Education and Public Outreach

Unique Education and Public Outreach (E/PO) opportunities are associated with Sun-Solar System Connection science. The top-level objectives, research focus areas. and science achievements that constitute the Sun-Solar System Connection Strategic Roadmap for the next 30 years provide powerful opportunities for Education and Public Outreach from the SSSC scientific community.

We recommend that E/PO activities stemming from the science achievements be developed to support the following five themes:

- **NASA keeps me informed about what's going on with the Sun**
- **The Solar System is an Astrophysical Laboratory for NASA**
- **NASA science helps us protect our society from hazardous space weather**
- **NASA science helps us understand climate change**
- **NASA science helps keep space explorers safe and supports exploration activities**

These messages are of high interest and relevance to the public and they span the range of scientific activity engaged in by the SSSC community. The traceability to the SSSC science and exploration objectives is clear. Chart A shows the logical flow-down outlining how the SSSC scientific objectives and associated research focus areas lead to the five E/PO themes. The themes then inform the implementation of programs of formal and informal education and public outreach.

The anticipated scientific achievements articulated in Part II Chapter 2 for each of the next three decades that relate most clearly to these themes are shown in Table B. The themes and achievements are color coded to show the most direct links. Table B also identifies the missions that are most closely associated with the achievements and themes.

An expanded and invigorated education and public outreach is essential to the achievement of the Vision for Space Exploration (VSE). NASA's Strategic Objective for Education and Public Outreach is to "Use NASA missions and other activities to inspire and motivate the nation's students and teachers, to engage and educate the public, and to advance the scientific and technological capabilities of the nation." The SSSC community emphasizes the connection between achievement of this strategic objective and the Vision for Space Exploration. The development of the workforce needed to achieve NASA's vision requires that E/PO activities engage young people and capture their interest and passion. We need to increase the capacity of our nation's education systems, both in school (Formal: K-16) and out of school (Informal), to prepare students for scientific and engineering careers.

SSSC science and mission activities provide valuable hooks for E/PO. For example, learning to predict the variable radiation hazards and space weather conditions that our astronauts and robots will encounter on excursions to the Moon, Mars, and elsewhere is very exciting scientific work that the public will want to know about. New advances using our Sun and solar system as astrophysical laboratories will fuel the generation of authentic, science-rich education resources that will increase the capacity of the nation's education systems.

Developing the workforce to implement the VSE will require substantial focus on underrepresented communities. The current demographic makeup of the science and engineering workforce in the USA is overwhelmingly white. Population projections to 2025 indicate that the percentage of traditionally underrepresented communities will increase. Successful E/PO efforts will benefit substantially by reaching presently under-represented groups.

An exciting example of E/PO targeted at underrepresented communities is NASA's Sun-Earth Connection Education Forum's (SECEF) Sun-Earth Day programming for 2005: *Ancient Observatories: Timeless Knowledge.* This broad program allowed NASA and Native American astrophysicists to share their research into the efforts of ancient cultures to understand the Sun and its affects on their lives, highlighting the importance of the Sun across the ages. Through programs such as these, SSSC scientists convey NASA's mission and research program activities to diverse audiences. Both English and Spanish language materials have been disseminated.

Integrate messages and utilize best-practice strategies for effective E/PO. Unification of NASA's scientific enterprise into the Science Mission Directorate presents opportunities for science education efforts all across NASA, including SSSC. While each NASA division, mission, and individual contributes unique content and experiences to E/PO; integration into a single science directorate has the potential to be more effective in terms of message and approach. Moving forward, it won't matter if it's Space Science, Earth Science, Solar Physics, Biological Research, or something else – the single 'brand' will be exciting, relevant NASA science. Furthermore, approaches to bring this content to the broadest possible audiences can take advantage of the best strategies of each of the former enterprises to create the strongest possible suites of products and programs. E/PO programs include the development of tools for evaluating quality and impact, in order to identify and disseminate best practices in E/PO.

The SSSC scientific community is vigorously engaged in E/PO and current E/PO efforts align well with SMD's education goals and priorities. SSSC E/PO programs already encourage the scientific community to share the excitement of their discoveries with the public. The programs enhance the quality of science, mathematics, and technology education. Efforts align with NASA's Science Mission Directorate's education goals and priorities to

inspire and motivate students to pursue careers in science, technology, engineering and mathematics (STEM) and to engage the public in shaping and sharing the experience of exploration and discovery.

E/PO activities are currently integrated throughout all the SSSC flight missions and research programs. As a result, a significant fraction of the SSSC research community contributes to a broad public understanding of the science and is directly involved in education at the pre-college and college level. Graduate student participation in SSSC research programs are enhanced by the Graduate Student Research Program, a cooperative program between NASA Education and the Science Mission Directorate. Vigorous E/PO programs also stem directly from various science programs within the SSSC community to effectively serve the needs of local communities.

Centralized efforts such as the Sun-Earth Connection Education Forum (SECEF; a partnership between NASA Goddard Space Flight Center and the University of California at Berkeley) strive to facilitate the involvement of SSSC scientists in E/PO activities and to establish strong and lasting partnerships with formal and informal education communities. These centralized efforts seek to develop a national network to identify high-leverage education and outreach opportunities and to support long-term partnerships. SECEF helps provide ready access to the products of SSSC science education and outreach programs. They also promote the participation of under-served and under-utilized groups in the SSSC science program by providing new opportunities for minorities and minority universities to compete for and participate in SSSC science missions, research, and education programs.

Sun-Earth Day

Sun-Earth Day is an annual national program supported by SECEF. Since 2001 the SSSC community has shared the science linking the Sun and Earth with educators, students, and the general public via informal learning centers, the Web, TV, and other media outlets through high-profile, well supported annual events. NASA science is connected to classrooms and museums in real time, and educational resources are disseminated via the Web and through NASA centers. In the context of an overarching emphasis on the Sun-Earth connection, a specific theme is created each year to continue to engage the public.

2001 - Having a Solar Blast

2002 - Celebrating the Spring Equinox

2003 - Live from the Aurora

2004 - Venus Transit

2005 - Ancient Observatories: Timeless Knowledge

2006 – Eclipse In a Different Light

Sun-Earth Day activities have broad reach. For example, the 2004 Sun-Earth Day website

received 40 million hits in 40 hours. There were 1000 news reports on various TV channels, including 40 interviews with NASA scientists. More than 12,000 packets of educational materials were distributed to teachers, museums, and amateur astronomers in support of the 2004 Sun-Earth day programming.

As part of the 2005 Sun-Earth Day program, the Ancient Observatories: Timeless Knowledge website (sunearthday.nasa.gov) and the Traditions of the Sun website (www.traditionsofthesun.org) were launched in fall 2004 to allow users to explore Chaco Canyon and other areas. Visited 500,000 times, these websites also highlight NASA research on the Sun and Native American solar practices within a larger historical and cultural context. Formal education programs engaged 75,000 teachers and 225,000 students, with all 10 NASA Centers hosting events. 100 NASA Explorer Schools also participated. Informal education efforts included programs hosted by 24 museums across the country and training for Girl Scout Master Leaders who ultimately engaged some 10,000 girl scouts in Sun-Earth Day activities. The culminating event for Sun-Earth Day 2005 was a live bilingual webcast from Chichen Itza, Mexico that reached thousands of Hispanic and Native American participants.

Examples of Strong Mission E/PO Programs: SOHO & IMAGE

SOHO, the Solar and Heliospheric Observatory mission, runs a vigorous program to disseminate images to informal audiences and to the media, regularly distributing near-real time images of the Sun (LASCO, EIT, and MDI images) on the Web, Weekly to the American Museum of Natural History's AstroBulletin, and to a variety of media publishers, including National Geographic. Sun and space weather 3-D/motion postcards (lenticulars) are a very popular tool for engaging students and the general public. Over 180,000 lenticulars have been distributed.

SOHO sponsors two model collaborations with educators and students. FiMS (Fellowships in Mathematics and Science), a partnership grant with the Pennsylvania Department of Education (in 3 school systems), provides a strong example of the power of working directly with the local formal education system. SOHO educators and scientists work with their local teachers to increase content knowledge and support their ability to develop and implement inquiry-based lessons tied to state standards and the current curriculum. The Endeavour program, a collaboration between SOHO/NASA and 18 school systems, gives teams of students real-life NASA problems to research. Students are supported by teacher team leaders that have been exposed to the content and training through professional development.

Efforts to broaden the reach of SOHO's E/PO efforts, including English and Spanish versions of presentations on the Dynamic Sun CD and of the build-your-own-spectroscope poster, have been very effective. In addition, SOHO brings the science and exploration of our Sun to the visually impaired through their ground-breaking "Touch the Sun" book.

IMAGE, the Imager for Magnetosphere-to-Aurora Global Exploration mission, has been at the forefront of providing teachers with math and space science classroom activities. The IMAGE team works hard to improve public awareness of space weather impacts and to improve student math skills. Its annual space math workbooks have been distributed to over 75,000 teachers through their *Space Weather* CD and their popular POETRY website (Public Outreach,

Education, Teaching and Reaching Youth; image.gsfc.nasa.gov/poetry). The Soda Bottle Magnetometer , designed by POETRY in 1997, has been a popular hands-on activity for millions of students and is a key element in the Student Observing Network (SON).

Recently, IMAGE created a new program called the 'Space Science Problem of the Week' that is distributed electronically to over 5000 teachers. These extra-credit math problems cover the entire gamut of science and engineering problems and give grade 7-12 students a hands-on and authentic math experience in solving key problems in SSSC science. IMAGE also sponsors the INSPIRE project which has allowed students of over 2000 high school teachers from North America and around the world to listen-in to low frequency radio signals called whistlers, that are made by Earth's magnetic field in space.

In informal education, IMAGE has created museum kiosks at the Houston Museum of Science, planetarium programs such as 'Force Five', and has contributed to the SECEF Space Weather museum exhibit, which collectively have brought SEC science and research to over 200,000 people annually.

E/PO Challenges and Recommendations

Strong opportunities exist to extend the power of SSSC science and related mission activities to engage and inspire students in formal education settings, audiences at informal learning centers, and the general public across the nation via the press and other communication outlets. Table C presents a summary of challenges to effective E/PO and a series of recommendations to expand and enhance NASA's E/PO activities.

Table C. Challenges and recommendations to effective E/PO.

Challenge	Recommendation
E/PO practices vary widely across NASA. This is a disadvantage for both PIs and for audiences. PIs are often in the position of inventing their own E/PO programs, products and activities and audiences need to constantly relearn how to take advantage of these efforts.	Generate uniform, standards-based product lines with themed content for schools, museums, and science centers, as well as the press and media outlets. Invest production resources in development of core products that can be used appropriately by a range of E/PO partners.

The formal, K-12 science education system needs strong connections with NASA's scientific, engineering and technological enterprises if it is going to play sufficient role in preparing the science and engineering workforce required to implement and achieve the Vision for Space Exploration.	Correlate NASA's activities, enterprise-wide, with national science standards (e.g. National Science Education Standards of the NRC and Benchmarks for Scientific Literacy, Project 2061) to develop a roadmap for infusing NASA resources into the formal K-12 system. Middle School presents a particular opportunity due to the level of concepts mastered; more flexible curricula can be designed for use in High School. Develop templates for products, programs and professional development that, combined with the roadmap, effectively connect NASA's ongoing, authentic activities to classrooms for educators and learners.
Too few undergraduates choose physics-based careers in particular and science and engineering careers in general. Extend focus from K-12 to K-16 to integrate cutting-edge SSSC topics into undergraduate physics courses along with other relevant NASA content.	Broad dissemination is required to achieve impact. Requiring individual PIs and Missions to create their own dissemination channels is burdensome and lessens impact. Expand existing, and develop new centrally supported channels for dissemination that mission and research-based E/PO can use to reach full range of audiences.
Use of E/PO investments are not maximized due to lack of sustained support and dissemination.	Make sustained investment over time in Web-based dissemination of NASA materials. Use of best-practice templates to create materials will facilitate maintaining currency.
Outreach, not advertisement, is required in order to keep the public informed and engaged at the level required if NASA is to make progress towards achieving the Vision for Space Exploration, particularly over the longer term.	Improve coordination between Public Affairs and Outreach and Education to conduct timely outreach that educates the public about NASA's activities and achievements, with appropriate explanation of risk.

Provide education and professional development resources for formal and informal science education that are consistent and coherent across the entire NASA enterprise. NASA needs to coordinate and centralize its educational outreach to better enable E/PO partners to take advantage of SSSC science to engage their audiences. Educators in the K-12 arena require standards-based educational resources coupled with high-quality professional development offerings to take advantage of NASA's constant stream of fresh, current, authentic scientific discovery and engineering activities. NASA creates resources such as informational websites, animated simulations, sets of data visualizations, teaching guides, sets of standards-based curriculum activities, on line

courses, video conferences, interactive modules, posters, opportunities to interact on line and by video with scientists, engineers and technicians, opportunities for student research, and regular updates. These must be coupled with appropriate professional development to ensure that educators always have NASA in their tool-kit for effective science education. Partnership with professional organizations such as the National Science Teachers Association has proven effective for NASA, and should be expanded.

SSSC and other NASA missions and activities likewise provide wonderful springboards for learning in the informal setting. But educators and exhibit planners in informal settings typically find using each NASA opportunity requires a significant effort simply to ramp up, since there is little consistency in what NASA produces, from center to center, or from mission to mission. It would be tremendously helpful for each NASA activity to have a standard set of resources with common interfaces and similar formats that are fairly consistent from activity to activity, e.g., an informational website, an annotated simulation, a set of opportunities to interact with scientists, engineers and technicians, and activities for out-of-school settings. Professional development is also required for informal educators; and current partnership efforts with professional organizations such as the Association of Science and Technology Centers have proven effective, and should be expanded.

Flexibility is, of course, essential. The unique opportunities and requirements of each activity should be exploited, technologies will evolve, and evaluation will inform revision. However, the ability to count on a standard package would likely reduce the learning curve for users and increase the usability and use of the resources. SECEF is a good example of the value of a coordinated national effort to develop and support E/PO activities; emphasis on standardized packages will strengthen this approach.

Promote and support the integration of the SSSC-related content more fully into standards-based K-12 science curricula. National science education standards provide direct opportunity to take advantage of SSSC science specifically and NASA science in general to improve science education on a national level. In this era of standards-based curriculum and high stakes testing, what gets taught is what is required in the curriculum and thus assessed on tests. State science curriculum standards generally map to these national standards, and thus tremendous opportunity exists for current SSSC science content to enrich and infuse these curricula. Influential science education standards such as the National Science Education Standards (National Research Council) and the 2061 Benchmarks for Science Literacy (AAAS) place substantial emphasis on SSSC related science concepts from the earliest grades through high school. The 2061 Benchmarks, for example, posit that in order to achieve scientific literacy students in grades K-2 master concepts such as ‘The Sun can be seen only in the daytime, but the moon can be seen sometimes in day and sometimes in night’ (4A/2); students in grades 3-5

further expand this understanding to 'Stars are like the Sun, some being smaller and some larger, but so far away they look like points of light' (4A/5); in grades 6-8 they learn that 'The Sun is a medium-sized star located near the edge of a disc-shaped galaxy of stars, …' (4A/1), and that 'Telescopes reveal that the Sun has dark spots' (10A/2); and by high school, that 'Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and X-ray telescopes collect information from across the entire spectrum of electromagnetic waves; … (4A/3). This progression of understanding highlights the role of understanding the Sun at many levels in developing scientific literacy. SSSC scientific research provides vivid, authentic examples to promote student mastery of these concepts.

The entire NASA enterprise could, for example, be mapped to the Benchmarks for Scientific Literacy, and/or the National Science Education Standards. The result would be a roadmap in itself for integrating NASA science and engineering activities into science curricula across the nation.

Extend focus to higher education in order to ensure adequate numbers of trained scientists and engineers for the SSSC community and the rest of NASA to achieve the VSE. Solar and space physics needs a national effort that relates the exciting applications in our field to specific curricular needs of introductory physics and astronomy – classes with substantial enrollments at just about every college in the nation. The excitement of space science can entrain and encourage more undergraduates through physics, math and engineering programs at the university level. This will compliment current programs geared towards providing early research experience (such as NSF's REU program) that are very important for attracting non-traditional students into the workforce. Attention needs to be paid to how the space physics workforce is developed – where do students come from and why – in order to ensure sufficient numbers for a healthy scientific community able to achieve NASA's goals.

Enhance existing and create new distribution channels for E/PO efforts: products, programs, and messages. It is not realistic or effective to make individual SSSC PIs responsible for building and sustaining their own dissemination relationships. This is not to say that individual PIs should not be encouraged to go into classrooms, make public presentations, or appear in the media. We recommend that NASA develop a spectrum of dissemination options that are supported and sustained centrally. In addition, NASA should support best practice use of World Wide Web for keeping products current and leveraging development efforts over time.

Emphasize unique learning opportunities that SSSC-related content can provide, in particular, the visualization of data, essential for advancing science learning and the nation's scientific capacity. Expand efforts already underway to create high production-value media programs around the scientific assets of NASA, including Sun-Earth System. Fully digital space

shows; large-format media projections, television productions, etc. are powerful vehicles for promoting public understanding of complex phenomena and teaching students of all ages critical skills for 21st century science involving collecting, analyzing, visualizing and communicating data and constructing, manipulating and interpreting scientific models and simulations. Increased efforts taking advantage of partnerships with media production groups and distributors will contribute substantially to achieving greater impact for E/PO programs.

Focus on innovative external partnerships to create programs that reach a broad range of the public. Through leveraging partnerships with informal science learning centers (museums, planetaria, science centers); national parks; community groups (Girl Scouts), publishers, and the media, SSSC science can be more widely disseminated by taking advantage of existing channels. For example, NASA has connected very effectively with the National Parks to provide content on the aurora and noctilucent clouds for summer programs in Alaska and information about the Sun in support of educational programs at parks in the southwest. Such programs provide amplified impact by enhancing the capacity of established channels to engage, excite and educate the public with science and engineering content. New avenues should also be explored, for example, products developed with the gaming industry could engage the public, young and old, in the Vision for Space Exploration.

To maximize impact of SSSC science for E/PO, efforts should take advantage of opportunities that exist at the intersection of the "formal" and "informal" education sectors. Too often in education policy and strategy, schools and museums are viewed independently, with isolated objectives and separate strands of efforts. While there are clear differences, substantial connections and overlaps exist. Many informal science education institutions already operate at the intersection of the two sectors – offering substantive professional development for teachers, providing learning experiences and field trips for classes, delivering after-school services, and developing and distributing curriculum materials and resources. A key strength of these institutions is local knowledge. The formal education landscape is highly variable and this local knowledge is key to successful connections between science and engineering-rich agencies, such as NASA, and science and engineering education efforts in the formal setting. NASA E/PO should take advantage of the existing connections and overlap between the formal and informal education arenas.

Develop better coordination with Public Affairs to maximize the effectiveness of E/PO efforts. Consistent messaging is essential to effective communication, and effective communication is key to strong E/PO. More substantial overlap should occur between Public Outreach and Public Affairs (PA). These activities are distinct: Public Outreach from SSSC covers a broad range of topics and targets the public directly, whereas

Public Affairs communicates specifically new and current discoveries to the media for dissemination to the public. However, the visual and editorial resources required by the two are very similar, and thus we recommend that Public Affairs team up with the E/PO group early in order to develop the same core messages and visual assets. This will facilitate getting better media coverage of scientific results and publicizing exciting E/PO events. It will also strengthen education programs because they can use the visual and editorial assets developed for Public Affairs and Public Outreach.

E/PO efforts need to focus on outreach, not advertisement. While it is important to raise public awareness of SSSC missions and activities, E/PO funds must be invested in products and programs that go beyond advertisement and truly engage and inform. Thus we strongly discourage the use of E/PO funds for lanyards, pins, etc., that are solely designed to advertise a mission.

Educate the public via outreach through informal and formal channels about the risks inherent in the exploration of space. As NASA pursues Return to Flight and the Exploration Vision, it will be very important for the public to be aware of the risks associated with these activities. In the event that accidents occur that result in tragic loss of life or even setbacks in mission activities, the public will be best able to respond appropriately if they were aware up front of the risks involved.

Shift in management and implementation of SMD E/PO. NASA E/PO has made a remarkable impact through commitment of substantial funds over the past decade or more. The value of having the scientific community intimately involved in the development and implementation of E/PO products and programs cannot be over emphasized. Thus we strongly advocate maintaining the established commitment of funds for E/PO.

For smaller efforts NASA should continue to offer supplements for which individual PIs can apply to support E/PO activities that stem from their scientific research and mission activities. New E/PO activities should map to one of the five themes articulated above. Themes will be modified and replaced as part of future SSSC strategic planning activities. However, rather than expect each investigator to invent a new set of E/PO activities, we recommend that the allocation of E/PO funds ordinarily be linked to a broad portfolio of approved, adaptable E/PO programs and product templates from which the PI may select. Further, NASA should require that dissemination ordinarily be through one or more of NASA's approved and maintained channels.

The portfolio of approved E/PO product and program suites should be developed using existing successful E/PO efforts as models, as well as taking advantage of best practices in formal and informal education. It is very important that these be developed through collaboration between the Science Directorate and the Office of Education. It also very important that investigators funded by the Science Directorate play a

significant role in the choice of allocation of their E/PO funds.

At the mission scale we recommend that each mission and instrument team should also be allowed to choose from an adaptable selection of approved product and program suites. PIs should identify the SSSC E/PO theme(s) to which their activities map and be required to utilize appropriate dissemination strategies and channels. While individual teams must demonstrate a genuine commitment to E/PO and teams with particular interest and expertise in developing new types of E/PO should be encouraged and supported, as a general rule PIs should not be burdened with inventing E/PO programs as they are putting together their mission proposals. In essence, science proposals funded by the Science Mission Directorate should continue to be selected on the basis of their scientific merit. Funding for E/PO derived from these scientific missions and programs should then be approved and selected using agency guidelines. The PIs should manage their own E/PO programs and help oversee the allocation of mission E/PO funds.

Sustained public engagement with, and support of, the VSE will be essential to NASA's success over the next 30 years. The SSSC community is excited to collaborate in the E/PO efforts designed to bring the public along on the VSE. Progress in SSSC science will not only enable the safe and productive transit and landing of human and robotic explorers on other bodies in our Solar System; it will also advance our capacity to mitigate hazardous space weather impacts and global climate change at Earth; and it will continue to open new frontiers of scientific discovery about the Earth, the Solar System, and the Universe.