role for ASP is more comprehensive than serving merely as a mechanism to move NASA products outward. ASP's networks with partner agencies could enable it to serve as a conduit for information from partners about their operational needs and research programs, offering potential to improve the value and relevance of NASA's research contributions to those operations.

ASP exhibits and communicates a commitment to product transfer and decision support on behalf of NASA. The program displays a strong drive to provide information about research products and to relate those products to decision-support frameworks. This commitment, energy, and momentum offer significant potential for further impact.

CONCLUSION 5: ASP has contributed to notable successes in encouraging and facilitating uses of NASA's data and research for societal benefits.

ASP's contributions to successes in encouraging and facilitating uses of NASA's data for societal benefits include (1) improved warning, monitoring, and recovery support from national disasters, such as hurricanes and floods; (2) more timely detection of tropical storms, resulting in much improved evacuation decisions; (3) improved wildfire detection; and (4) improvements in El Niño forecasting for the planning and protection of crops. While these successes are not solely due to ASP's actions—these examples of benefits from NASA programs had their genesis in the basic NASA Research and Analysis program—they do provide a reason to encourage continued and enhanced interaction between NASA and external user communities through a formal program such as ASP.

CONCLUSION 6: ASP's interactions with federal agencies and other potential users of NASA data and research show wide variations in experiences.

Strengthening and improving NASA's partnerships with users involves not only ASP action, but is also dependent upon organizational issues at the partnering agency and variations in the motivation of potential partners to use a formal collaboration with NASA to realize social benefits. A mature level of engagement in partnering with NASA is apparent on the part of the National Oceanographic and Atmospheric Administration (NOAA) and agencies in the Department of Defense which have committed personnel resources to ensure they receive NASA priority support through ASP. Other agencies such as the U.S. Department of Agriculture and the Environmental Protection Agency have generated programs that help focus NASA efforts to solve their problems. Yet others, such as the Department of Homeland Security, a young agency, have a more passive relationship in which they are presently only recipients of NASA data. Even in cases of mature partnerships such as NASA's relationship with NOAA in the area weather research and prediction applications, much room for improvement still exists in the research-to-operations transition process.

CONCLUSION 7: ASP currently does not engage the full range of potential users of NASA products to benefit society. Direct relationships with nonfederal users are notably missing from ASP's portfolio and their absence limits ASP's potential to be responsive to the full base of potential users of NASA products.

The users of NASA products include not only federal agencies but also a broad community of state, tribal, and local governments, the private sector, nongovernmental organizations, and academic researchers. Because these users lie outside the federal system, the present lack of a formal structure that delineates the respective roles of NASA and its nonfederal partners leaves success of eventual partnerships largely to chance. While there are examples of successful development and employment of DSSs by nonfederal entities, the general ad hoc nature of the relationship between ASP and potential nonfederal users of DSSs suggests that maximum benefit is not being obtained.

CONCLUSION 8: The full potential of societal benefits from NASA products will not be realized unless users are involved directly in determining priorities, designing products, and evaluating benefits. ASP also lacks a strong process to guide applications toward achieving societal benefits. ASP will be more effective in its bridging role between NASA and the users if it promotes two-way communication from the mission planning stages through to the incorporation of NASA products in DSS by external partners.

Comprehensive assessments of benefits to society derived from NASA products do not include direct feedback from all the beneficiaries. Specific weaknesses in communications include: 1) documentation of implementation processes and practices that apply NASA products to achieve societal benefits consist largely of third-party evaluations without direct evaluations from the beneficiaries; 2) iterative, multidirectional communications about applications of NASA products also lack input from users and beneficiaries; and 3) current metrics for evaluating program performance do not meet needs for evaluating and assessing societal benefits of NASA products. The situation is not aided by the distribution of ASP's work across a wide variety of application areas with relatively limited resources.

Examination of the research-to-operations transitions between NASA and users indicated no direct link with the nonfederal research community, and no active, established feedback mechanism from the user community to NASA. Such a mechanism is needed from the initial stages of mission planning to ensure that requirements are considered. A feedback mechanism needs to be sustained, even as sensors and models move to operations, to ensure science-based support, data quality, and a path for developing new and creative management solutions. Structures do not exist for user needs and priorities to be considered in NASA program agenda setting and design, nor for users to convey their data needs to NASA on a routine basis.

RECOMMENDATIONS

Based upon the foregoing conclusions, the committee makes the following set of recommendations:

RECOMMENDATION 1: ASP should be assigned the responsibility within NASA to review and help establish the requirements and guidelines offered in Chapter 5 of the Decadal Study (NRC, 2007a) for effective extension of data and research to applications that meet societal needs. As part of this action, the committee recommends incorporating an ASP representative on NASA mission design and selection teams to aid ASP in increasing the use and impact of NASA products in the user community. This recommendation derives from Conclusions 1, 2, and 3.

Chapter 5 of the Decadal Study (NRC, 2007a) addresses improving the process by which research and applications interact, to the benefit of society. To foster the effective extension of data and research to applications for societal benefits, the chapter outlines the following requirements:

-understanding of the research to applications chain, including societal information needs, conducting research on the uses of information, generating relevant scientific observations with value and benefits recognized in advance, transforming the observations into useful information, and distributing the information in a form that is accessible and meets private and public requirements;

-cultivating broad institutional and organizational capacity amongst potential applications users in public, private, and not-for-profit sectors;

-creating an informed citizenry through education about the application of Earth science data and research to societal benefits;

-defining the research and application goals of a potential measurement, the degree to which existing or proposed measurements support those goals, and developing an optimal implementation strategy;

-developing strong links between the measurements themselves and those who will use the measurements through the entire lifecycle of a mission.

Because the issue of ensuring that NASA's data and research achieve societal benefits falls under ASP's purview, our committee recommends that implementation of the proposed requirements in Chapter 5 of the Decadal Study (NRC, 2007a) should be assigned to ASP. This assignment would give ASP direct involvement and voice in affecting better and more effective communications with its NASA colleagues, and with the external community of active and potential partners. As part of the recommendation, NASA should engage both ASP and the user community in the mission planning and selection process.

RECOMMENDATION 2: **ASP, in collaboration with other parts of NASA, should help to develop a formal plan and structure for effective transitions from research to operations with direct input from the entire range of users and with support from Congress.** This recommendation derives from Conclusions 1, 4, and 8 above.

Many previous NRC studies have identified issues that have prevented greater success in ensuring effective transitions from NASA research to external partner operations. This committee found some of the same issues affecting the success of these transitions in its examination of ASP. ASP's role is to ensure effective transitions of NASA products to operations and applications that result in societal benefits. As such, ASP is positioned to make an impact on making these transitions effective and should be granted the main role in establishing and formalizing plans and structures to affect these transitions between NASA and the range of users of NASA products. The plans and structures for these transitions should be appropriate and applicable both to federal partnerships and to partnerships with members of the broader user community, as determined by input from these groups. In order to make these plans effective across agencies, Congressional support is needed.

RECOMMENDATION 3: ASP should link NASA data and research to users and beneficiaries through communication in both directions, not simply in one direction that disseminates NASA products without user feedback. Communication between ASP and external users should be enhanced, as should ASP's communications with other groups in NASA that conduct research on Earth-based observations. This recommendation derives from Conclusions 3, 4, 6, and 7.

Whether the main partner to extend research to operations is a federal agency or a nonfederal entity, ASP will be more effective if it understands and responds to user needs and perspectives through an established feedback loop. Input from the broad community of users is also necessary to aid ASP in developing plans that ensure users can communicate and partner effectively with NASA. To avoid a unidirectional transfer of NASA products outward to partners for the purpose of achieving societal benefits, ASP should document: 1) whether all the elements in the chain leading from inputs to societal benefits exist, 2) whether the elements are adequately connected, 3) how various organizations at the federal, state, and local levels fit into the chain, and 4) how the flow of communication and information would be managed. In direct communication with the broad spectrum of users, ASP should identify the outcomes and impacts to be realized from application of NASA products so that activities and resources can be targeted accordingly—a formal feedback loop will enhance ASP's ability to communicate effectively.

RECOMMENDATION 4: ASP should develop processes for sustained interactions with a broader base of users and beneficiaries of NASA observations. ASP should assess user benefits of applications of NASA observations, with public comment and user reviews, in order to evaluate levels of importance to society and to inform the development of outcome metrics. ASP should prioritize intended societal benefits from NASA products and focus efforts on high-priority benefits. This recommendation derives from Conclusions 6, 7, and 8.

Engaging the broader community of users in direct dialogue will help ASP to define user needs, communicate these needs to NASA, and assist in defining appropriate metrics to assess the success of eventual partnerships with these users. NASA's prioritization of intended societal benefits from its products would aid ASP in targeting its limited resources to reach the most appropriate user communities.

RECOMMENDATION 5: To ensure the program's success in facilitating effective partnerships between NASA and users of NASA products to generate societal benefits, ASP should

1. **directly engage with a broader community of users—not just federal agencies;**
2. **add rigor to performance metrics;**
3. **evaluate the number and focus of its applications areas;**
4. **improve the transparency and documentation of the process by which a partner agency engages the broader community, including clarification of the partner agency responsibilities in realizing the shared goal of benefits to society; and**
5. **clarify and broaden its policies regarding productive relationships and collaborations with the private sector, including but not limited to remote sensing data products.**

This recommendation derives from Conclusions 5 through 8.

ASP's emphasis on developing federal partnerships for NASA, in effect since 2001 when ASP was established in its current structure, should be expanded to include partnership development with the many potential nonfederal users of NASA products. While similar conceptually to the broad user base with which NASA Applications programs communicated prior to 2001, this committee recommends in these new engagement efforts that ASP expand and build upon its current structured approach, as outlined in the 5 points above, to ensure that users generate effective and innovative applications of NASA data to achieve societal benefits.

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APPENDIXES

A

Committee and Staff Biographies

Thomas J. Wilbanks, *Chair*, is a corporate research fellow at the Oak Ridge National Laboratory and leads the laboratory's Global Change and Developing Country programs. He conducts research and publishes extensively on such issues as sustainable development, energy and environmental policy, responses to global climate change, and the role of geographical scale in all of these regards; he has more than three decades of experience in relating nature-society knowledge to decision support, including federal agency implementation of the Government Performance Results Act. Dr. Wilbanks is a past president of the Association of American Geographers, a member of the Board on Earth Sciences and Resources of the National Research Council, chair of NRC's Committee on Human Dimensions of Global Change, a member of the Panel on Earth Science Applications and Societal Needs of the NRC decadal study of Earth Science and Applications from Space: A Community Assessment and Strategy for the Future, and a member of a current NRC panel on public participation in environmental assessment and decision making. He is also a member of the Scientific Steering Group for the U.S. Carbon Cycle Research Program and is serving as coordinating lead author for the Intergovernmental Panel on Climate Change's Fourth Assessment Report, Working Group II, Chapter 7: Industry, Settlement, and Society. Dr. Wilbanks received his B.A. from Trinity University, and his M.A. and Ph.D. from Syracuse University.

Michael Auerbach, Ph.D., biological science, Florida State University, is executive director and research professor for the Division of Earth and Ecosystem Sciences at the Desert Research Institute. His previous experience in research administration and project supervision includes service as chair of the Department of Biology, University of Charleston (South

Carolina), acting director of the Grice Marine Laboratory (Charleston, South Carolina), and director of the Ecology Program at the National Science Foundation. Dr. Auerbach held a postdoctoral position at Hebrew University, Jerusalem, before joining the Biology Department at the University of North Dakota. His research expertise is in population and community ecology, with a focus on insect and plant interactions, particularly those involving non-native taxa; forecasting ecological change along environmental gradients; and food web stability. Dr. Auerbach's past research has also included examination of the determinants of species richness and biodiversity and patterns of endemism. He received his M.S. in biological science from Florida State University and his B.S. in biology from State University of New York at Stony Brook.

Nancy M. Dickson, M.S. of Regional Planning, Cornell University, is a senior researcher at Harvard University's Kennedy School of Government and codirector of the Sustainability Science Program. Her research addresses the question of how science, technology, and knowledge can be more effectively brought to bear on creating solutions to problems of public policy. Her work focuses on two areas. The first is on knowledge systems for decision support—understanding how the choice of institutions and procedures for linking practitioners and experts influences knowledge production and its effects. The second is on sustainability science, an area encompassing use-inspired fundamental research on interactions between human and environmental systems.

George L. Frederick, M.S., University of Wisconsin, is strategic development manager for Vaisala Wind Profilers in Boulder, Colorado. He began his career in meteorology as a weather officer in the U.S. Air Force after graduating from the Air Force Academy with a B.S. degree in engineering science. He retired as the commander of the Air Weather Service after 30 years in the Air Force. During his military career he planned for the use of unmanned aerial vehicles for weather reconnaissance, developed the roadmap for modernization of the Air Weather Service, and directed planning for weather support for B-2 bombers. He has served as president of the American Meteorological Society (AMS) and the National Weather Association, is an AMS fellow, and has served on the AMS Council and Executive Committee. Awards for his work have included the Bronze Star and the Legion of Merit. Mr. Frederick served as a member of the NRC Committee on NOAA NESDIS Transition from Research to Operations, Committee on Weather Research for Surface Transportation: The Roadway Environment, and as a member of the Board on Atmospheric Sciences and Climate.

B. John Garrick (NAE), Ph.D., engineering and applied science, University of California, Los Angeles, is an independent consultant who currently serves as chairman of the U.S. Nuclear Waste Technical Review Board (presidential appointment). He has an active consulting practice in the development and application of the risk sciences to systems in the nuclear, space, chemical, and marine fields. His research interests include the quantification and importance ranking of risks to humans and the environment to support societal decision making. He has served on numerous NRC committees, the most recent of which are the Committee on Assessment of Options for Extending the Life of the Hubble Space Telescope, Committee on Combating Terrorism, and Committee on End Points for Spent Nuclear Fuel and High-Level Radioactive Waste in Russia and the United States. He received the Society for Risk Analysis Distinguished Achievement Award and was appointed to the U.S. Nuclear Regulatory Commission's Advisory Committee on Nuclear Waste in 1994. Dr. Garrick was elected to the National Academy of Engineering in 1993.

John R. Jensen, Ph.D., University of California at Los Angeles, is a Carolina Distinguished Professor in the Department of Geography at the University of South Carolina. Dr. Jensen has served on the following NRC committees: Steering Committee for the Conference on Remote Sensing and Spatial Information Technologies for Transportation, Committee on the Geographic Foundation for Agenda 21 (chair), and Steering Committee on Space Applications and Commercialization (chair), and Committee on Research Priorities in Geography at the U.S. Geological Survey. He is a member of the NRC Mapping Science Committee.

Thomas L. Mote, Ph.D., geography (climatology), University of Nebraska-Lincoln, is associate professor of geography at the University of Georgia, where he is also director of the Climate Research Laboratory. He previously held a faculty position in the School of Aerospace Sciences at the University of North Dakota. His current work involves development of global databases of seasonal snow cover using blended satellite, modeled and observational sources. He has also been involved in research regarding the hazards of severe weather across the United States. Dr. Mote received his M.A. in geography (climatology) from the University of Nebraska-Lincoln and a B.A. in geography and communication from the University of North Dakota.

Dr. Frank E. Muller-Karger, Ph.D., University of Maryland, is dean of the School of Marine Science and Technology at the University of Massachusetts at Dartmouth. He was a professor of biological oceanography and directed the Institute for Marine Remote Sensing at the College of Marine Science, University of South Florida, in St. Petersburg. Dr. Muller-Karger conducts research on marine primary production using satellite remote sensing, large data sets, networking, and high-speed computing. Dr. Muller-Karger is currently serving on the NRC Ocean Studies Board and as a U.S. representative on the Scientific Committee on Oceanic Research of the International Council for Science.

Dennis Ojima, Ph.D., Colorado State, is the interim director and a senior research scientist in the Natural Resource Ecology Laboratory at Colorado State University. Recent research interests and investigations focus on understanding ecosystem dynamics in relation to Earth system science and the impact of human intervention. Dr. Ojima has served on the following NRC committees: U.S. National Committee on Scientific Committee on Problems of the Environment (SCOPE) and Panel on New Research on Population and the Environment.

Jonathan A. Patz, M.D., Case Western Reserve University, M.P.H., Johns Hopkins University, and medical boards in occupational and environmental medicine, is an associate professor of environmental studies and population health at the University of Wisconsin-Madison. He directs a universitywide initiative on global environmental health. He is an adjunct associate professor in the Department of Environmental Health Sciences at the Johns Hopkins Bloomberg School of Public Health, and also an affiliate scientist of the National Center for Atmospheric Research.

James Rattling Leaf Sr., B.S., environmental science, University of Colorado-Boulder, is the Land and Natural Resource Program director of the Geo-Spatial Applications Center and the Sicangu Policy Institute, Sinte Gleska University, South Dakota. Mr. Rattling Leaf manages a wide area of education, research, and outreach activities that utilize GIS, GPS and remote sensing tools to develop programs designed to increase leadership capabilities and technological consciousness in tribal colleges and universities. Recent grants from NASA Research, Education, Applications Solutions Network and from NASA Goddard, NSF, NOAA, USGS Earth Science and Climate Change Programs have been part of these efforts. Active in establishing partnerships in the Upper Midwest Aerospace Consortium, he has also taken a leading role in establishing a new partnership model between government, industry, and tribal communities, a result of which was the implementation of a Memorandum of Understanding with the USGS.

Andrew R. Solow, Ph.D., Stanford University, is a senior scientist and director of the Marine Policy Center at the Woods Hole Oceanographic Institution. His research is in the area of environmental and ecological statistics. Dr. Solow's most recent participation on NRC committees are the Committee on Evaluation of the Sea Grant Program Review Process, Committee for Review of the U.S. Climate Change Science Program Strategic Plan, and the Committee on Future Needs in Deep Submergence Science.

National Research Council Staff

Elizabeth A. Eide (study director from November 2005 to September 2006 and from August 2007; co-study director from October 2006 to July 2007) is a senior program officer with the Board on Earth Sciences and Resources of the National Academies. Her areas of expertise include geochronology, petrology, and geochemistry applied to crustal processes and regional tectonics. Before joining the Academies, she worked for the Geological Survey of Norway, managing a noble gas geochronology laboratory and administrating personnel, budget and research programs in geology and geophysics. She received her Ph.D. in geology from Stanford University and a B.A. in geology from Franklin and Marshall College.

Paul M. Cutler (co-study director from October 2006 to July 2007) was a senior program officer with the Board on Earth Sciences and Resources of the National Academies. His interests are in surficial processes, hydrology, glaciology, global change, mapping science, and geographical science. Earlier work at the National Academies was with the Polar Research Board and Board on Atmospheric Science and Climate. Before joining the Academies, Dr. Cutler was an assistant scientist and lecturer in geology and geophysics at the University of Wisconsin. He holds a Ph.D. in geology (University of Minnesota), an M.S. in geography (University of Toronto) and a B.S. in geography (Manchester University, England). In addition to postdoctoral work on numerical modeling of the Laurentide and Scandinavian ice sheets, he has carried out fieldwork in Alaska, Antarctica, Arctic Sweden, the Canadian Rockies, the Swiss Alps, and the Karakoram Mountains of Pakistan.

Jared P. Eno (until April 2006) is a senior program assistant with the Board on Earth Science and Resources. Before coming to the National Academies, he interned at Human Rights Watch's Arms Division, working on the 2004 edition of the *Landmine Monitor Report*. Jared received his A.B. in physics from Brown University.

Nicholas D. Rogers (from April 2006) is a senior program assistant with the Board on Earth Sciences and Resources. He received a B.A. in history, with a focus on the history of science and early American history, from Western Connecticut State University in 2004. He began working for the National Academies in 2006 and has primarily supported the Board on Earth Sciences and Resources on Earth resource and geographical science issues.

B

Questions and Requests for Information, NASA Applied Sciences Program

1. As a supplement to the information available on the AIWG site, can a matrix be provided for the 80+ projects in the Applied Science Program (ASP) that shows their relation to the six 'Focus Areas', the twelve 'Applications Areas', the data platform used (MODIS or otherwise), the year started, the year of completion, the benchmark report date (past or projected), and external benchmark publication/citation (if any)? It was mentioned that about 60 of these 80+ projects were competitively awarded. Were the other 20+ all earmarks, or were some NASA initiatives?

2. Can we be provided with the written annual Office of Management and Budget (OMB) requirements to NASA ASP and with the Congressional language that prohibits direct decision support? We are particularly interested in language that sets limits on what ASP is and is not allowed to do (e.g., reporting on measurements below 10 meters due to commercial concerns).

3. What were the ASP evaluation metrics sent to the OMB for each of the past five years?

4. Why were the original seven Application Areas expanded into twelve? What were the seven original?

5. What are the technical definitions of the Applications Areas (NASA ASP specific) and the Focus Areas (NASA-wide)? What are the practical differences and relationships between these two areas in terms of categorizing projects and measuring project progress and success in ASP?

6. How does ASP document adoption, incorporation, implementation, and/or use of benchmark reports (through general public literature (peer reviewed or other), ISI citations, patents, conferences, web site citations, etc.)? Is ASP required to record such evidence?

7. What are the best resources for assessing the benefits of ASP for the broader community, especially the private sector and local governments? Is there information about the most active nonfederal users of NASA/ASP products? Was there an assessment of NASA services to these categories of users before NASA was directed not to undertake direct decision support?

8. Does ASP record website hits for the Earth Science Gateway and AIWG? If so, can we be provided with these hits, sorted by whatever user identifications are possible (preferably by e-mail extension [e.g., .org, .gov, .com, .edu])?

9. Can we be provided with a case study or studies of research-to-operations transition for selected users in agriculture and/or water resources?

10. How have the "Decadal Outcomes of Agencies Use of NASA Data and Information" been measured (found on pp. 38-39 of Earth Science Applications Plan, far right column)?

11) Could you provide us with a list of all funded and non-funded proposals to the ASP over its history (since the inception of the 2001-02 systems engineering structure), with either the proposing organization stated explicitly or a categorization according to federal agency, non-federal government agency, tribal agency, academic organization, private company, and any other category (if confidentiality must be maintained for the non-funded proposals). The AIWG site does a great job listing the active proposals, but the non-funded proposals and those dating back to the early years (funded/non) are not available as far as we've seen.

12) We were told at one time of a 2006 Earth Science Applications Plan (draft)--could you tell us the status of this document and whether or not the committee might be able to see the document or receive a summary of the content/highlights?

13) The memoranda of understanding or of agreement (MOU/MOA) were mentioned fairly often last Thursday. How many such MOU's does ASP have with other agencies--could these be listed according to agency (with which ASP has the MOU) and the time at which they were initiated? Does such an MOU/MOA structure exist for private/non-federal entities (between those entities and ASP)? If ASP has some of these arrangements with non-federal groups, could these also be listed for us?

14) Somewhat related to the above (3), what sort of officially documented governance structures, if any, does ASP have to establish and develop new interactions/partnerships (whether federal or otherwise)?

15) Enterprise Architecture--is ASP actively involved with this?

16) Could a list of the current interagency and cross-disciplinary working groups/arrangements in which ASP is involved be provided to us?

C

Open Meeting Agendas and Study Contributors

Committee on Extending Observations and Research Results to Practical Applications: A Review of NASA's Approach
Board on Earth Sciences and Resources
National Research Council of the National Academies
Keck Center, Room 109
500 Fifth Street, NW
Washington, DC 20001
Meeting, January 26-27, 2006

Day 1 - Thursday, January 26, 2006

08:00-10:00 CLOSED SESSION (Committee and NRC Staff only)

10:00-16:00 OPEN SESSION (Open to public)

10:00-12:00 — *Ron Birk, NASA*
Presentation by and discussion with sponsor: the NASA program and study issues—Extending the benefits of NASA Earth science research results for society

12:00-13:00 *Lunch*

13:00-13:45 — *Brad Doorn, USDA*
Use of NASA data and observations by the USDA

13:45-14:30 *Otis Brown, University of Miami*
Use of NASA data and observations in marine research—applications from MODIS

14:30-14:45 *Break*

14:45-15:30 *John Kappenman, Metatech Corporation*
Use of NASA data and observations in the power industry—modeling electromagnetic storms

15:30-16:00 *Tom Wilbanks, Chair*
Concluding discussion with external speakers

End of open session

16:00-17:30 CLOSED SESSION (Committee and NRC Staff only)

Day 2 – Friday, January 27, 2006

08:00-15:00 CLOSED SESSION (Committee and NRC Staff only)

Committee on Extending Observations and Research Results to Practical Applications: A Review of NASA's Approach
Board on Earth Sciences and Resources
National Research Council of the National Academies
Keck Center, Room 204
500 Fifth Street, NW
Washington, DC 20001
Meeting April 27-28, 2006

Thursday, April 27, 2006

08:00-09:30 CLOSED SESSION (Committee and NRC Staff only)

10:00-15:00 OPEN SESSION (Open to public)

10:15-10:30 — *Jack Kaye,NASA*
Presentation of NASA-NOAA partnership, past and present

10:30-10:45 — *Ron Birk, NASA*
NASA Applied Sciences data and research contributions to NASA-agency partnerships, examples from NASA-NOAA

10:45-11:00 Questions — *Tom Wilbanks, Chair*

11:00-12:30 — *Moderated by George Frederick*
Panel group 1 -- Discussion
Louis Uccellini (NOAA)
Robert Adler (NASA Goddard)
Sethu Raman (North Carolina State University)
J. Marshall Shepherd (University of Georgia)

12:30-13:30 Lunch

13:30-15:15 — *Moderated by B. John Garrick*
Panel group 2 -- Discussion
Brad Colman (NWS)
John Murray (NASA Langley)
Mike Steinberg (AccuWeather)
Mitch Roffer (Roffer's Ocean Fishing Forecasting Service, Inc.)

15:15-15:30 Concluding remarks — *Tom Wilbanks*

15:30-17:00 CLOSED SESSION (Committee and NRC Staff only)

Committee on Extending Observations and Research Results to Practical Applications: A Review of NASA's Approach
Board on Earth Sciences and Resources/Space Studies Board
National Research Council of the National Academies
Keck Center, Room 110
500 Fifth Street, NW
Washington, DC 20001
Meeting, July 13-14, 2006

Day 1 - Thursday, July 13, 2006

08:00-09:00 CLOSED SESSION (Committee and NRC Staff only)

09:00-16:00 OPEN SESSION (Open to public)

09:00-09:10 Welcome and introductions *Tom Wilbanks, Chair*

09:10-12:00 *Moderated by John Jensen*
Federal government users -- Discussion
Chris Barnard (SAIC and DHS, Geospatial management office)
Alexis Lugo-Fernandez (Minerals Management Service)
Diane Powers (NGA)
Charlie Walthall (USDA)
Dorsey Worthy (EPA)

12:00-13:00 Lunch

13:00-16:00 *Moderated by John Garrick*
Non-federal users -- Discussion
Pietro Ceccato (Columbia University)
Gerald Galloway (University of Maryland)
Ricardo Lopez-Torrijos (IAGT and New York Dept. of Environmental Conservation)
Laurie Ames (Nez Perce)
Joseph Russo (ZedX, Inc.)

16:00-16:15 Concluding remarks *Tom Wilbanks*

16:15-17:00 CLOSED SESSION (Committee and NRC Staff only)

Day 2 - Friday, July 14, 2006

08:00-16:00 CLOSED SESSION (Committee and NRC Staff only)

Other contributors to the study

Paul Doraiswamy, USDA Hydrology and Remote Sensing Lab

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Fritz Pollicelli, NASA Goddard

Cynthia Rosenzweig, NASA-Goddard and Columbia Earth Institute; Center for Climate Systems Research; (has had NASA ASP grants)

Ed Sheffner, NASA ASP

Alex Toyahov, retired, NASA

Mark Weltz, USDA Agriculture Research Service, National Program Leader

D

Acronyms and Abbreviations

ACE	Applications, Commercial, Education
ACT	Applied Coherent Technologies
AGRISTARS	Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing
ASP	Applied Sciences Program
AVHRR	advance very high resolution radiometer
CCRI	Climate Change Research Institute
CCSP	Climate Change Science Program
CDC	Center for Disease Control and Prevention
CESAS	Committee on Earth Science and Applications from Space
CLIVAR	Climate Variability and Predictability
CSC	Coastal Services Center
CSCOR	Center for Sponsored Coastal Ocean Research
CSS	decision-support system
CVC	Climate Variability and Change
DAAC	Distributed Active Archive Centers
DHS	Department of Homeland Security
DOE	Department of Energy
DOI	Department of Interior
DOT	Department of Transportation
DSS	decision-support system

ECOHAB	Ecology and Oceanography of Harmful Algal Blooms
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statements
EOS	Earth Observing System
EPA	Environmental Protection Agency
EROS	Earth Resources Observation Systems
ERTS	Earth Resource Technology Satellite
ESE	Earth Science Enterprise
FAA	Federal Aviation Administration
FAWG	focus area working groups
FCA	Full Cost Accounting
FEWS	Famine Early Warning System
FGDC	Federal Geographic Data Committee
GB	gigabyte
GEOSS	Global Earth Observing System of Systems
GoM	Gulf of Mexico
GRACE	Gravity Recovery and Climate Experiment
HABHRCA	Harmful Algal Bloom and Hypoxia Amendments Act
HDF	Hierarchical Data Format
IEOS	Interagency Earth Observing System
IOOS	Integrated Ocean Observing System
ITO	Interagency Transition Office
IWG ESA	Interagency Working Group in Earth Science Applications
JCSDA	Joint Center for Satellite Data Assimilation
LACIE	Large Area Crop Inventory Program
MMS	Mineral Management Service
MOA	Memorandum of Agreement
MODIS	Moderate Resolution Imagery Spectroradiometer
MOU	memorandum of understanding
MPAR	Metrics Planning and Reporting System
NASA	National Aeronautics and Space Administration
NCEP	National Center for Environmental Prediction
NEON	National Ecological Observatory Network
NGA	National Geospatial-Intelligence Agency

NIMA	National imagery and Mapping Agency
NOAA	National Oceanic and Atmospheric Administration
NOPC	National Orthophoto Program Committee
NRC	National Research Council
NSGIC	National States Geographic Information Council
NSPIRES	NASA Solicitation and Proposal Integrated Review and Evaluation System
NWS	National Weather Service
OCS	Outer Continental Shelf
ORION	Oak Ridge Isochronous Observation Network
OSIP	Operational Satellite Improvement Program
OSSE	Observing System Simulation Experiment
OUA	Office of University Affairs
PART	Program Effectiveness Rating Tool
PECAD	Production Estimates and Crop Assessment Division
POC	Point of Contact
R&O	Research and Operations
R20	Research to Operations
REACT	Rapid Environmental Assessment and Composition Tool
REASoN	Research, Education, and Applications Solution Network
ROSES	Research Opportunities in Space and Earth Sciences
S&T	Science & Technology
SMD	Science Mission Directorate
TB	terabyte
TM	Thematic Mapper
UAV	unmanned aerial vehicles
USAID	U.S. Agency for International Development
USBoR	U.S. Bureau of Reclamation
USDA	United States Department of Agriculture
USGCRP	U.S. Global Change Research Program
USGS	U.S. Geological Survey
USGS EDC	U.S. Geological Survey EROS Data Center

E

Earth Science System Components

The chart at this link, http://www.artpo.ssc.nasa.gov/m2m_legacy/documents/Components_Chart_v8.1.pdf (see also Figure E-1 below), identifies Earth Observation sources, physical parameters measured, models and analysis systems, model outputs/predictions, and decision support tools. This chart is a very organized effort by ASP to develop a catalog (i.e., inputs) of the enormous variety of NASA products in one place.

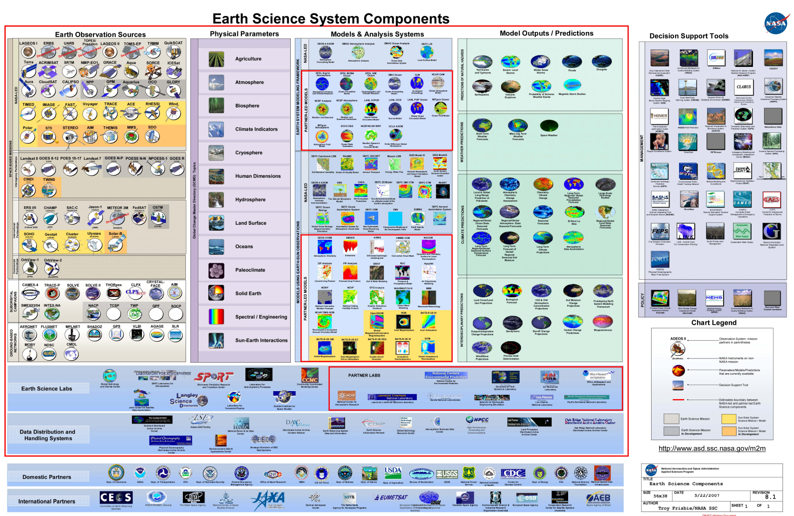

FIGURE E-1. The Earth Science System components knowledge base. SOURCE: http://www.artpo.ssc.nasa.gov/m2m_legacy/documents/Components_Chart_v8.1.pdf