OFFICE OF SPACE SCIENCE: EDUCATION/PUBLIC OUTREACH

Phase III Final Evaluation Report
October 2001—October 2003

National Aeronautics and Space Administration
Washington, DC

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March 2004

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Office of Space Science
Education/Public Outreach
Phase III Final Evaluation Report

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EXECUTIVE SUMMARY

Given the complexity of the Office of Space Science Education/Public Outreach (OSS E/PO) goals and intentions, the system has maintained its vision and purpose in the face of ongoing challenges. It has focused it efforts consistently on meeting the needs of the various entities that it serves, including the educational community, the scientific community, and NASA administration.

During the period of this evaluation, the OSS E/PO Effort has greatly expanded its reach and impact on the populations the Effort is designed to serve. The expansion has manifested itself by an increase in the number and variety of resources that OSS provides to its audiences. At the heart of its growth is a strong reliance on forging partnerships and leveraging opportunities and resources. The result has been a growing commitment within the OSS community to share space science with external populations, a commitment that is becoming ubiquitous throughout the system.

The OSS Support Network members and E/PO resource developers hold themselves accountable to their audiences. The Effort is building capacity by expanding its knowledge of current education research, assessing user needs, partnering with education experts, and soliciting user feedback. Formal and informal educators have reported that OSS resources are useful in motivating, inspiring, and educating the audiences with which they are shared. Educators express an appreciation of OSS professional development (PD); many say that they benefit from support in translating space science resources to meet the needs of their own settings.

Data collected over the course of the evaluation show a significant positive shift in the attitude of the space science community toward education. Scientists report that they consider E/PO to be an important, if challenging, activity. The Support Network (SN) has been working to help scientists find a way to contribute more efficiently to space science education.

The OSS E/PO Effort recognizes that its various audiences have different needs, and that impact manifests itself differently within each group of users. The table below is derived from data collected from each audience about its needs. It defines impact for each audience and details the attributes of effective resources for that audience.

Audience	Definition of Impact	Attributes that Contribute to Impact
Classroom Teachers	Providing educators with the content knowledge, skills, and confidence they need to engage and educate students	Scientifically accurate; exciting and accessible; aligned with standards; easily adaptable to multiple curricula and student populations; supported by strong PD; mindful of time and technology constraints; respectful of teachers and students
Museums and Science Centers	Bringing visitors to the institution, engaging them so they prolong their visits, and providing appropriate content	Exciting and accessible; up-to-date and updateable; easy to implement; supported during installation and exhibition; available at a range of costs and technical complexity
Minorities	Increasing the number of minority researchers and students who become active members of the space science research community	Respectful of the culture; cognizant of the constraints of the communities; personally interactive and engaging; collaborative between minority and non-minority developers; supported by strong PD; institutionally supported
The General Public	Attracting audiences to events that provide exciting and comprehensible space science	Immediately engaging; current and up-to-date; adaptable to diverse locations and populations; well-publicized; leveraging existing networks; having multiple entry points; providing pointers to more in-depth information
Scientists	Increasing the involvement, commitment, and effectiveness of scientists in space science education	Appropriate to individual scientists' needs and constraints; respectful of scientists' time limitations; supported by education experts; recognized by the scientific community as important; contributing to the body of scientific knowledge
The Support Network and E/PO Developers	Having impact on each audience *as defined by the audience itself*, while remaining flexible enough to adapt to changing audience needs, and meeting NASA and OSS E/PO goals	Providing sufficient information to all parties involved; supported by coherent communication system; leveraging the resources within the system; supported by appropriate PD; providing guidelines for effective decision-making at all levels, including a readily-accessible shared body of knowledge; influenced by information from audience members; allowing fiscal predictability

The OSS E/PO Effort has increased the quality and impact of its resources by meeting audience members' expectations of accurate and up-to-date content framed in a variety of ways that can be easily accessed and adapted to meet their needs. However, information about user needs and current educational practices is not systematically and coherently disseminated throughout the system. The OSS E/PO Effort has been identifying systems and resources that could be improved to increase the effectiveness of the system. These include:

- Clarifying and communicating the objectives and direction of the E/PO Effort, including the roles of individuals and institutions within the Effort
- Creating a system to share understanding of user needs and available resources across the network
- Developing strategies for gathering and using user input consistently for the development of effective resources
- Providing support for the development of E/PO resources that are aligned with user needs

Challenges related to coherence and communication, which are to be expected in any rapidly growing organization,[1] have been present since the inception of the current E/PO Effort, and all have been addressed with varying degrees of success. The OSS E/PO Effort is working constantly to enhance its own impact and effectiveness. In March 2001, the Space Science Advisory Committee (SScAC) set up a Task Force to carry out an external review of the OSS E/PO Effort. The Task Force and the Support Network itself have suggested a variety of strategies to address infrastructure challenges, several of which have already been implemented. These include:

- Developing a space science framework with multiple entry points for organizing educational resources; such a framework would provide both a coherent and rational way for end-users to find resources and a method for identifying gaps and redundancies within the range of E/PO resources
- Providing a professional development program for SN members and E/PO staff to increase understanding of current educational research and best practices
- Holding a series of separate retreats for Forums and Broker/Facilitators (B/Fs) to discuss and address the issues these institutions face
- Holding regularly scheduled telecons between each Forum and the B/Fs to share information about Forum activity
- Creating a calendar of selected OSS E/PO events to be shared across the Support Network to alert members of important activities
- Developing a matrix of networks (of both science and educational organizations) that have developed partnerships with the OSS E/PO Effort and who may be able to provide various types of support and information

[1] See Appendix B for further discussion.

In addition, evaluators' recommendations include:

- Creating a library of shared knowledge
  A unified repository would provide a single access point for developers seeking information.
- Designing and implementing a system of evaluation and assessment
  A more consistent assessment effort would provide useful information for developers refining existing resources or creating new ones. It would also allow the OSS E/PO Effort to highlight its own successes to the larger NASA community.

As a consequence of these and other growing efforts to develop a common information base shared across the E/PO system, SN members will be able to coordinate and share their knowledge base about quality and effectiveness. The challenges teachers and other groups have identified relating to usability will diminish as people in the E/PO Effort share their skills and knowledge about the various attributes of successful resources for the multiple populations they work with.

INTRODUCTION

From its inception in 1958, the National Aeronautics and Space Administration (NASA) has sustained an agency-wide commitment to education. During the period December 1993–February 1995, the NASA Office of Space Science (OSS) developed *Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs* (1995, referred to as the Strategic Plan). This publication articulated the goals of developing a variety of Education/Public Outreach (E/PO) resources and integrating them with existing efforts to create a coherent vision for education. *Implementing the Office of Space Science Education/Public Outreach Strategy* (developed May 1995–September 1996, referred to as the Implementation Plan) specifically addresses the methods by which the goals articulated in the Strategic Plan were to be realized.

PROJECT DESCRIPTION

The OSS E/PO Effort is dedicated to realizing the goals of the Strategic Plan, which was developed with the mission of making "education at all levels and the enhancement of public understanding of science integral parts of space science research activities."[2] The intent was to build a bridge between OSS and the public, particularly with the formal and informal educational communities. The goals of the Effort as outlined in the current OSS Strategic Plan are:[3]

- To share the excitement of space science discoveries with the public
- To enhance the quality of science, mathematics, and technology education, particularly at the pre-college level
- To help create our 21st century scientific and technical workforce

Virtually all OSS E/PO is funded through OSS flight missions,[4] through grants for Supporting Research and Technology[5], and through the activities of the Support Network (SN).[6] OSS

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[2] *Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs*, 1995, p.1.

[3] *The Space Science Enterprise Strategic Plan*, 2000, p. 23. Note that the original Implementation Plan had four goals, which have been reframed into the current goals as a result of input from the larger space science and educational communities.

[4] Missions are large-scale, long-term research projects. The funding process for missions utilizes Announcements of Opportunity (AOs). The OSS E/PO Effort has mandated that all new missions allocate 1–2% of their budget for

guidelines require that scientific staff be involved with the development of E/PO related to their missions and research. Scientific staff are often supported by personnel dedicated specifically to development of E/PO resources.

One of the main actions of the OSS E/PO Effort was the development of the Support Network, which comprises four Forums and seven Broker/Facilitators (B/Fs). The Forums correspond to OSS's four themes (Solar System Exploration, Sun-Earth Connection, Structure and Evolution of the Universe, and Astronomical Search for Origins). As each OSS mission is aligned with at least one of the themes, the Forums reach every OSS mission. The B/Fs are distributed throughout the country, working regionally with developers and users of OSS's educational products, identifying the needs of the populations served by the OSS E/PO Effort. The Forums and B/Fs (the SN), together with personnel from OSS and NASA's Office of Education (Code N),[7] form the basis of the OSS Education Council—the group created by OSS to ensure coordination of E/PO efforts and implement the OSS-wide plan. The OSS Education Council has met regularly to share information and experience, to develop the necessary infrastructure and resources to support the continuing activities of the OSS E/PO Effort.

The SN has provided a variety of useful services since its inception; many of these are highlighted in the first three PERG reports[8]. As a consequence of SN activity, the OSS E/PO Effort as a whole has increased in connectivity and integration. During the period covered by this report, the SN and its components continued and expanded the work it had been involved with over the previous years, including outreach to the educational, scientific, and underserved communities; development and implementation of educational resources and systems; refinement of the SN infrastructure; and coordination of activities with NASA's Code N.

Recent activities of the OSS E/PO Effort have included efforts to reach more people across a wider range of audiences. E/PO leads, SN staff, and mission and research scientists have increased their distribution of materials, as well as the scope and content of workshops and

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education and public outreach. Older missions, such as Voyager, are exempt from this mandate, although many do support some type of E/PO development.

5 Grants for Supporting Research and Technology are smaller grants, covering relatively small, short-term research projects that provide basic research supporting the flight missions. The funding process utilizes NASA Research Announcements (NRAs), and grants submitted in response to NRAs are not required to include funds for E/PO. While educational components are not mandated for Supporting Research, scientists working on Supporting Research are encouraged to develop E/PO resources in conjunction with the scientific content of the grants.

6 There are a few smaller grants programs, such as IDEAS, that provide E/PO funding that is not tied to specific NASA missions or Supporting Research. These represent a very small proportion of the OSS E/PO budget. In addition, Guest Observer Grants (which support guest scientists on missions) may involve E/PO components.

7 NASA's educational program is currently undergoing restructuring, and Codes FE and EU have been subsumed by the new Code N. It is hoped that the coordination and collaboration that existed between the OSS E/PO Effort and NASA Education will continue and increase.

8 Available by request from Dan Woods (dwoods@mail.hq.nasa.gov).

other interactive experiences. The opportunities for interactive experiences occurred at schools and other community locations, museums, space science organizations, conferences, and a myriad of other sites. In addition, the space science community codified, catalogued, refined, and created an expanded range of products for their audiences, disseminating them through the Web where possible, and in hard copy form for multiple groups including classrooms, libraries, museums, and science centers. The Space Science Education Resource Directory (SSERD) was completed and made accessible to the public through the Web site http://teachspacescience.stsci.ed.

The OSS sponsored a conference in Chicago in June 2002 that was dedicated to creating effective space science and education partnerships. OSS will also sponsor *A Workshop to Foster Broader Participation in NASA Space Science Missions and Research Programs*, to be held June 2004. The focus is to "seed personal contacts among a much more diverse community of investigators than has traditionally been active in NASA space science missions."[9]

The aforementioned conference in Chicago in June 2002 was enormously significant. Convened by the OSS E/PO Support Network, it was dedicated to a three-day discussion about how to create effective space science and education partnerships to further the goals of the OSS E/PO Effort. Participants included scientists and other personnel from OSS and across NASA; representatives from a number of formal and informal education organizations; members of a range of minority professional organizations; and education and research faculty from a range of colleges and universities across the country. The conference fostered extensive dialogue about the range of interests, resources, issues, and conditions for each population that create both opportunities and challenges to partnerships and collaborations for all participating communities.

In March 2001, the Space Science Advisory Committee (SScAC) set up a Task Force to carry out an external review of the OSS E/PO Effort. The Task Force produced a report, *Implementing the Office of Space Science Education/Public Outreach Strategy: A Critical Evaluation at the Six-Year Mark* (2003). This report found the OSS E/PO Effort to be worthwhile and effective. The report included several substantive recommendations for the improvement of the OSS E/PO Effort. The OSS Administration has implemented several of these recommendations and has plans to implement more of them.

Partly as a function of the Task Force Report and findings from PERG evaluation efforts, the Education Council meeting agendas have been modified to include a range of interactive activities and professional development (PD) opportunities for its members. The agendas have also included expanded opportunities to dialogue directly with members of Code N, as well as other groups such as the minority professional organizations and other NASA Enterprises.

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[9] *A Workshop to Foster Broader Participation in NASA Space Science Missions and Research Programs*: http://analyzer.depaul.edu/Chicago2004/

EVALUATION

The NASA Office of Space Science contracted with the Program Evaluation and Research Group (PERG) of Lesley University in October 1998 to conduct an external evaluation to determine how effectively the OSS E/PO program is meeting the objectives laid out in the Implementation Plan. The PERG evaluation plan to date has been conducted in three phases presented in three separate reports. This report represents the work completed during Phase III.

- **Phase I**
  The first report focused on documenting and describing the **infrastructure** of the OSS E/PO Effort,[10] especially the Support Network (SN), a network of institutions across the nation that help achieve the goals of the OSS E/PO Strategic Plan. This report dealt with variables affecting the SN itself. Thus, the data analyzed were collected primarily from members of the OSS E/PO community. Data were collected between November 1998 and October 1999, and the report was delivered in May 2000.
- **Phase II**
  The second report focused on describing and explaining the total OSS E/PO Effort **implementation**, beyond the development of the Support Network infrastructure. Data for this report were gathered between January 2000 and May 2001, from both members of the OSS E/PO community and the communities it serves directly (educators,[11] scientists, and the rest of NASA). This report focused on the actions of the OSS E/PO Effort to meet the goals outlined in the Strategic and Implementation Plans, the successes of the program, and the challenges that it faced.
- **Phase III**
  The third report focuses on examining the **impact** of OSS E/PO activities on those audiences for whom the products and services are designed (e.g., teachers who participate in OSS teacher training programs, visitors to OSS museum exhibits, etc.). Data sources included the audiences or "end-users," as well as those populations who were included in the first two reports. Phase III of the evaluation took place over a two-year period that began in October 2001.

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[10] In this report, we use the term "OSS E/PO Effort" to refer to the individuals and organizations that participate in or contribute to the creation of OSS E/PO material, and all activities carried out in support of the Strategic and Implementation Plans.

[11] In this report, we use the term "educator" to refer to any individual or organization that is responsible for disseminating information to a larger audience. This includes (but is not limited to) classroom teachers, museum staff, librarians, Girl Scout leaders, speakers presenting to the public, etc.

EVALUATION METHODS

Data Collection Activities

Evaluators employed a suite of data collection methods including formal and informal interviews and surveys; ongoing Web site review; and document review which included the including the Strategic and Implementation Plans, the SScAC Task Force report, *Implementing the OSS E/PO Strategy: A Critical Evaluation at the Six-Year Mark*, internal and external newsletters, the 2000–2002 Annual Reports, and the Space Science Education Resource Directory (SSERD) among others. They engaged in numerous informal conversations with both end-users and members of the OSS E/PO Effort throughout the data collection period.

Evaluators attended a variety of events hosted by the SN and/or its component institutions including conferences, workshops, teacher trainings, and the first OSS Education conference. Evaluators also observed classrooms and workshops that utilized OSS E/PO resources. At these events, evaluators observed interactions, interviewed participants, and provided formative feedback, as appropriate. These observations provide first-hand evaluative evidence supporting data gathered from resource developers and users, creating triangular support for interview-based findings.

Evaluators also attended a variety of scientific and educational conferences—such as the meetings of the American Geological Union (AGU) and the National Science Teachers' Association (NSTA) – which featured a strong OSS E/PO presence. At these conferences, evaluators observed OSS presentations and workshops, interviewed or surveyed attendees, and engaged participants in informal discussions on topics relevant to the evaluation.

In addition, evaluators conducted three in-depth studies of selected education resources to study the Effort's effects in a more closely focused way. In-depth studies included observations, interviews, surveys, and reviews of documents and artifacts. Site visits involved intense on-site data collection, which included observations and associated interviews and surveys as appropriate. Table 1 lists the number of each data collection activity. It does not include innumerable informal interviews that occurred during Phase III.

Table 1: Data Collection Activities

Data Collection Activity	Estimated Total Collected
Formal interviews	375
Surveys	163
Site visits (includes observations)	23

In-depth studies	3

Data Sources

For this report, we gathered data from a wide range of individuals whose comments, ideas, and concerns are reflected in the report. These people include:

- Members of the OSS Education Council—includes the SN, as well as OSS E/PO administration, and staff from NASA's Code N (Education)
- OSS E/PO personnel—includes staff working on E/PO within OSS missions, E/PO developers associated with OSS research projects, and others playing important roles in the creation of OSS E/PO
- NASA Office of Education (Code N) staff
- Scientists—mission scientists, research scientists, and discipline scientists; scientists interviewed include NASA civil servants, employees of organizations working with NASA, university professors, and others actively engaged in OSS activities
- Formal and informal education personnel—K–12 teachers, museum staff, librarians, and others engaged in the process of educating the public
- Other OSS E/PO partners—publicly- and privately-funded organizations and individuals who have worked with OSS personnel to create space science education resources, identified by OSS E/PO staff and the OSS E/PO Annual Reports
- Volunteers—current and former space scientists, as well as amateurs with knowledge of and interest in sharing space science information
- Space science education providers beyond OSS—publicly- and privately-funded organizations and individuals who have created space science education resources without input from OSS personnel (outside of identified partners)

The audiences interviewed and surveyed are described in Table 2. Because site visits generally include interactions with a range of individuals within different audiences, they are not included in the table. However, interviews and surveys conducted during site visits are included.

Table 2: Participant Audiences

Audience	Interviews	Surveys
Support network	28	0
E/PO leads	52	0

HQ	3	0
Scientists	40	15
Formal educators	80	84
Higher education (including Minority Institutions)	27	0
Museums and science centers	54	0
Community groups	10	0
Libraries	22	0
Volunteers	41	64
Others	11	0
Total	368	163

THIS REPORT

The full period of the Phase III report is October 2001–0ctober 2003. The findings result from analysis of all data collected during Phase III of the evaluation, including the data that informed the Interim Report, released in 2003.

The Findings section of the report focuses on the various audiences impacted by the OSS E/PO Effort: classroom teachers, museums and science centers, minorities, the general public, scientists, and the Support Network and E/PO developers. For each audience, we present a focused definition of impact, followed by some of the attributes that are present among resources that have impact for that audience, and finally a discussion of findings from the data. The report includes findings related to the OSS E/PO infrastructure and implementation, as these are directly correlated to the impact of the OSS E/PO Effort.

The data presented in this report are primarily *qualitative.* Qualitative data allow for deep exploration of a variety of areas, including many that are uncovered during the data collection process. Analysis of qualitative data can uncover ideas, beliefs, attitudes, challenges, etc. that are present in the population of interest. Unlike quantitative analysis, qualitative analysis cannot be used to estimate the prevalence of any specific variable, because the data are not representative of the larger population beyond the participating sample. For example, the analysis can reveal beliefs that some scientists hold about education, but it *does not* indicate the *proportion* of scientists that hold a specific belief.

Throughout the report, there are citations from the data. They are included to add context and richness to the discussions and to illustrate the perspectives of those engaged in the work. All data cited in the report have been selected to *represent the themes and trends* that emerged from the data and are characteristic of the *perspectives voiced by multiple respondents* and issues related to the program during the report period.

This report also incorporates brief descriptions of specific programs that highlight impact on various audiences. The programs included in this report are just a few of the many exemplary resources supported by the OSS E/PO Effort.

FINDINGS

OVERVIEW

The OSS E/PO Effort has grown and expanded significantly. There are now more points of contact between the OSS E/PO Effort and the audiences it is trying to reach, and therefore more opportunities to impact learners.

OSS has supported the creation of an expanding array of resources that serve to share space science findings with schools, museums, and the general public. In 2003 alone, the OSS E/PO Effort was responsible for creating over 460 E/PO activities and 20 new educational resources, and for conducting over 5,000 discrete E/PO events.[12]

> I was surprised at the number of educational programming options that NASA had put together. (Education conference participant)

OSS E/PO activities for FY 2003 reached into all 50 states, as well as the District of Columbia and Puerto Rico, and directly involved over 390,000 students, formal and informal educators, and members of the general public. In addition, over 3 million visitors to museums, science centers, lectures, and public events were exposed to OSS E/PO materials, and over 6 million accessed OSS E/PO resources over the Internet.[13] Data indicate that the reach of the OSS E/PO Effort has expanded to include groups of learners who have not previously benefited from NASA's educational resources, while continuing to engage audiences that NASA has traditionally served. OSS's success is reflected in the more than 30 awards or other forms of recognition that it received in 2003 alone.[14]

The OSS E/PO Effort has made steady progress toward creating partnerships between scientists and educators by orchestrating and supporting a variety of situations in which scientists and educators come together to share knowledge and work toward a common goal, including resource development meetings, review sessions, and long-term mentoring programs.

> We're mobilizing the scientific workforce for education. It's a tangible culture change. It's a unique contribution. It's not just the educators that need to teach science; it's not just the scientists that need to teach science. It's a partnership.

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[12] *Space Science Education and Public Outreach: A Report to the American Astronomical Society*, 2004.

13 Ibid.

14 Ibid.

> We've been able to bring these people together—kicking and screaming sometimes, but it's working. (SN member)

The OSS E/PO Effort has stated that audience needs should be the starting point for developing effective educational resources. There has been a significant increase in the involvement of audience members and education experts in the creation and assessment of new resources.

- The OSS E/PO strategy mandates that E/PO development teams comprise both scientists and teachers; this practice is becoming more prevalent throughout the Effort. Data indicate that when scientists and teachers develop resources together, each brings their own expertise: scientists bring their understanding of scientific content while teachers bring their understanding of student needs.

> Seemed like if we wanted to develop lesson plans that teachers could use, we would need a teacher . . . best way is to work with teachers to develop these types of things that I certainly don't know how to do. Also get a teacher's perspective on what would be useful and the kinds of things those students would find interesting. (Scientist)

- The OSS E/PO Effort has created some very effective resources working in conjunction with organizations such as TERC, Lawrence Hall of Science, and McRel. Such partnerships allow scientists to utilize their content expertise while others, more familiar with current educational research, shape the content into pedagogically sound resources.

> Collaboration between someone who's an expert in the subject and someone who's an expert at teaching, that's the best way to do it.(Resource developer)

> We recognize that we don't have expertise, so we subcontract E/PO money to the experts. (E/PO lead)

- Audience members are involved in panels responsible for reviewing E/PO NRA proposals, products under development, and existing products. Thus end-users have the opportunity to give input at all stages of development.

> Input from users is increasing—this leads to resources that better meet user needs, as well as more buy-in from audiences. We ask them what they want. That makes it a whole lot easier to provide products. It also makes people want to work with you, so you have another arm. (E/PO lead)

- OSS E/PO resource developers have utilized feedback from users (gathered via Web pages, post-workshop surveys, or informal, unsolicited comments) to aid in resource revision.

> Based on feedback, we decided where to go and what people needed. And we revised. (E/PO lead)

> The success for E/PO should be defined by the reaction of the people it is trying to benefit. (Administrator)

Information from end-users and experts has provided the E/PO Effort with information about the needs and constraints of its various audiences, allowing for the development of more effective resources.

> In developing programs or materials, first we figure out what the product will be used for—that makes a big difference. (E/PO lead)

There has been a shift from focusing on the science of a specific mission or program to an emphasis on how the resource will be used and how it can best meet the needs of its audience.

> The big goal is to try to get a more educated population. It doesn't matter if they learn the specifics of ACE or TWINS, but we want them to learn some science.(E/PO lead)

The increased input from users and output from the OSS E/PO Effort has led to increased **impact** on its various audiences. The Cambridge International Dictionary of English[15] defines impact as "A powerful effect that something, especially something new, has on a situation or person." Impact manifests itself somewhat differently for each audience. Discussion of impact for each of the audiences is informed by a variety of data sources, including interviews, surveys, and informal conversation. Site visit data provide firsthand evaluative evidence for information reported by individual audience members.

[15] *Cambridge International Dictionary of English*, Cambridge University Press, 2003.

CLASSROOM TEACHERS

IMPACT: Providing educators with the content knowledge, skills, and confidence they need to engage and educate students

Analysis indicates that resources that have impact in the classroom have the following attributes:

- Focus on science, not the missions
- Scientifically accurate
- Exciting and accessible
- Aligned with standards
- Easily adaptable to multiple curricula and student populations
- Supported by strong PD
- Mindful of time and technology constraints
- Respectful of teachers and students

OSS has built upon NASA's commitment to formal education by working with teachers themselves to develop resources that have impact in the classroom; classroom teachers are not a new audience, but they are better served through new approaches implemented by OSS.

- OSS is developing resources for formal education that incorporate both current research on pedagogy and user feedback about the type of resources that contribute most effectively to learning. Audience members have identified a range of OSS resources that are particularly effective in meeting their needs. These include:
  - Activities based on the scientific method, especially those that encourage students to raise their own questions and conduct experiments to address these questions

    > [My students] are getting a better understanding of how science works and what it is, and much more confidence in their ability to *do* science. (Teacher)

  - Resources that provide opportunities to engage in authentic research, including collecting and analyzing live data

    > I was particularly interested in collaboration efforts with real scientists and participating in real research. (Teacher)

- Activities that are developmentally appropriate for learners of different ages and with different levels of readiness to learn space science content, and resources that can be altered by educators to meet the needs of different populations

> I adapted [activities designed for younger students] for my students; it was easy to do. The labs for younger students provide a lot of information. I took some of the information out and had the students do their own research on the Internet. (Teacher)

SUNBEAMS

The Students United with NASA Becoming Enthusiastic About Math and Science (SUNBEAMS) program is a partnership between NASA's Goddard Space Flight Center (GSFC) and the Washington, DC public school system, which serves an urban minority population. Teachers spend five weeks working with a scientist mentor at GSFC, after which they create a curriculum based on what they learned. During the following school year, teachers implement the curriculum they designed at the summer institute and are visited by the scientist in their classroom. For one week during the school year, teachers bring their students to GSFC every day where they meet the scientist mentor and are immersed in math, science, and technology activities. Finally, students share the work that they did during the year with the larger community through a *Family Science Night*.

A number of factors have led to the success of the SUNBEAMS program. These include a well-designed program with appropriate support and follow-up activities; an environment that fosters respect and ownership of the work; and qualified and dedicated people leading it who understand and are able to meet the needs of their audiences (which include urban classroom teachers and students, and Goddard space scientists). Data indicate that SUNBEAMS impacts scientists, teachers, students, and the general public.

- Teachers report a variety of benefits from the program including:
  - Increased content knowledge and confidence in working with space science concepts
  - New strategies for teaching, especially about inquiry-based and hands-on approaches
  - The opportunity to create standards-aligned space science activities
  - A range of resources for their classroom
  - Skills for using new technology, particularly computer-based technology
  - Inspiration as a result of working closely with scientists
- Data suggest that students are impacted by:
  - Accurate and appropriate curriculum on space science
  - Exposure to computer technology
  - The opportunity to meet scientists and visit GSFC
- Scientists report that their involvement provides them with:
  - Personal satisfaction mentoring a teacher
  - Leverage for OSS E/PO funding opportunities
  - Educational expertise to help inform future E/PO activities
- The general public and the larger school community are reached through the *Family Science Night.*

- OSS has worked to bring scientists, teachers, and students together, providing benefits for all parties.
  - Scientists report that formal education experience gives them direct information about what teachers and students need and want, which helps them understand how they can use their time and energy to make the most significant contributions.

    > I have a better sense of what does and doesn't work in the classroom because I have contact with teachers. (Scientist)

  - Data indicate that students find meeting scientists to be exciting and motivating.

    > Their thirst for knowledge has increased tremendously. (Teacher)

  - Teachers report that meeting scientists in person helps humanize people in the profession.

    > They're people! [A scientist] has come to class and students ask him questions. It's amazing; he's a person just like me. (Teacher)

- OSS has increased the number and variety of workshops it provides to teachers, including several which target areas such as serving students with special needs, engaging students from traditionally underserved populations, or building partnerships between educators and scientists. Teachers who benefit from OSS-supported professional development (PD) increase the impact of OSS E/PO resources by sharing their knowledge and understanding of space science with their students.

  > Our main focus now is increasing our impact. Making sure our materials and activities are useful to teachers. We're now focusing on teacher and educator PD. It doesn't help to have something good if teachers don't know how to use it. If they don't know how to use it, they'll be afraid of it. It will sit in a drawer somewhere. (SN member)

  > I received extensive knowledge into space and science. It filtered on down through the scientist into my classroom. (Teacher)

- Ongoing programs such as SUNBEAMS and Amazing Space foster long-term relationships between teachers and scientists. Teachers involved in longer-term PD activities often have the opportunity to develop activities or curriculum units specifically for their own classrooms. In some cases, scientists or science education experts are available to work with the teachers in developing or adapting resources.

  > We're a very informal group so we try and be very, very open to the teachers and try and meet them on even footing even though they've come to us. I don't look at it as we're some how above them. And they're trying to learn from us, but it's more of an equal type of relationship. They're trying to learn science and we're trying to learn education. (Scientist)

> It has to be a relationship, a continuing relationship between teacher trainers and NASA. It can't be a one-time deal. (Teacher)

- OSS supports programs in colleges and schools of education that provide preservice teachers with both training and materials to use in the classroom.

  > It's a good way to get them a comfortable experience with science. Teachers will get this packet of classroom activities to take into their classes later. (Scientist)

- To maximize the effectiveness of teacher PD, OSS has leveraged existing networks of teacher-leaders. These leaders attend OSS workshops and share the knowledge and skills they develop with teachers in their own schools and districts.

  > What NASA needs to do is support and continue to excite a cadre of people around the country who will go out there and get that message out. (Teacher)

  > If you train them, they train teachers in their states. We establish networks to increase the size of our audience. Getting more science to the teachers, so they'll use more. (SN member)

- OSS has supported the development of printed resources such as posters, litho sets, and bookmarks that bring the latest images of space into classrooms. The OSS E/PO Effort has tried to meet the needs of institutions with limited technological capability through "low-tech" resources such as paper-plate astronomy. OSS has supported the development of educational activities that use common items, such as candy bars, tennis balls, and Styrofoam and has disseminated these activities through Web pages and workshops.

  > They had a lot of hands-on applications, yet it was easy to get the point across and using common cheap items. (Community educator)

- OSS reaches teachers and students in urban schools through programs like the Chicago Urban Initiative and through partnerships with institutions supported by the Minority University Initiative (MUI; see page 21 for more information).

- The OSS E/PO Effort is developing resources that are developmentally appropriate for learners at different ages and levels of preparedness to learn space science content. As a consequence, the Effort has expanded the range of complexity of its resources.

The OSS E/PO community recognizes that the science standards and standardized tests are driving curriculum and pedagogic decisions nationwide. The need to create standards-based materials is a challenge for all developers of formal education materials. The phrase "standards-based" is somewhat opaque, because there are multiple standards that apply in most contexts: national, statewide, and regional.

Data indicate that formal education resources are most effective when they:

- Are immediately adaptable to meet regional standards and student needs
- Can be easily integrated into existing curricula
- Support non-science content standards

> I hear from teachers, "I'd love to do this, but I have to spend most of my time doing literacy." That's why we try to tie literacy into what we're doing. They can teach writing using science content as well as anything else.(SN member)

Teachers report that they would benefit from a directory of resources that concretely and coherently presents the content of the standards. The OSS E/PO Effort has recognized teachers' need to align with standards and has explored a number of strategies to create a coherent system of categorizing resources to meet teacher needs, including the following:

- The Space Science Education Resource Directory (SSERD) is a searchable, electronic database of on-line OSS E/PO resources. Users can search the SSERD using topics based on the National Science Education Standards (NSES), state science standards of New York and Texas, and district standards of San Francisco, California. Feedback from teachers has been used to shape the directory to address a range of teacher needs. Data gathered in 2003 suggested that many educators were unaware of the directory or had difficulty using it. A revised version of the SSERD was released as data collection for this report was being completed; the access and usability issues raised by our respondents may be addressed by recent revisions. The evaluators have not yet collected data on the most recent release of the SSERD.
- There have been several schemes that associate each OSS E/PO resource with one or more national standards, including the Space Science Concepts Matrix, the Quilt on Education Standards, and the Concept Strands. Feedback from educators suggested that the resources were not effective, in and of themselves, at helping teachers meet standards-based criteria.
- As recommended in the Task Force report,[16] the SN has recently taken steps to build on the schemes mentioned above to develop a space science framework to function as an organizing system for E/PO resources. The framework will be designed to provide more coherence at the user-interface level, to practically guide the user to resources that will meet specific needs, and to allow multiple entryways

[16] *Implementing the Office of Space Science Education/Public Outreach Strategy: A Critical Evaluation at the Six-Year Mark*, 2003, pp. 10–11.

to the system. The framework is intended to meet teachers' needs by aligning with national standards, linking standards to OSS themes, and telling the space science story in the context of standards.

OSS has been proactive in working with teachers and education experts to address the challenge of aligning OSS resources with standards. This is a complex and continuing issue, and OSS has made a commitment to devote significant resources to addressing it.

MUSEUMS AND SCIENCE CENTERS

IMPACT: Bringing visitors to the institution, engaging them so they prolong their visits, and providing appropriate content

Analysis indicates that resources that have impact in museums and science centers have the following attributes:

- Exciting and accessible
- Up-to-date and updateable
- Easy to implement
- Supported during installation and exhibition
- Available at a range of costs and technical complexity

Data suggest that visitors to museums, planetaria, and science centers find space science to be engaging and exciting, and that staff appreciate the opportunity to incorporate OSS materials into their venues. The OSS E/PO Effort recognizes that there are many varieties of informal institutions, each with different needs and constraints.

> For informal education, the fact that it's so large and so diverse. Everybody has a different flavor so you have to do a lot more tailoring to the individual needs.(SN member)

- OSS has developed traveling museum exhibitions such as *Cosmic Questions* and *Space Weather*. OSS has been responsive to the needs of smaller venues by creating differently-sized and -priced exhibits using similar content. For example, *Destination: Mars* addresses many of the same educational issues that the larger exhibit *MarsQuest* addressed, but is more appropriate for venues with limited size and budget. Similarly, there are two versions of the *Hubble Space Telescope* exhibit to meet the needs of a wider range of venues.

> [The OSS exhibit] was successful in making something static come alive.(Museum staff member)

> Over the three months [of the OSS exhibit], our attendance increased 100% over the previous year. (Museum staff member)

- OSS creates materials such as posters, litho sets, and planetarium shows that bring the latest images of space into museums, science centers, and other venues.

> The thing that NASA has a handle on better than anyone else is that they have the most up-to-date images and information. (Museum staff member)

- OSS provides access to current, ongoing research that can be incorporated into existing programs and resources; this leverages the knowledge and expertise of the museums and science centers that provide OSS resources to their visitors.

> Now they are supporting a whole range of programs that museums come up with. They have access to scientific research, images, and so on. Things can come out of that. (ASTC member)

COSMIC QUESTIONS

Cosmic Questions (CQ) is a 5000-square-foot, interactive exhibition, developed to promote reflection about and interest in "big questions" about the universe and humanity's place in the cosmos, along with providing the most up-to-date information about the universe. The exhibition is also designed to give visitors direct experiences in using the tools of space science and knowledge of how scientists investigate the universe. Through their experiences in the exhibit gallery and at the related activities of CQ—the play, the demonstration, and the planetarium show—visitors are encouraged to construct meaning and to find relevance in relation to their own world views and life experiences. There was also associated training and resources provided to museum staff and volunteers, and formal educators, on the content of the exhibit.

θ The Cosmic Questions exhibition had a number of impacts on the museum and its staff, including:

- Bringing in more visitors
- Enhancing the museum's reputation via the connection to NASA
- Offering an effective resource for teachers
- Fostering new internal and external relationships
- Providing training and support for museum staff

θ The exhibition impacted visitors by:

- Offering a wide range of activities that met the various age ranges, needs, interests, and learning styles of visitors
- Actively engaging visitors in the learning process through designing components that required them to construct their own meaning
- Meeting user needs by basing exhibition development on data-based knowledge of visitors' understanding about the concepts
- Including supporting activities that reinforced the fundamental concepts in different ways

θ Finally, the exhibit, and the teacher PD that accompanied it, impacted educators and students by:

- Providing teachers with new teaching strategies
- Giving students more information about the scientific concepts covered in the exhibition
- Increasing teacher confidence
- Focusing teachers and students on outstanding "cosmic questions"
- Providing access to the latest scientific theories
- Providing teachers with information that was helpful in designing classroom activities

- Many informal exhibits utilize exciting new technology. Exhibit components such as remote-controlled spacecraft, interactive computer displays, and kiosks that provide the

up-to-date astronomical information are popular with museum staff and visitors alike. However, some smaller institutions have reported difficulties in keeping these materials functioning, and have requested more support from OSS in maintaining complex electronic components.

> The [exhibit component] was up and down for a month. We never really found out what happened. Our technician was working with the designers. We were replacing boards, and other stuff. That was a problem, because it was the best piece in the thing, and when it worked, it was great; when it didn't, it was disappointing. (Museum staff)

- Resources such as Space Place and ViewSpace provide high-quality, inexpensive materials to smaller venues that can reach audiences that may not otherwise have access to space science materials.

> The bulletin board is an excellent addition to our museum and to the programs we design for teachers during the school year and for our summer program. It helps me do the research I need to stay current and design space exhibits.(Museum staff member)

- Recently, the SN has discussed the development of modular space science exhibit platforms to be installed at small space science museums and planetaria, which would accept modular attachments to deliver particular exhibit content. Such a resource would allow the development and distribution of small, inexpensive exhibits tailored to meet the constraints of smaller venues.

- While users say that they appreciate OSS materials, some informal science educators report that they face challenges finding and obtaining materials.

> Knowing what will become available and how we can speed up the process of finding out what is available [would be helpful]. And being able to reach someone in a position who can make a commitment to make it happen.(Museum staff member)

By listening to and partnering with informal educators, the OSS E/PO Effort has been creating resources that are increasingly effective at reaching visitors to museums, planetaria, and science centers.

MINORITIES

IMPACT: Increasing the number of minority researchers and students who become active members of the space science research community

Analysis indicates that resources that have impact on minorities have the following attributes:

- Recognizing the importance of cultural norms and characteristics
- Cognizant of the constraints of the communities
- Supportive of partnerships between minority and non-minority developers
- Personally interactive and engaging
- Supported by strong PD
- Institutionally supported by host organizations and partners

The OSS E/PO Effort has placed emphasis on increasing participation of minorities in space science, with the goal of diversifying the space science workforce. OSS staff are forging relationships with minority institutions and minority professional organizations, and are targeting urban schoolteachers working with multi-ethnic populations.

> Of all the organizations I've dealt with, NASA is the most supportive and proactive about finding out what we're all about. They'll send people to our meeting; they'll listen and will try to come up with ideas and things to do. Much more proactive than NSF or DOE. (Minority science organiz

> NASA is clearly the leader amongst federal agencies in having a real, true, demonstrated interest in trying to expand the scope of schools that are involved with NASA programs. (Professor of color)

OSS worked with MURED[17] to create NASA's first Minority University Initiative (MUI), a program to fund space science opportunities for students and faculty at minority institutions.[18] MUI funding guidelines encouraged funded minority institutions to partner with other science research institutions, such as research universities and NASA centers. One component of the program involved the development of projects to

provide outreach to the larger minority communities in which the funded institutions are situated;

[17] NASA's Minority University Research and Education Division.

18 The first funding cycle, which started in January 2001, is now complete, and a second cycle has been funded.

NEW YORK CITY SPACE SCIENCE RESEARCH ALLIANCE

The New York City Space Science Research Alliance is a multi-campus research center based in the City University of New York (CUNY). The Alliance is funded by OSS's Minority University & College Education and Research Partnership Initiative in Space Science or MUCERPI (formerly the Minority University Initiative or MUI) and is bolstered by a partnership involving CUNY, the Hayden Planetarium, and the NASA Goddard Space Flight Center (GSFC). The Alliance has supported the creation of a multi-campus space science major in the CUNY BS degree program, as well as three space science concentrations, each housed at one of CUNY's 18 campuses. Data indicate that these programs will continue beyond the duration of the grant. In addition, the Alliance has supported new research and enhanced existing research, utilizing community college faculty, and has increased student and faculty presence at national conferences.

The Alliance has impacted high school students through CUNY's Science Engineering Mathematics Academy (SEMA), through the Radio Jove Project, and through a relationship with John Dewey High School. These activities were not part of the initial grant proposal, but developed as CUNY became more involved in space science education.

- The grant money supported the development of a number of partnerships:
  - Within CUNY itself, various campuses worked together to develop the degree program.
  - As mandated by the grant, CUNY partnered with both a NASA center (GSFC) and a non-minority institution (The Rose Center). These partnerships have provided a variety of opportunities for faculty and students at CUNY.
  - Further relationships were fostered by the involvement in the MUCERPI program: CUNY has been working with Dewey High School, an inner-city high school with a large minority population; with South Carolina State University, another minority institution supported by the MUCERPI; and with Passport to Knowledge, which utilized the Alliance's connections to bring Marsapalooza to New York City.
- The grant has supported a strong PD program for faculty at CUNY, ranging from collegial sessions to discuss space science research to workshops teaching faculty to use Interactive Data Language (IDL) for data mapping and imaging.
- CUNY faculty and mission staff are actively seeking ways to involve minority scientists at CUNY in NASA missions; this will provide a means for faculty and students to stay actively involved in OSS research beyond the

approximately one-third of the funded institutions included outreach as part of their MUI-funded activities.

By promoting partnerships between minority institutions and other research facilities, the MUI supported the creation of a network of minority and non-minority researchers. This provided the mainstream research community access to input from minority researchers, and benefited underserved communities in a variety of ways, including the following:

- The minority institutions that were funded by the MUI report a variety of successful outcomes that have the potential to impact all members of the university community.
  - All MUI recipients have either created new, or have significantly increased existing, programs in astronomy and space science.

> It's improved the delivery of science here. Before, we had astronomy on the books, but it was never taught. (MUI recipient)

> We've set up a university-wide degree program in astronomy. We also initiated minors at various campuses. (MUI recipient)

- Some minority institutions have used MUI funding to create and improve space science facilities, many of which will last beyond the grant period.

  > We are now looking at our new Science and Technology building that will open next month. (MUI recipient)

- Faculty members report being invigorated and excited about working with NASA scientists.

  > Professionally, I'm having the best time of my academic life. (MUI recipient)

- Several undergraduate students have changed majors and/or decided to pursue a graduate degree related to space science, attended the NASA Academy programs (including the first student to attend from a Tribal College), or attended national conferences where they presented their own research.

  > In at least two or three cases, [programs supported by the MUI have] provided an impetus for students to pursue a science career.(MUI recipient)

- Several of the programs supported by funds from the MUI include outreach into the K–12 community, either through teacher education programs or through programs that directly involve K–12 students. For example:
  - One institution developed a Saturday program for high school students.
  - One institution funded a laboratory that provides K–12 curriculum for community students.
  - Several institutions developed or enhanced existing programs for preservice science teachers. At least one provided workshops for in-service teachers.

    > We had a [PD for in-service teachers] workshop for the second largest middle school in the state. All but one of their science teachers came. (MUI recipient)

- Some MUI-funded institutions have impacted underserved minority communities through outreach activities beyond formal education.
  - One tribal college used some of its funds to purchase space science books for the reservation library.
  - The MUI provided funding for professors to speak at local planetaria, reaching interested community members. Because scientists at MUI-funded institutions are usually members of the underserved communities themselves, they act as role models.

> Being a speaker in the community, I'm able to go out to community activities and raise awareness. I'm African-American and I find myself a spokesperson to raise the awareness of our students.(MUI recipient)

- Through partnerships supported by the MUI, faculty at funded institutions have educated themselves about current space science events, and have shared information on events such as eclipses and launches to capture the public's interest.

> We reach a very different audience. We were interviewed by the "freebie" papers—those have a very large, different audience from the more elite papers like the New York Times and the Washington Post. (MUI recipient)

- The process of integrating students and faculty from minority institutions into the mainstream of space science research has provided opportunities and motivation to individuals who have traditionally been underserved by the scientific research community.

> We've found that there is nothing better than sending a scientist. It needed a personal connection where the scientist went out and said, "Yes, I'll take you as my student." (Professor of color)

Partnerships between minority institutions and mainstream science research institutions have proven to be an effective first step toward making space science accessible to underserved communities. Because the MUI PIs are situated within the underserved communities the program is meant to support, they are able to tailor projects to meet the communities' needs more effectively than a scientist outside the community could.

> Most mainstream science courses are grounded in mainstream culture. If you're not attuned to the culture you are at, you don't realize that science is not culturally neutral. All cultures have within them levels of knowledge. (MUI recipient)

The first MUI grant period has finished. OSS and NASA's Office of Education have funded a second version of the MUI (renamed the Minority University & College Education and Research Partnership Initiative in Space Science or MUCERPI). Previous grant recipients could re-apply, provided that they proposed major extensions of the work already funded or new directions of development. Two-thirds of the institutions that had been funded by the MUI were also funded by MUCERPI, allowing them to build on work funded by the MUI.

To broaden impact beyond minority colleges and universities, OSS is developing relationships with minority professional organizations. Data indicate that several meaningful partnerships are being nurtured.

The OSS E/PO Effort continues to be proactive in reaching out to underserved communities. Plans are currently underway for a *Workshop to Foster Broader Participation in NASA Space Science Missions* to be held in June 2004. The overarching goal of the conference is "to seed personal contacts among a much more diverse community of investigators than has traditionally been active in NASA space science missions."[19] The conference will focus primarily on scientific research, but there will be support and encouragement for the development of E/PO resources, as well.

19 From the workshop's Web page at http://analyzer.depaul.edu/Chicago2004/

THE GENERAL PUBLIC

IMPACT: Attracting audiences to events that provide exciting and comprehensible space science

Analysis indicates that resources that have impact on the general public have the following attributes:

- Immediately engaging
- Current and up-to-date
- Adaptable to diverse locations and populations
- Well-publicized
- Leveraging existing networks
- Having multiple entry points
- Providing pointers to more in-depth information

The OSS E/PO Effort has taken steps to reach out to the science-attentive public in a variety of ways to provide them with information about space science and OSS missions.

- Several B/Fs have developed and fostered partnerships with existing networks of libraries, small science centers, and community groups. OSS has connected scientists with these networks, providing support and expertise for the development of better scientific understanding among network members. These networks reach into rural and urban areas that may be underserved by more traditional space science resources.

  > I think it's a wonderful way to excite the kids and open their minds to other possibilities. This is a rural area, and kids don't go towards this type of science field. (Librarian)

  > I'm seeing more astronomy programming being offered, whether it's looking at constellations . . . We have an astronomy club of high schoolers who teach astronomy to elementary kids. (Community group leade

- The OSS E/PO Effort has partnered with leaders within networks of users, individuals who share the knowledge they receive at OSS workshops with other community group leaders, librarians, etc. Disseminating OSS E/PO information through these leaders increases the scope of OSS PD. In addition, the leaders are

SOLAR SYSTEM AMBASSADORS (SSA) PROGRAM

The Solar System Ambassadors (SSA) Program, based at the Jet Propulsion Laboratory (JPL) in Pasadena, CA, is a public outreach program designed to work with motivated volunteers across the nation. Ambassadors are asked to organize and conduct public events that communicate exciting discoveries and plans for exploration in SSE research and technology to the general public in a number of venues.

Ambassadors range from retired space scientists, to classroom teachers, to enthusiastic amateur astronomers. Ambassadors receive an initial intensive training, which is followed up with monthly on-line trainings, usually involving a guest speaker from NASA. The on-line trainings provide a means of motivation to engage the SSAs in the program, as well as increase their space science content knowledge. Ambassadors are provided with up-to-date information on missions, and with materials and resources to share with their audiences.

The SSA program provides a vehicle for space science information to be shared with the broader community. Ambassadors are required to hold a minimum of four events per year on the missions that support the SSA program. Each ambassador gets to decide where, when, and how they present the information.

The SSA program includes a number of attributes that maximize the positive impact on both the ambassadors and the audiences to which they present space science content:

- The program leverages pre-existing interest in space science, both in terms of the ambassadors themselves and the individuals who show up at ambassadors' presentations.
- The program is flexible and allows SSAs to conduct presentations in ways that utilize their own strengths and interests, and that are appropriate for the particular venues and audiences at their presentations.
- There is long-term professional development provided to SSAs. Topics are based on the participants' interests, and often involve interaction with a NASA scientist or engineer.
- There are a number of communication vehicles to keep the SSAs informed, engaged, and connected. These include monthly trainings, on-line posting of trainings, a calendar of events, a newsletter, and a listserv.

members of the audience being served and have experienced the needs and constraints of the audience firsthand.

> Having them sharing the activities as they have . . . [with] the girls can be real enlightening for the new ones, and the 40 of us who came are representative from all over the US. It would help to make the transition. Those guys are from NASA and they are not [members of our community]. (Community group leader)

> Most of us were very pleased with the presentation of the workshop; [they] didn't make us feel dumb or inadequate; we were amazed at some of the things.(Librarian)

- OSS supports its own networks of volunteer ambassadors who share space science findings with the public in a variety of venues. Data suggest that the ambassadors are effective at using OSS materials to stimulate and inform the public.

  I reach the more casual fan, which is the one you really need to be informing. Most of them will tell you that they support the program in principal but they had no idea what is going on and would never have sought on the information if I had not brought it to their attention. (Ambassador)

- OSS offers activities to the public that engage various modalities, including imagery, hands-on, and auditory components, reaching a wider range of learners than would more traditional materials.

  Visual and hands-on activities leave the participants with more vivid memories. I think this stays with them longer. (Ambassador)

- OSS resources utilize media such as television, newspapers, magazines, and radio to expand its impact beyond those who can personally attend OSS E/PO events.

  You name it, we're doing it: Radio, TV, traveling exhibits. (Scientist)

- OSS has a large presence on the Internet. All of the SN institutions and many missions have Web pages that share educational material about OSS.

  Things I get by going directly to the mission Web sites. Right now I'm looking for Mars images for posters. So direct links where new images are available are very useful. We just want people to have interesting images. (Museum staff member)

  - Virtually every person in our data sample has visited OSS or NASA Web sites. Many users report that OSS Web-based resources are extremely effective and are the most efficient way of getting up-to-date space science information.

    I get the latest research and see what is being done. (Teacher)

    [On-line OSS material] is always recent. That's the nature of something coming off the Web site. I'm using materials just recently listed. (Museum staff member)

  - On the other hand, a small but significant subset of users report challenges arising from the format and content of OSS Web pages. These challenges make it difficult for users to find and use the information they seek.

    - Each institution within the SN and many individual missions maintain their own Web sites, with little central coordination of Web pages. Users report that non-standard formats make it difficult to navigate through the NASA Web pages to find what they need.

> It's a big Web site with lots of stuff. Sometimes I get lost in there for hours, going from place to place, and then I don't remember why I went there. (Teacher)

- Users report that the content of some pages is too complicated to be useful. Some pages provide little context for information presented; others assume a great deal of pre-existing knowledge.

> The sheer volume of stuff on the sites is a barrier to usefulness. Make an interface for educators that won't pull up tech facts.(Teacher)

- The OSS E/PO Effort has expanded its public outreach to include resources at public spaces; for example, a permanent scale model of the solar system on the National Mall in Washington DC and traveling exhibitions at shopping plazas and theme parks reach a population beyond those that are exposed to space science in school or at museums.
- Because OSS is developing inroads into new communities, there is a need to be proactive in reaching out to users and informing them of opportunities. Data suggest that marketing is more pressing when reaching out to learners beyond the classroom and the museum. Some community group members report difficulty finding information about workshops or resources.

> I would not have known about this if I had not heard about it through the grapevine. I'm not sure there was much coverage about it in the paper. It's important that they create an awareness of the program and that would be beneficial. (Librarian)

Reactions of the public to such events as the Mars rover landings are indicative of the excitement that space science can generate. The OSS E/PO Effort is taking steps to leverage that excitement to create resources that impact the public.

SCIENTISTS

IMPACT: Increasing the involvement, commitment, and effectiveness of scientists in space science education

Analysis indicates that resources that have impact on scientists have the following attributes:

- Appropriate to individual scientists' needs and constraints
- Respectful of scientists' time limitations
- Supported by education experts
- Recognized by the scientific community as important
- Contributing to the body of scientific knowledge

Engaging scientists in education and public outreach has been one of the stated goals of the current OSS E/PO Effort since its inception. Data indicate that scientist involvement in education has been steadily increasing since the development of the current OSS E/PO Effort.

> I have evidence that scientists have bought into the E/PO Effort. The change has been so significant that I think there would still be education going on in space science research even if the Support Network went away. (SN member)

> I think the change is very positive. The number of resistant scientists is small and decreasing. I think the community is seeing the importance of using space science to grab young people's attention. (Scientist)

As discussed in the earlier PERG evaluation reports, most extensively in the August 2001 report,[20] the scientific culture (and the culture of NASA itself) has traditionally presented many challenges to scientist engagement in education. OSS has successfully taken steps to make involvement in education more attractive to scientists, including:

- Providing PD for scientists who want to learn more about E/PO or who want support in developing proposals
- Creating an infrastructure to support scientist involvement; for example, the B/Fs work with scientists to develop connections within the education community to leverage and amplify scientists' contributions

20 *The OSS Education Public Outreach Effort Evaluation Report*, 2001, pp. 6–22.

GOLDSTONE APPLE VALLEY RADIO TELESCOPE (GAVRT) PROJECT

The Goldstone Apple Valley Radio Telescope (GAVRT) Project is a partnership involving NASA, JPL, The Lewis Center for Educational Research (LCER), and the Apple Valley Unified School District. The GAVRT project utilizes a decommissioned 34-meter radio telescope at the Goldstone tracking station in CA's Mojave Desert.

Teachers attend a six-day training at LCER where they learn the fundamentals of radio astronomy; are given instruction in how to use the telescope remotely to collect data, analyze these data, and share the results; and receive guidelines for using a variety of activities and curriculum units covering space science areas related to space science in general and radio astronomy in particular.

The teachers use their new knowledge to teach their students about space science and radio astronomy. Students have the opportunity to collect data via the Internet using the radio telescope under the guidance of their teacher and with remote support from GAVRT engineers. These data are used by JPL scientists who are doing primary research in various areas. For example, students around the country helped map the surface of Mars to identify potential landing sites for the Mars Exploration Rovers.

- The design of the program benefits both the educational community and the scientific community:
  - Teachers say that they feel more comfortable with space science and with space scientists as a result of their interactions via the GAVRT program.
  - Students are extremely enthusiastic about the program and eager to work on the telescope; teachers report increases in excitement, interest, and efficacy. The program reaches students at a range of preparedness and is effective with special needs students.
  - Scientists report that participation in the program has helped them with their own research. It has provided more data than they could collect themselves and has connected them to other scientists working in similar fields.
- The GAVRT program has been successful at developing and utilizing partnerships, on a variety of levels: Administratively, in the relation between scientists and teachers, and in the classroom. Students experience first-hand the benefits and challenges of working as a team to collect and analyze data.
- GAVRT lesson plans are organized by standards (national & CA). The activity book identifies the major themes and ideas in each activity. It provides teachers with sufficient information and flexibility to align the material with regional standards

- Designing educational programs that have the explicit goal of benefiting the scientific community while increasing science awareness in the lay population

> It seemed like they could help me out by collecting data more frequently than I could at an observatory. (Scientist)

> It's the first educational program I encountered where they said one of their goals was to do publishable science. (Scientist)

- Becoming more sensitive to the constraints scientists face

> I encourage them to do what they feel most comfortable doing. They don't have to give talks, work with kids, etc. We will work with them to fit in the work with what they do best. (Program coordinator)

- Mandating that each mission dedicate 1–2% of its budget to E/PO

As more scientists devote time to education, the scientific community places more value on involvement in education, further increasing participation. Scientists report that their involvement with E/PO provides networking opportunities with others sharing their interests.

> It's been professionally rewarding, providing me with a framework to contact other researchers who I might not otherwise talk to. (Scientist)

The culture change within NASA has had an impact on the larger scientific community, which is providing more formal recognition of scientists' educational contributions; this is particularly important for younger scientists who want to move forward in their field.

> I think the community is seeing the importance of using space science as the way to grab young people's attention, just to get them turned on to science, math, and engineering in general . . . It's working better and better as time goes on. (Scientist)

The context in which the OSS E/PO Effort is working has fundamentally changed. There has been a groundswell of support in various organizations. For example:

- Astronomy Education Review (a new refereed journal sponsored by the American Astronomical Society and the Astronomical Society of the Pacific) provides a vehicle for recognizing scientists who have contributed to science education.
- The International Astronomical Union recently passed a resolution recognizing and acknowledging the value of astronomy education.
- The American Geological Union has changed rules for submitting papers for their conventions; scientists can now submit both a scientific paper and a paper on education.

When OSS began implementing its current E/PO strategy, there was a great deal of resistance. Data collected at that time indicated that many scientists held negative attitudes about education.[21] Current research on organizational development indicates that culture change is a slow process and requires learning at a systems level that is fueled by the experience and competencies of members of the culture.[22] Data show clearly that OSS has made great progress in creating a more positive environment for scientists who wish to participate in E/PO. However, attitude change has not been consistent throughout the scientific community. Despite

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[21] See the first PERG evaluation report, 2000, pp. 14–15, 28–30, and the second PERG evaluation report, 2001, pp. 8–13 for a more in-depth discussion of this topic.

[22] Gerhard, M.A., Marsick, V. J., Van Buren, M.E., and Spiro, M. S. (1996). Learning Organizations Come Alive. *Training & Development*, 50 (12), 35–45.

increasing awareness of the benefits of involvement with E/PO, scientists report that they still face a variety of challenges:

- NASA scientists have a great many demands on their time. Mission science deadlines take priority, leaving little or no time for E/PO activities.

  > Education products or endeavors are seen as a time sink by the scientist members of the team . . . If you ask [the PI], he would say he is interested in educational outreach, but in terms of what he needs to spend time on right now, it's analyzing the data. (E/PO lead)

- Some scientists express a desire to get involved, but say they need the support of others who can make the most of their contributions.

  > I want to help with E/PO work, but I can only commit a fraction of my time. I want to contribute and I want my time to be well used, but I don't want to be required to learn all about the educational system to do so. (Scientist)

- Another challenge articulated by scientists is the difficulty of understanding the system for reviewing E/PO proposals. While scientists responding to Announcements of Opportunity[23] may have education experts to help with their E/PO proposals, some of those responding to NASA Research Announcements[24] report that they are responsible for developing the E/PO aspect of the proposal themselves and need more support in understanding and meeting the criteria for acceptance. They also express a desire to see examples of proposals that have been funded.

  > I feel like I'm really at a disadvantage there. I don't know what they mean. It's all this sort of coded language and it's difficult to figure out. (Scientist)

  > It's largely a mystery to me, so it was difficult to know whether we were hitting the target that the reviewers had in mind. (Scientist)

The increase in scientist involvement in the OSS E/PO Effort has had a number of positive impacts on E/PO resource development, such as ensuring scientific accuracy, allowing for scientist-educator partnerships, and providing opportunities for the public to hear about space science from those directly involved with research.

[23] Announcements of Opportunity (AOs) are requests for proposals to participate in NASA missions.

[24] NASA Research Announcements (NRAs) are requests for proposals for grants for Supporting Research.

THE SUPPORT NETWORK AND E/PO DEVELOPERS

IMPACT: Having impact on each audience *as defined by the audience itself,* while remaining flexible enough to adapt to changing audience needs, and meeting NASA and OSS E/PO goals

Analysis indicates that resources that have impact in the OSS E/PO community should have the following attributes:

- Providing sufficient information to all parties involved
- Supported by coherent communication system
- Supported by appropriate PD
- Leveraging the resources within the system and within the science and education communities
- Providing guidelines for effective decision-making at all levels
- Including a readily-accessible shared body of knowledge
- Influenced by information from audience members
- Allowing fiscal predictability

The OSS E/PO Effort has consistently shown a capacity to identify and solve problems as they arise. This capacity is present at all levels, from the administration, through the Forums and Brokers, to the individuals within these institutions.

> [The Effort has been] getting started, implementing, and now having impact. I think we've been flexible, which is useful. Our main focus now is increasing our impact. (SN member)

> We've got a lot of freedom to define what we're going to do; I think that's energizing. I think the fact that there is the ability to have top-down *and* the bottom-up approach encourages people to do it in a way that work for them.(SN member)

The way in which the Effort addresses problems has a significant impact on both the Effort itself and the audiences it serves. As the Effort has grown, SN members and the SScAC Task Force have suggested a number of steps to enhance the impact of the system, several of which are currently being implemented:

DESIGNING PROFESSIONAL DEVELOPMENT FOR TEACHERS OF SCIENCE AND MATHEMATICS

In Spring 2003, The Structure and Evolution of the Universe Forum (SEU) provided support for its E/PO developers to attend a week-long institute on "Designing Professional Development for Teachers of Science and Mathematics," which was offered by WestEd consultants. The goals of the workshop, as articulated by the PD institute literature, were to "Develop a coherent PD experience that explore SEU themes; develop a better understanding of the PD design; learn strategies for facilitation skills as professional developers; develop a share vision of inquiry; learn strategies for engaging diverse learners; [learn] how to evaluate a PD experience."

The SEU E/PO developers worked together in a facilitated team. In addition to teamwork sessions, the institute included large group activities and presentations on a variety of topics including:

- Professional development strategies and design
- Communication skills
- Educational pedagogy
- Mentoring

The institute was a successful event for the SEU Forum. During the course of the institute, participants drafted the SEU story, developed a strategic plan for the Forum, and designed strategies to develop workshops for a range of audiences. The institute impacted participants on a variety of levels:

- Allowing individuals in the group to participate in the process of creating goals and designing the Forum's action plan, motivating them and providing them with a sense of ownership of the process
- Increasing the expertise within the system by:
  - teaching developers how to create effective professional development opportunities
  - increasing their understanding of educational strategies and pedagogies
  - improving meeting and facilitation skills
- Building relationships across the SEU E/PO community
- Working directly with the audiences they are developing resources for (including the formal education community) and learning their needs and constraints

- A professional development program for SN members, E/PO staff, and scientists to create a shared understanding of current educational research and best practices; a working group has been formed to design an implementation plan for PD
- The development of a coherent approach to guide the work of all aspects of the OSS E/PO Effort; a leadership group has begun to lay the groundwork for a framework (discussed on page 16) to provide such coherence
- A Support Network-wide calendar, comprising activities that each institution deems most important, to address the challenge of sharing information about resources that are available or under development

- A formal system to ensure regular communication between Forums and B/Fs and allow B/Fs to get involved early in the development of major SN and E/PO activities

Rapid growth in large systems has a tendency to exacerbate communication and coordination challenges. These challenges are articulated in the Task Force report,[25] which states that "in a system as diverse and geographically distributed as the OSS E/PO Effort has become, clear and efficient communication is essential."

> I think the focus right now needs to be on us working together more. That's happening, but I wish it were happening faster. I think after five years, Forums and B/Fs should be more aware of each other's activities. That's been slow to happen. (SN member)

The SN, with its Forums and B/Fs, was conceptualized as a flexible system. The OSS E/PO Effort has shown itself able to change and adapt to meet challenges, to grow quickly when appropriate, and to drop strategies that are ineffective. Various individuals throughout the Support Network have indicated that it has taken them time to operationalize their roles and therefore to serve the system's audiences.

> The confusion is in our role. It's fine if [the administration] wants to encourage everyone to do their own thing. But what exactly are we supposed to be doing? (SN Member)

Over the past year, there have been a number of Forum and Broker retreats, as well as meetings of individual institutions within the system, to improve communication and clarify roles. Data indicate that the OSS E/PO Effort is developing a clearer understanding about the roles of the Forums and B/Fs and the functioning of the SN.

> Our role has become much clearer. And we've become more known and helpful to the missions, in particular. Connections with the Forums are getting better after this past retreat. (SN Member)

Data indicate that members of the OSS E/PO Effort have greatly increased their collaboration with audience groups and education experts. Consequently, many individuals within the Effort have acquired a knowledge base about user needs and effective resource development. This knowledge base holds potential as an extremely valuable resource to aid all members of the Effort in creating resources that have impact on users.

SN members, scientists, and E/PO staff report that information is not systematically communicated. Because the Effort lacks a coherent system for sharing information, some members of the E/PO Effort have incomplete access to expertise present within the system that

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[25] *Implementing the Office of Space Science Education/Public Outreach Strategy: A Critical Evaluation at the Six-Year Mark*, 2003, p. 16.

could support them in developing effective resources, and to information about what resources are currently available.

> We need to be better at communicating what we've learned from the collaborators to the rest of the Support Network. (SN member)

> It would be so cool if I could get an idea ahead of time who's doing PD, and who's involved and what type of teachers. (SN member)

Data suggest that time and energy are critical resources for supporting communications systems and knowledge sharing. Several SN members indicated that conflicting demands prevent them from devoting resources to community building.

> I wish we had more time to mentor these groups into the system. Maybe [the administration] could assign a Forum and a Broker that are tasked with mentoring each new Broker. That would probably save money overall. (SN member)

As the system expands, members of the OSS E/PO Effort report a growing awareness of the need for criteria and tools to assess the impact of the resources and programs created by the OSS E/PO Effort. Each Forum has either internal staff who are expert in assessment or outside consultants to assess their products. In addition, some larger missions have assessment staff[26]. Forums, programs, and missions with trained assessment staff have instituted regular assessment and user feedback, with the intention of creating effective resources that meet user needs.

> We have a product review system. We look for what's good, where are the gaps. We do our own internal review . . . Two aspects of review: Give it to teachers and see what they think of it. What grade level would they use it for? Would they use it in the classroom? Then give it to scientists, make sure it's up-to-date and accurate. (SN Member)

Leads on smaller missions and programs funded by E/PO Grants to Supplementary Research Awards report that financial constraints often preclude the hiring of assessment experts. Some E/PO leads report that they have developed their own ad hoc assessment programs, despite having little or no expertise in the area. Consequently, resource assessment is inconsistently implemented across the system.

> We don't have a credentialing system. You're sort of making it up as you go along. You wouldn't do this in science. [We] need to learn the literature, not reinvent the wheel. (Scientist)

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[26] To avoid confusion with the term "program evaluation" which is a larger effort encompassing the entire OSS E/PO Effort, this report uses the word "assessment" to refer to assessment of specific resources. The terms "evaluation" and "assessment" are often used interchangeably, and several of the people quoted in this report use the term "evaluation" to refer to assessment of individual resources.

Data indicate that the lack of consistent assessment and feedback on resources has caused some smaller programs to implement a trial-and-error approach to resource development. At present, there is no coherent and consistent method for distinguishing between resources that have impact on users and those that are less effective.

> There is a systematic review of instruments on spacecraft, letting NASA know if something is ready for flight. There isn't anything like that for E/PO. (E/PO lead)

Funding challenges are a reality for anyone working on soft money. Data suggest that missions often lack sufficient money to cover scientific needs, and so tap into E/PO funds. This leads to a lack of predictability, which is cited as a challenge by E/PO leads who are working to create resources that can be integrated into a coherent framework.

> For me, budgets are constantly coming and going. I'm at the whim of the mission funding. (Program manager)

The OSS E/PO Effort has shown itself to be capable of meeting the challenges described above. All of these problems have been solved *by discrete entities within the system*. The challenge now facing OSS is the development of a consistent and systematic method to ensure that the solutions that are working locally are applied to the larger E/PO Effort.

RECOMMENDATIONS

The OSS E/PO Effort has shown itself to be adaptable and responsive to the needs of its members, its environment, and its audiences. Over the tenure of the current E/PO Effort, it has consistently moved to better itself as it grows in size and in awareness of user needs. Data suggest several other actions might be helpful to increase capacity for user impact.

Many of the steps that would best further the goals of the OSS E/PO Effort have already been suggested by the Effort itself or by the SScAC Task Force; several have already been implemented. The following recommendations are strongly suggested by this PERG evaluation.

CREATE COHERENCE FOR USERS

Many audience members report confusion and frustration when trying to find OSS resources to meet their needs. They have difficulty navigating the Web sites, finding the appropriate contact person, and getting access to physical resources. Both scientists and E/PO developers share this frustration, as do the formal and informal educators the system is designed to serve. The OSS E/PO Effort can take several steps to make itself more user-friendly:

- Focus effort and energy on the development of a space science framework. Both the Task Force and the SN itself have recognized the need for a space science education framework. As stated in the Task Force report,[27] this framework would serve "to develop a bridge between the science and mathematics of OSS missions and research and the needs of the educational system." Data gathered for the current evaluation strongly support this recommendation. The first step toward developing a framework is to create a shared understanding of what such a framework should accomplish.
- Once the space science framework has been formalized, establish (and possibly mandate) guidelines for development to ensure that gaps in the body of space science E/PO resources will be filled and redundancies minimized.
- Expand the effort to use and unify Forum Themes to create coherent stories, aligned with space science standards; these stories could form the underpinnings of the space science framework.

[27] *Implementing the Office of Space Science Education/Public Outreach Strategy: A Critical Evaluation at the Six-Year Mark*, 2003, p. 10.

- Develop a consistent template for OSS educational Web sites and a coherent network of links to move between them.

PROVIDE PROFESSIONAL DEVELOPMENT FOR E/PO STAFF

Many individuals and institutions within the SN have already acknowledged the benefits of working with education experts to expand their own understanding of user needs and E/PO resource development. Others, who may not have had the opportunity to develop their skills in this area, admit their limited understanding of current educational theory and practice. The Task Force report[28] suggested strengthening and expanding current professional development efforts. Our data support this suggestion, and provide some pointers for the development of PD that will have maximum impact on OSS E/PO developers and users.

Development of a coherent PD program should rely on data from:

- Users, who can provide information about what needs are unmet by existing resources
- SN members and E/PO developers, who can provide information about what types of PD would be most attractive and useful to them
- Existing research, which can provide information about what resource development strategies are likely to work and which are likely to be less effective

Making PD opportunities available to *all* individuals who are involved with E/PO development can provide knowledge, skills, and confidence to create resources that have impact on their users.

- Forum staff would benefit from PD that allows them to develop, support, and disseminate educational resources, including materials that align with the space science framework and appropriate PD for users of these materials.
- B/F staff would benefit from PD that allows them to more fully understand the needs of the user groups they serve and to develop effective strategies for meeting those needs.
- E/PO leads would benefit from PD that provides them with the nuts and bolts of resource development and assessment so that they have the tools needed to create effective resources, including pedagogically-appropriate materials and appropriate PD for end-users.

28 Implementing the Office of Space Science Education/Public Outreach Strategy: A Critical Evaluation at the Six-Year Mark, 2003, p. 15.

- Scientists would benefit from PD that provides them with a basic understanding of current education research and pedagogy so they can understand how their own expertise can best be used.
- The entire system would benefit from PD in cultural competency so that they can develop the tools they need to reach underserved populations.

CREATE A LIBRARY OF SHARED KNOWLEDGE

The OSS E/PO community has recognized and articulated the need to create a system that provides the OSS E/PO community easy access to the E/PO Effort's knowledge base about the attributes of successful resources. A unified repository would provide a single access point for developers seeking information. The library might include:

- Relevant current research about best practices in educational resource development, PD, and applications of science in formal and informal settings
- Information about building and sustaining partnerships that prove fruitful for the various populations served by the OSS E/PO (education, libraries, scientists, community-based organizations, after-school programs, etc.)
- Histories of OSS resource development, including mistakes that should be avoided and procedures which led to success
- Information about space science educational materials developed beyond OSS; such information is essential to identifying gaps in existing resources; in addition, exemplary resources can serve as models for OSS E/PO developers
- Personnel lists and protocols from successful E/PO projects that can be accessed for future development

INTEGRATE EVALUATION AND ASSESSMENT

While the OSS E/PO Effort as a whole benefits from external program evaluation, and E/PO programs with relatively large budgets usually have dedicated assessment staff, there is not a systematic method for assessing the effectiveness of individual resources. A more consistent assessment effort would provide useful information for developers refining existing resources or creating new ones. It would also allow the OSS E/PO Effort to highlight its own successes to

the larger NASA community. The Task Force report[29] has acknowledged the need for more stringent resource assessment. Actions to address this need include the following:

- Support the practice of creating review panels with both educators and scientists; such panels allow assessment of both the pedagogical appropriateness and scientific content of resources.
- Pilot materials before wider distribution; this might best be accomplished using networks of educators, which are already being fostered by some institutions within the SN.
- Undertake a meta-analysis of existing assessment and evaluation efforts to determine the areas of greatest need and identify exemplary models.
- Mandate a specific level of support for evaluation in large programs (NSF mandates 10%) to ensure that major educational efforts receive appropriate assessment at all points of development and dissemination.
- Develop templates and assessment tools that can be utilized by smaller E/PO programs unable to develop individualized evaluation programs.
- Make assessment staff (and evaluation consultants) available to E/PO staff to provide support and consultation in developing assessment plans.
- Provide PD in assessment for all E/PO developers so that they can make informed decisions about assessment activities.

[29] *Implementing the Office of Space Science Education/Public Outreach Strategy: A Critical Evaluation at the Six-Year Mark*, 2003, p. 13.

CONCLUDING REMARKS

The OSS E/PO Effort has made remarkable progress during its relatively short tenure. It has expanded its reach both in terms of the number of individuals within NASA who support and contribute to education and public outreach and in terms of the range and diversity of audiences served by the resources it creates.

The system has been increasingly responsive to the needs and constraints of its audiences, with the result that it has been able to create resources that have greater impact on those they are meant to serve. This has led to a greater willingness on the part of users to utilize OSS E/PO resources and to partner with the Effort to create further materials. In particular, OSS has been proactive in reaching out to audiences that have traditionally been underserved by space science education resources. This has led to a number of important partnerships between the traditional space science research community and minority researchers and educators who are working to translate OSS content into educational resources that impact an ever-widening audience.

The members of the Support Network and the larger community of E/PO developers have consistently shown an ability and readiness to acknowledge and solve the communication and coherence problems that are the inevitable outcome of such rapid growth. The OSS E/PO Effort is taking steps to increase coherence: It is supporting the creation of a framework to organize the efforts of the growing OSS E/PO community, and it is planning a professional development program for those involved with E/PO development. PERG's findings support taking these steps, as well as steps to enhance resource assessment and improve the flow of information throughout and beyond the OSS E/PO Effort.

Data indicate that the Effort is highly effective at improving and strengthening itself. Many of the problems identified by PERG in the early stages of the program have been dealt with proactively and effectively. There is strong evidence that the system will continue to expand, adapt, and evolve over time, allowing it to have impact on the educational community by providing pedagogically sound, up-to-date space science E/PO resources . . . as only NASA can.

APPENDICES

APPENDIX A
COMMENTARY: COHERENCE

The Office of Space Science Education and Public Outreach has taken on a rare challenge and made startling progress towards its E/PO goals, as evidenced in this report. Its capacity for creating an effective infrastructure by identifying and addressing problems and opportunities has been documented previously by PERG and the SScAC Task Force reports. The challenges of:

- defining and understanding target audiences;
- establishing a collaborative E/PO community;
- managing conflict and change within that community; and
- clarifying roles, responsibilities and outcomes

either have been, or are being, addressed.

All of these accomplishments are necessary for the OSS E/PO to conduct its work effectively. But they are not sufficient.

The pathway to achieving the elusive goal of coherence still remains. Coherence is a term that has been raised repeatedly over the last few years. It has been named as a goal and an indicator of success. Coherence is a descriptor that in the case of the OSS E/PO, applies to a highly functioning system of resources which relate logically and obviously to one another. Coherence does not just happen in programs. It results from a set of carefully orchestrated strategies that include professional development, guidelines, shared information resources and data, and some fundamental agreements or principles that define the parameters of the work. Most important is that all those working in the system have similar ideas about their purposes and the content of their work, and adequate measures for determining their progress and success.

Examples or models of coherence that resemble the OSS E/PO effort are sparse, but there are some programs that have moved from an idea to a full, coherent organization over 5-8 years.

For example:

One organization committed itself to working with school districts to adopt and implement a range of quality mathematics and/or science curricula. They had no knowledge base about such an undertaking, only some funding. They set up a system for selecting and funding school districts interested in curriculum reform and found out that the districts didn't know much about curriculum but did want the funds. So they set up a curriculum showcase, with some choice curricula in each content area and representatives who could talk with district staff about each curriculum and demonstrate its benefits. Soon these folks were faced with the need to determine how well the funded districts were doing, whether they were spending the money well and implementing curriculum appropriately. They realized that they needed lots of professional development for teachers, but didn't know what kind or what it should do. They also saw that

principals were a problem, that school-based leadership was a problem, and that the expansion of participating districts over the years created huge management challenges. They hired staff to mentor and monitor districts and funded curriculum specialists to help teachers manage the implementation in lots of school districts.

Over the years, they realized that curriculum adoption and implementation required its own infrastructure, both within the school districts and at the regional, and even national, levels. And they learned that curriculum adoption and implementation was a new and critical area of research and knowledge generation.

The process required at a minimum:

- Multiple types of specially-trained folks to help school districts select the curriculum and integrate it into existing district standards and other ongoing curriculum materials;
- Each subject area required its own specialists;
- Teachers required an array of professional development experiences that responded to teachers at different levels of experience, provided content knowledge for novice and experienced teachers, and recognized teachers' years of working with the curriculum;
- Professional development for principals and superintendents that addressed their own specific needs;
- Addressing the need for information about the expanding collection of quality science and mathematics curricula emerging from NSF and other funding, which gave birth to a document or guide for school districts interested in adopting and implementing these curricula;
- Districts required support for matching curriculum K–12 that would relate to one another and help students progress in their skill and content learning throughout their schooling; and
- School districts required outreach to parents that demonstrated the curriculum and provided ongoing information about its benefits for students and the community, including the private sector.

Each structure in this system was designed in relation to the emerging needs and supported all of the other resources. Together, the program team determined that the collection of resources were both necessary and sufficient to accomplish the goals.

That is coherence in action.

The task before the OSS E/PO is to take the big idea of the education effort and transform it into the various forms required by the mix of populations the Effort is serving. The big idea is Space Science, which is abstractly identified by the Forum themes; the challenge is to make it rational and understandable for non-space scientist groups. While the organization of the NASA

Office of Space Science may be complex, the organization of space science information does not have to be. The community is engaged in creating a framework for the collection of findings which have resulted from the space science missions. Those findings integrate into the various Forum themes and the questions that identify each Forum's particular research concentration. The structure suggested by the Forum themes and the resulting findings from the theme-related missions is similar to the structure of many of the hands-on physics curricula, such as FOSS. Perhaps creating kits for particular themes (which could be called strands) is one approach to building coherence into resource organization and production process.

The OSS E/PO SN and others have identified three strategies that will contribute substantially to building a coherent system. Professional development for all OSS E/PO participants and a system for resource development guided by clear criteria and assessed for quality are the next steps the OSS E/PO system must take in its effort to create coherence. The concept requires that the community make choices about the types of resources they should develop, the range of most useful formats based on user needs, the criteria or set of ideas that should guide the process. They should also create the resource assessment process and focus on dissemination strategies that are efficient and effective for the audiences the system serves.

This commentary was intended to reflect a bit on what coherence for the OSS E/PO Effort means and what next steps are necessary for reaching that state. Bringing coherence to programs that have multiple goals and audiences is very challenging. Coherence is not a permanent state; it requires conscious and continuous nurturing and management. It enables people to work effectively to both maintain the system and manage internal changes.

The greatest challenges to coherence in education-related programs are significant changes in external conditions, such as education policy, accountability structures, and new social priorities. There is always a lag time between a significant change and its impact on the education system, time that forces programs to suspend or slow their work until they can make sense of the consequences of the shifts for their work. To be sustainable, a program must have the capacity to stay current and adapt, without compromising the core of the work and its contribution to education and the other populations. Coherence is the glue that holds the central purpose and program values together.

APPENDIX B
EXCERPT ON THE CONCEPT OF COLLABORATION

All quotes taken from:

Gray, Barbara. (1989). Collaborating: Finding Common Ground for Multiparty Problems. San Fransisco: Jossey-Bass.

Collaboration is essentially an emergent process rather than a prescribed state of organization. By viewing collaboration as a process, it becomes possible to describe its origins and development as well as how its organization changes over time. Hence, collaboration can be thought of as a temporary and evolving forum for addressing a problem. Typically, collaborations progress from "underorganized systems" in which individual stakeholders act independently, if at all, with respect to the program (Brown, 1980) to more tightly organized relationships characterized by concerted decision making among stakeholders. (p. 15)

Once initiated collaboration creates a temporary forum within which consensus about the problem can be sought, mutually agreeable solutions can be invented, and collective actions to implement the solutions can be taken. Understanding how this process unfolds is critical to successfully managing the kinds of multiparty and multiorganizational relations described earlier in the chapter.

Envisioning interorganizational relations as processes rather than as outcomes in which stakeholders assume decision making responsibility for their collective future permits investigation of how innovation and change in currently unsatisfactory exchange relationships can occur. IF COLLABORATION IS SUCCESSFUL, NEW SOLUTIONS EMERGE THAT NO SINGLE PARTY COULD HAVE ENVISIONED AND ENACTED (emphasis added). (p. 16)

A kaleidoscope is a useful image to envision what joint appreciation of a domain is all about. As the kaleidoscope is rotated different configurations of the same collection of colored shapes appear. Collaboration involves building a common understanding of how these images appear from their respective points of view. This understanding forms the basis for choosing a collective course of action. (p. 5)