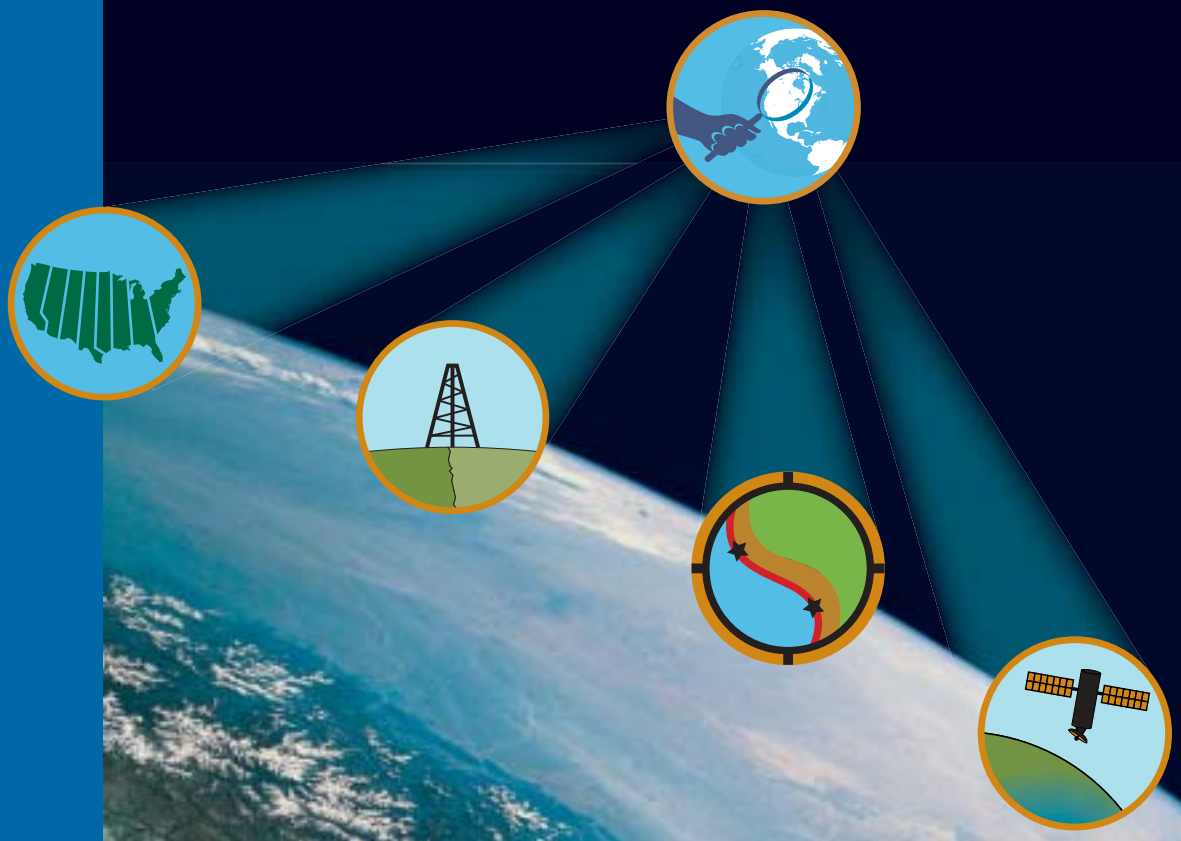
earthscope

AN
UNPRECEDENTED OPPORTUNITY
FOR EDUCATION AND OUTREACH
IN THE EARTH SCIENCES



EDUCATION
& OUTREACH
PROGRAM PLAN

Submitted by the EarthScope E&O Committee. Visit the Education and Outreach (EON) web site at www.earthscope.org. Participate in the EON discussion group at www.dlese.org. Select EarthScope from the list of discussion groups.

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NOVEMBER 2002

This report is based on the ideas and encouragement of many members of the EarthScope community and developed by:

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Contents

Executive Summary

EarthScope is a decade-long experiment to understand the formation, structure, and evolution of the North American continent. EarthScope's geological, geochemical, and geophysical datasets, generated by the EarthScope facilities and the broader geoscience community will provide researchers with a wealth of new information to advance our understanding of Earth in a holistic fashion; the experiment will also provide the Earth science community with an unprecedented opportunity to teach about Earth in a similar way. EarthScope data and discoveries will form the core of the education and outreach program and allow us to educate the public about Earth science and to involve them in conducting the experiment itself.

To address the challenge and opportunity of EarthScope education and outreach, the geoscience and geoscience education community, through a series of workshops and discussions, is calling for development of an EarthScope Education and Outreach Network (EON). The network will consist of a national EON office that collaborates with and facilitates the efforts of the EarthScope facilities, a variety of local EON alliances distributed across the country, and numerous partners representing national and local organizations with similar science, education, and outreach goals.

EON Goals

The EarthScope EON will provide the interface to make EarthScope science, and the advanced technology and modern approaches used to understand Earth, relevant and beneficial to those audiences most vested in advancing Earth science education. At the center of our educational enterprise is a set of goals that define the EON efforts, and an evaluation plan to measure our success:

- Goal 1: Create a high-profile public identity for EarthScope that emphasizes the integrated nature of the scientific discoveries and the importance of EarthScope's various research initiatives.
- Goal 2: Establish a sense of project ownership among scientific, professional, and educational communities and the public so that a diverse group of individuals and organizations can and will make contributions to EarthScope.
- Goal 3: Promote science literacy and understanding of the EarthScope experiment among all audiences through informal education venues.
- Goal 4: Advance formal Earth science education by promoting inquiry-based classroom investigations that focus on understanding Earth and the interdisciplinary nature of the EarthScope experiment.
- Goal 5: Foster use of EarthScope data, discoveries, and new technology in resolving challenging problems and improving our quality of life.

EON activities in support of our goals fall in two broad categories: (1) resource development and dissemination, and (2) program development and implementation. Resource development includes creating public relations information, posters, fact sheets, and news releases; producing educational videos; developing supplemental curriculum resources and visualization and analysis tools; and sponsoring museum exhibits. This effort is at the core of creating a unified EarthScope program identity through EON. The scale of the effort and diversity of resources will require contributions from the entire community.

Program development and implementation activities include public relations support for deployment, solicitation of partnerships and opportunities for knowledge transfer to other technical professionals, formal education programs such as K-16 faculty professional development, and informal education activities at parks and community centers.

It is essential that careful assessment of EON be conducted at every stage to ensure that the program is responsive to audience needs and effective in achieving its goals. Evaluating a program with the complexity of EON and the diversity of stakeholders will require the services of an independent external evaluator from the outset. The evaluation process will evolve to meet changing programmatic needs as we learn from our efforts over the next decade.

EON Structure and Management

The proposed EON structure provides opportunities for a broad range of individuals and groups to contribute to EON and addresses the challenges of a continental-scale, decade-long effort. Each EarthScope EON component has a well-defined role and responsibilities to maximize program impact and coordination.

The national EON office is envisioned as the focal point for EarthScope education and outreach efforts and the broader EarthScope community. It has the primary responsibility for advancing EON's vision and creating opportunities for the community to realize EON's goals. The national EON office will do this by promoting, facilitating, and coordinating the contributions of the local EON alliances, EON partners, and EarthScope facilities. It is also responsible for creating resources and programs that establish a national identity and that facilitate the EarthScope experiment.

Local alliances distributed in communities across the country will provide the human interface between EarthScope science and facilities and the public. Local EON alliances have the primary role of implementing programs, building partnerships, and customizing, developing, and disseminating EON resources for the local audience. These alliances can provide customized services that engage culturally, economically, and geographically diverse audiences. Local alliances will also provide support for instrument deployment as appropriate, and promote knowledge transfer to key groups and organizations that could directly benefit from EarthScope science and education programs. Local EON alliances can take on many sizes, shapes, and responsibilities but must address, at a significant level, multiple EON goals and serve multiple target audiences. In addition, they must coordinate their work with the efforts of other alliances and the national EON office.

Partnerships with a range of organizations that are already active in areas of importance to EarthScope education and outreach will add both depth and breadth to EON. The partnerships will facilitate sharing resources and expertise and will allow EON to efficiently leverage and build upon existing programs. Partnerships will bring together a dedicated group of professionals at the national or local level who are capable of bridging the gap between scientists and educators by distilling the science into valuable and needed resources.

The EarthScope facilities and data centers are at the heart of the EarthScope experiment and EON. The EarthScope facilities are responsible for collecting, maintaining, and creating access to EarthScope data streams in support of the scientific experiment. EON's goal is to make EarthScope data streams, complementary geological datasets, and the scientific results accessible to a wider audience. This

will require close collaboration among the national EON office, the facilities, scientists, and the local alliances to create resources appropriate for target audiences.

The facilities are responsible for communicating and collaborating with the EarthScope EON during deployment so that EON can provide support and use deployment as an opportunity for outreach. Finally, it is expected that the facilities may create resources that educate the public about their work. Resources might include establishing a visitor center on the SAFOD site or creating a video explaining the deployment effort. Using the expertise available in EON will help the facilities to develop and disseminate these resources.

EON requires a management plan that is responsive to the community and to changes that will occur over the life of EarthScope. Thus, the proposed management plan imposes only basic standards for participation while allowing efforts to grow out of local needs and interests. It is essential that all partners, facilities, local alliances, and target audiences are well represented and that the local and national efforts function as a single, integrated facility that addresses EON's goals. To carry out EON requires that the national EON office have the core funding and authority to coordinate and facilitate the education and outreach efforts. It also requires effective communication and a well-defined reporting structure among the EarthScope facilities, data centers, national EON office, and the EarthScope community.

Community representation will be achieved in several ways. First, the national EON office will rely on the help of a small, diverse, and broadly representative advisory board (including scientists, science educators, partners, facilities, and members of target audiences) to guide EON's development and implementation. The EON Advisory Board and national EON office will be responsible for gathering information from the community on EON needs and articulating new directions for EON efforts. Community input will be gathered through discussions on the EarthScope EON electronic discussion group (at www.dlese.org) and through an annual meeting of the EON community. Second, the EON Advisory Board will report this information to the EarthScope Science and Education Advisory Board, which will advise NSF on new directions for the EarthScope EON program.

The national EON office will work with NSF to help the EON community and EarthScope facilities develop proposals that address the identified needs and new directions. EarthScope EON will be carried out by individuals and groups, who in a competitive proposal process at NSF, other federal and state agencies or private foundations, put forth the best ideas and methods to achieve EON's goals. Funding will go directly from NSF to the successful individuals and groups. Through the peer reviewed proposal process, the community will have additional opportunities to guide and contribute to the education and outreach efforts.

Basic Structure of the EarthScope EON Effort

Introduction

After the Civil War, the Congress of the United States of America funded a grand exploration of the West called the Geologic Survey of the Territories. Between 1867 and 1879, Ferdinand Hayden, Clarence King, and John Wesley Powell led a series of geological expeditions throughout what is now the western United States. The images and writings produced by these explorers captured the public's imagination and spurred many others to follow in their footsteps. These great journeys of discovery shaped the public's view of geology for generations and helped steer the making of America.

In 2003, a new grand exploration of our continent, called EarthScope, will get underway. EarthScope is a decade-long experiment to understand the formation, structure, and evolution of the North American continent and how those processes impact us today. It will provide scientists with a new, highly detailed view into Earth that can be used to address some of the most pressing problems facing our society. EarthScope's seismic, geodetic, and geologic data will help scientists understand the driving forces of earthquakes and volcanic eruptions and develop better predictive models. Satellite imagery, combined with geochemical and geological evidence preserved in Earth's rock record, will foster better management of our natural resources and could provide clues to Earth's climatic variability.

The continental scale of the EarthScope experiment and the breadth of associated research have the potential to spawn whole new areas of research and trigger great leaps forward in our understanding of Earth, having an impact on science similar to the Hubble Space Telescope. EarthScope will revolutionize how we conduct geoscience investigations by providing data, tools, and instrumentation to support an integrated experiment. Scientists envision real-time data streams, automated development of geophysical data products and geological databases for the broad Earth science community, and new Earth models that represent the integrated thinking of a diverse community of geophysicists, geochemists, geologists, and others. There is great excitement among the solid Earth science community for EarthScope and that excitement will transfer well to the public.

The EarthScope experiment, like the Geologic Survey of the Territories, has great potential for educating the public and encouraging future generations to follow in the scientists' footsteps. EarthScope can dramatically change how Earth scientists communicate with a diverse public, and how the public perceives and uses Earth science information. The scientific data generated by EarthScope, and the discoveries made with them, will provide an extraordinary opportunity to engage the public, both formally and informally, in Earth science research. EarthScope's real impact will occur when this program's discoveries permit us to make better-informed decisions about issues that affect our planet, thus ensuring an EarthScope legacy that will live on for many generations.

To carry out the EarthScope experiment, the National Science Foundation will provide support to build modern observational, analytical, and communications facilities and technologies to collect a wide variety of geological and geophysical data. These facilities are the backbone of the EarthScope experiment, and include:

United States Seismic Array (USArray), a digital seismic array installed across the continent to record ground shaking, combined with magnetotelluric instruments to measure the crust's electrical conductivity, will produce three-dimensional images of the North American continental crust and mantle.

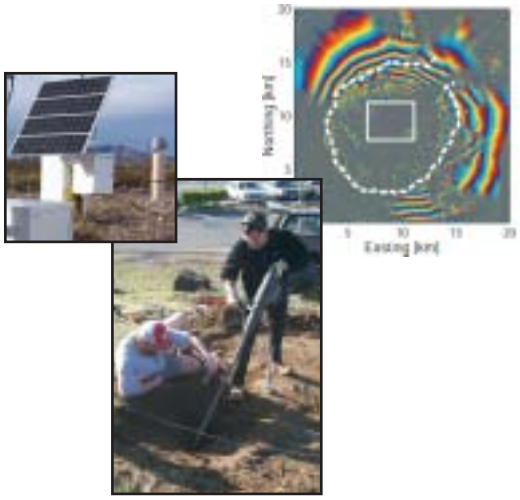


Plate Boundary Observatory (PBO), a network of global positioning satellite receivers and strainmeters, will be combined with satellite radar imagery (InSAR) to measure and map the smallest (down to 1 mm) movements along faults, magma movement inside active volcanoes, short- and long-term changes in groundwater basins, and the wide areas of deformation associated with plate tectonic motion.

San Andreas Fault Observatory at Depth (SAFOD), a 4-km-deep borehole, will permit scientists to directly measure subsurface conditions and rock behavior within one of the world's most active faults.

Equally important to the experiment are the geologic datasets required to advance our understanding of the North American continent such as petrologic, structural, and geochronologic data. These data must be gathered and disseminated to the diverse community of scientists interested in EarthScope. Just as the scientists will use and integrate these datasets for deeper understanding, so will geoscience educators as they teach a broad audience about Earth.

Creating the EarthScope Legacy

A Community Plan

This report presents a plan for education and outreach activities in support of EarthScope and advancing public understanding of Earth. This plan was initiated during discussions at the January 2002 workshop in Boulder, Colorado and refined at the August 2002 workshop in Tucson, Arizona. It also incorporates ideas from discussions held over the past several years at a variety of EarthScope and other scientific meetings.

The result of these discussions is a community-based plan calling for development of an EarthScope Education and Outreach Network (EON) consisting of a national EON office, a variety of local alliances distributed across the country, the EarthScope facilities, and numerous partners representing national and local organizations with similar science, education, and outreach goals. With this diverse community representation, EON will:

- educate a broad audience about EarthScope data and discoveries and the importance of understanding Earth.
- support the efforts of the facilities and scientists engaged in the EarthScope experiment.
- enable wide exploration and exploitation of EarthScope data.
- provide training and opportunities for students, educators, technical professionals, and the public to participate in, and benefit from, the experiment.
- develop strong partnerships with institutions and organizations that have a vested interest in Earth science education and information dissemination.

The EarthScope EON will carry out educational activities ranging from research experiences for students in grades K-16 to professional development for technical professionals and educators in both formal (e.g., K-20 classrooms) and informal (e.g., museums and parks) venues. It will also provide a wide range of outreach activities from organizing town halls or other local meetings in advance of an instrument deployment, to developing radio, print, and video materials that inform the public about the EarthScope experiment and discoveries. Our plan is guided by the belief that this education and outreach effort:

- is the prime mechanism for developing an EarthScope identity and legacy that extends from the EarthScope scientific community to the general public, K-16 students and educators, community and government leaders, and Earth science and other technical professionals.

EarthScope's Education and Outreach Mission

...is to ensure the EarthScope experiment creates as its legacy a public more knowledgeable of basic Earth science concepts and that has a deep understanding of the scientific and societal contributions made by the EarthScope experiment. It will fulfill this commitment by developing and disseminating products that use the broad range of EarthScope data, models, technology, and discoveries and that support existing Earth science education and outreach programs.

Scenario: EarthScope in the National Parks

Each year millions of visitors come to Grand Canyon National Park and stand in awe of nature's beauty, yet they remain unaware of the dynamic geologic processes that have shaped these natural wonders. The short time visitors spend in the park examining nature is not long enough for them to really grasp the concept of geologic time and how small-scale processes acting over long periods of time build majestic mountains or wear away deep canyons. Park interpreters are excited this season because new technology installed through EarthScope is providing real-time seismic and GPS data, and maps to show visitors just how active Earth is on a daily basis. The exhibits enable visitors to interact with a seismometer, learn how to read seismic records, and interpret plate motion maps. A satellite interferometry image shows the extent of the landslide that occurred in the backcountry of the park. Combining the seismic and GPS data showing short-term changes with the geologic history in the rocks, park rangers have developed short animations of how the geology of the park evolved through time.

These exhibits were developed through a partnership between EarthScope and the National Park Service, which brought interpretative rangers, informal science education specialists, and EarthScope scientists together to ensure the content was accurate and the delivery systems appropriate for multi-level audiences. The exhibits, site bulletins, activity material, trail sites, and learning programs created in this project are reaching visitors from around the world. Evaluation of the pilot program showed the effectiveness of these new interpretive approaches. The concept is so successful it is being expanded to other national parks.

- will be developed in a true collaboration between the EarthScope education community and EarthScope science community, for the benefit of both communities.
- must integrate the individual EarthScope scientific studies and facilities in ways that help the public understand and value the contributions of EarthScope and Earth science to society.
- is a critical supporting element for the EarthScope experiment and facilities.

A Great Opportunity for Education and Outreach

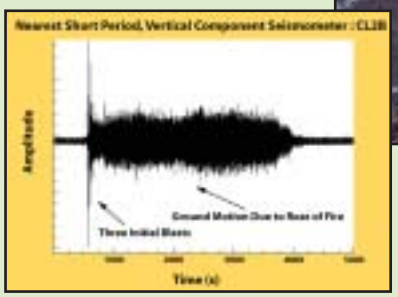
The EarthScope experiment incorporates many features that make it ideal as the focus of a sustained, comprehensive education and outreach effort. It will allow EON to reach, through a variety of programs over a long period of time, many people in need or desiring knowledge of Earth's dynamic systems.

The rolling grid of seismometers and magnetotelluric instruments in USArray, combined with the flexible arrays of seismic and GPS instruments deployed for specific research targets, will bring EarthScope activities to nearly every state and county in the nation. Corresponding education and outreach opportunities that place the geophysical observations in a geological framework will arise naturally as EarthScope instruments are deployed. The education and outreach efforts can highlight both important regional geological questions and an evolving continental-scale picture. Targeted local experiments will make EarthScope's scientific investigations and discoveries relevant for educational efforts on a region-by-region basis. The research and discovery process, revealed through new scientific models and discussions, will provide a genuine example of the nature of our scientific methods and how scientific thinking changes as new data become available. Making these models and rich data sets accessible to a broad audience will involve the public in the discovery process and provide timely opportunities for learning about Earth.

The excitement of a huge science experiment in one's own backyard piques interest, but we need to provide resources and experiences to capitalize upon this excitement and create opportunities for learning in homes, classrooms, and offices. Too often, science is presented in schools, museums, and popular literature as a process that scientists do and the rest of the world reads about or passively observes. EON promises to make science a process of inquiry for many by involving the local communities in the experiment and by providing research opportunities for K-16 students and educators. It will deliver data and models to local technical professionals and policy makers and will provide profes-

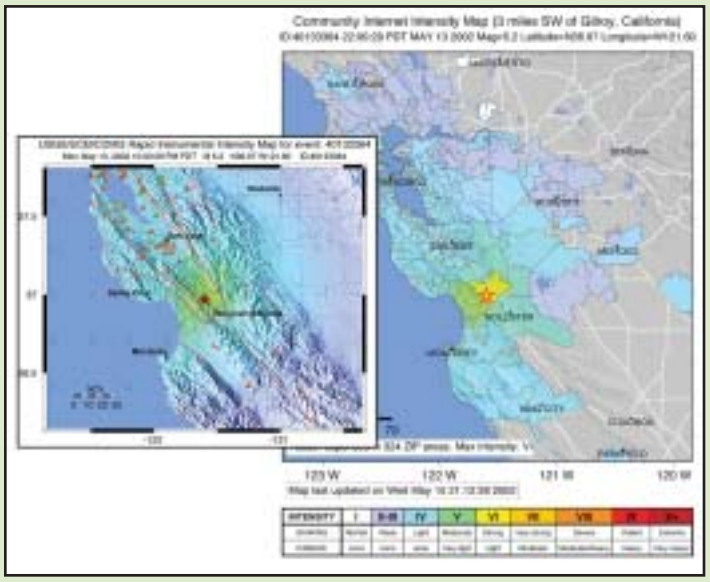
Forensic Seismology

Applying EarthScope data to everyday problems can have real impact on society. Distant events can be detected and details of event size, location, and timing can be revealed with seismology. The field of forensic seismology has generated strong public interest (McKenzie, 2001) because of its importance in deciphering the events that led to, for example, the sinking of the Kursk submarine, and the death of 12 people as a result of a gas pipeline explosion near Carlsbad, New Mexico. The precision of EarthScope's seismic networks will permit the public to see first-hand Earth's dynamic response to both human and natural events in their hometown and around the country. Combining real-time seismic data streams from USArray with the "Did you feel it?" web site (see box on page 9) and an understanding of geologic forces at hand has the potential to create a sense of ownership by involving Americans in the EarthScope enterprise.



Did You Feel It?

The power of involving the public in critical scientific research is demonstrated well by the web site "Did you feel it?" (http:// pasadena.wr.usgs.gov/shake/), developed by the U.S. Geological Survey (Wald, et al, 1998). It permits people to report any unusual shaking that they believe could be related to an earthquake in their area. Created initially for the southern California area, "Did you feel it?" has become a tremendous success both in generating public interest and in gathering critical information about reported damage and ground shaking that can be correlated with seismic recordings. It is typical that the public will register shaking reports on the web site within minutes of an event; there can be thousands of reports within a few hours, even for earthquakes occurring in the middle of the night. In addition, visitors to the site can see the results of their participation in the data-collection process in the shaking intensity maps created.



sional development opportunities so that they can incorporate EarthScope discoveries in their work. Educational resources and programs will be made available in many communities through museums, parks, and other informal gathering places that facilitate the public learning about EarthScope and Earth systems.

The scientific problems being addressed by EarthScope are relevant to our lives and represent a core set of knowledge that all Americans should possess (AAAS, 1994; Stout et al., 1994; NSF, 1996, 1997; Ireton et al., 1997, Barstow and Geary, 2002). Every day there is some impact on our lives resulting from decisions made using Earth science data and discoveries. From siting private or commercial structures to extracting natural resources to build and operate them, we need high-quality data and a deep understanding of Earth's dynamic nature to make sound decisions.

EarthScope is not only relevant to answering questions about current or everyday events but can also provide information for those seeking to answer scientific, philosophical, and societal questions about Earth systems. Questions about the age of Earth, how mountains form, whether all mountains are old volcanoes, and whether humans can predict or effectively control Earth processes are commonly asked. These questions get at the fundamental understandings of how Earth works. People not only want answers, they also want to see evidence and understand how scientists make decisions and discoveries.

EarthScope EON Addressing Needs of Scientists

EON's success depends upon a strong bond between the EarthScope scientists and the outreach and education community. EON can help the scientists more broadly communicate their ideas within the science community and outside it. EON can provide tools for scientists to easily and rapidly post new developments in their EarthScope research to custom EarthScope web sites. EON can provide training and outlets for scientists to communicate those results to the public. Working with EON, scientists could design more effective tools, models, and data products that enable scientists in other disciplines to use those resources and more effectively collaborate. Going one step further, scientists could provide data that are easy-to-use and interpret for K-16 students and the public. These efforts can have many impacts from helping to recruit a new generation of Earth scientists to facilitating a field experiment.

EON can provide opportunities for scientists to explore partnerships with science educators in schools, parks, and museums. Evidence shows that with a little training, many scientists have formed partnerships with local schools that improve the Earth science curriculum. EON can provide the training, help identify target schools and teachers, and provide resources for the K-12 classroom. The goal is to provide scientists with tools and opportunities to bridge the gap between their work and audiences that can benefit from it.

EarthScope EON Addressing Needs in College and University Education

The most immediate impact of EarthScope and EON will be in undergraduate and graduate education because many of the scientists involved in EarthScope are also undergraduate educators, and the EarthScope data and data products (e.g., displacement vectors, structure profiles, petrologic data) are also most appropriate for educational efforts at this level. The resources developed for undergraduate teaching can be shared with faculty across the country.

The development of inquiry-based activities using EarthScope data and resources for introductory undergraduate science courses is a natural initial target as well. Exercises that integrate a variety of geological and geophysical data from EarthScope can help students develop a holistic understanding of Earth and leave them better equipped to make everyday decisions that affect our planet. As an added benefit, educational products developed for introductory undergraduate courses are easily modified and enhanced for use in grades 11 and 12.

Beyond the introductory course, EON products and services can facilitate integration of new data and technology into courses for geoscience majors. Teams of students can use EarthScope data to investigate local geologic phenomena, from the structure of the crust and mantle to exploring hazards in regions with infrequent but damaging activity, such as in South Carolina or New York. Students in non-active regions can experience exciting research by comparing their tectonic region to modern analogs such as the Colorado Plateau and the Andes of South America.

EarthScope provides a rich opportunity for institutions of higher learning to engage undergraduate students in a state-of-the-art experiment. For many institutions, EarthScope could expand significantly the scope and role of undergraduate research in their educational mission.

Under-represented groups often populate smaller undergraduate institutions such as community or tribal colleges. The active engagement of these students in a scientific experiment could be a turning point in their development as a scientist and represents a tremendous opportunity for EarthScope to recruit the next generation of Earth scientists. In addition, faculty at these institutions should also enjoy an enhanced opportunity to participate in and lead research on the geologic structure and evolution of their local area. The data products and technology for data dissemination will help to greatly expand the research process, enabling faculty at undergraduate institutions to participate in the EarthScope experiment as researchers.

EarthScope's impact at the undergraduate level will be increased by several important actions. The data must be made easily discoverable and usable. Small grants can be made available through the national EON office to jump start local alliance efforts that need to be implemented sooner than the

Scenario: The EarthScope Experience — A Teacher Professional Development and Student Learning Program for Secondary Schools

Kathy, Glenn, and many other students in the Seattle Public Schools are exploring the nature of seismic and volcanic risk for people living in the shadow of Mount Rainier. Their teacher, Ms. Pradeep, is using the EarthScope Experience resources, a newly adopted supplement to the school district's EarthComm curriculum. Using a GIS database of historic mudflows in the metropolitan area, Kathy and Glenn are determining how many people in the area would be affected by a similar event today. Another team of students are identifying exit routes from the city in case a giant tsunami is generated by a large subduction zone event.

Ms. Pradeep has been working with Hau, a university graduate student and a NSF K-12 Teaching Fellow, for the past year to learn more about the geology of Seattle and to implement this new curriculum. Hau works in the classroom daily to learn more about teaching from Ms. Pradeep and to help teach more in-depth Earth science content. Hau and Ms. Pradeep both participated in district professional development this summer to learn how to implement the EarthScope resources. Last week, Hau and Ms. Pradeep took the students in the field to map locations of buried trees that died a few hundred years ago when the last major subduction zone earthquake occurred. This week the students are adding that information to their GIS database.

Seattle science teachers recognize that the EarthScope geological and geophysical data can be used to enrich their students understanding of what it means to live on an active plate margin. The data provide sensitive records of vibrations induced by the flow of magma beneath Mt. Rainier, and the rocks record many historical events as well. Combining the data in the EarthScope Experience with EarthComm motivates students to pursue some of the key questions that drive the EarthScope initiative.

NSF proposal cycle responds or to fund projects of local interest that will also add value to the EarthScope data. There must be opportunities for students and faculty at undergraduate institutions to participate in ongoing experiments. Curriculum developed locally and ideas for undergraduate research must be shared nationally so that others can benefit.

EarthScope EON can also address several unmet needs in graduate and faculty professional development in colleges and universities. It can provide resources and pedagogical training to graduate students who often teach the laboratory sessions where inquiry and data analysis are easiest to incorporate. EON can assist young faculty in developing new courses that incorporate EarthScope data and technology and can even provide young faculty with assistance in writing grant proposals that bridge their EarthScope science and education interests (e.g., CAREER proposals). Finally, EON can help senior faculty revitalize their courses and incorporate pedagogical changes to encourage scientific inquiry in the classroom.

EarthScope EON Addressing Needs in K-12 Education

At the K-12 level, EarthScope's EON can contribute to established systemic reform efforts in science education, both at the national and state level, and lend support to nascent initiatives that specifically address the transformation of Earth science education. EarthScope education and outreach will build on these efforts by supporting the creation and dissemination of a wide variety of education and outreach products. By aligning EarthScope EON with national and state reform efforts, we will ensure a higher level of impact and participation of K-12 students and teachers in the experiment. In addition, EarthScope will capitalize on the understanding that science educators working directly with scientists to develop inquiry-based instructional materials in Earth science yield some of the best results.

It is important to note that NSF, NASA, and FEMA have funded a significant number of K-12 Earth science curriculum projects that contain inquiry-based investigations relevant to the EarthScope science content. EarthScope EON does not need to reinvent these. Instead, EarthScope EON can provide scientists trained to use these high-quality resources and excited to work with schools and the public. Scientist-teacher partnerships can have tremendous impact when properly designed, and many school districts actively recruit scientists to work with them. Thus, EarthScope EON will build upon what exists and provide only new supplemental resources that enrich the high-quality resources currently available for K-12 students.

Scenario: Using EarthScope Models in the Classroom

Phillipe selects "6 months" on the time interval control bar and points to a section of the fault where the last significant seismic event occurred 121 years ago. He tells Carlita, "the next quake's going to occur right here." Professor Renwald interjects, "It's hard to know for sure what's going to happen, but I'll go with Phillipe's forecast." Carlita disagrees with both of them, pointing to another section of the fault where the last big event occurred 60 years ago. She notes resolutely, "This section is bracketed by two huge quakes that occurred during the last 20 years. I think the stress is highest here, and it's gonna rip!" Carlita takes the mouse and clicks the step button about a dozen times, and suddenly shouts, "I knew it!" as a magnitude 6.8 event occurs along the interval that she selected. Phillipe responds, "OK, you got it. But I'm going to go with my section again for the next event." After five more clicks, his section suddenly slips. "Well, that was a close second," he claims. Professor Renwald developed the stick-slip animation to help students understand and model earthquake patterns on complex faults. He uses a similar model in his own EarthScope research.

Defining Goals and Measuring Success

In his best selling book, *The Map That Changed the World—The story of William Smith and the birth of modern geology*, Simon Winchester describes geology as one of the great fundamental fields of study "...which, arguably, like physics and mathematics, is a field of learning and endeavor that underpins all knowledge, all understanding." EarthScope's scientific goals and discoveries have the potential to convey a keen appreciation of the profound importance of Earth science as expressed so eloquently by Winchester, and instill a sense of wonder and awe about the dynamic Earth to a broad audience.

At the center of our educational enterprise are a set of fundamental Earth science principles that are not unique to EarthScope, but which form the core of all Earth science investigations.

Earth is dynamic. Earth is composed of a number of dynamic sub-systems whose processes and interactions are responsible for the state of Earth as we observe it. These processes can be gradual and continuous (e.g., erosion) or abrupt and discrete (e.g., an earthquake). Many of these processes can be modeled and understood, and provide a means for interpreting Earth's past and its future.

> Geology "...which, arguably, like physics and mathematics, is a field of learning and endeavor that underpins all knowledge, all understanding."
>
> Simon Winchester, *The Map That Changed the World—The story of William Smith and the Birth of Modern Geology, 2001*

The present is the key to the past. Processes that we observe today have occurred in the past. Thus, we can learn about phenomena that have shaped Earth in the past by studying those that we observe today.

Physical laws govern Earth. Physical laws that can be discerned and tested through scientific methods govern Earth's environment, its processes, and the products we derive from Earth.

Scale is fundamental. Processes acting on Earth do so at a wide variety of temporal and spatial scales. Understanding the range of scales at which different processes act is key to understanding Earth.

Human activities impact Earth. Major changes in our land, biota, water, and air are occurring as a result of human activities. These changes are impacting human societies and need to be better understood.

These principles help us appreciate how small changes to one of Earth's sub-systems can have dramatic impacts on others, and how Earth processes that occur at rates too slow to observe on human time scales can result in major changes over geologic time. They help us to comprehend processes occurring today and to forecast events. The terabytes of new data gathered each year of the EarthScope experiment will provide an enormous amount of information about the present and the past, the scales at which processes occur, and how the processes are inter-related, providing a rare opportunity to teach these principles to a broad audience. Using the process of inquiry and these principles, scientists and the public alike can make observations to better understand how Earth functions.

EarthScope EON Goals

EarthScope's education and outreach effort has a tremendous opportunity to make EarthScope science, advanced technology, and modern approaches used to investigate Earth, relevant and beneficial to broad audiences. EON efforts can provide the glue that binds the community of scientists and science educators together with the facilities to form a complete program. We will use EarthScope science, data, and discoveries to fuel the education and outreach effort and demonstrate the integrated nature of Earth processes. We will work to enhance the public's understanding of relevant Earth science issues, revitalize undergraduate Earth science curricula, contribute to K-12 education and educational reform efforts, and serve policy makers, planners, and other technical professionals. The distributed nature of the EarthScope experiment also provides a unique opportunity for the Earth science community to actively pursue programs that increase the participation of minority-serving institutions and professional societies.

Here we present our primary goals, associated activities, and example scenarios that show how EON can make EarthScope and the fundamental Earth science principles relevant to target audiences.

EarthScope's Education and Outreach Network will...

- Create a sustainable infrastructure for the community to achieve EarthScope's education and outreach goals.
- Encourage contributions from groups of different sizes for varying time periods to achieve national coverage.
- Ensure a coordinated and integrated education and outreach effort.
- Engage the interest and participation a broad community to serve EarthScope.
- Support the EarthScope experiment.

Goal 1: Create a high-profile public identity for EarthScope that emphasizes the integrated nature of the scientific discoveries and the importance of EarthScope's various research initiatives.

Why is this needed?

A significant public relations effort is needed to make a broad audience aware of EarthScope and how they might benefit or contribute. A public relations effort is also critical to successful deployment of EarthScope instrumentation and field campaigns, and it will create a public identity for the program that builds trust and goodwill. The scale and longevity of the EarthScope experiment means it can have an impact on many individuals and organizations including landowners, emergency management agencies, engineering professionals, community water management boards, geological surveys, schools, colleges, and libraries. The EarthScope community can anticipate many groups that need to know about EarthScope data and discoveries, but we cannot identify them all.

How to Accomplish This

- Establish an EarthScope identity and a signature look on all resources associated with the experiment.
- Identify and establish national, regional, and local outlets for media and press interaction.

- Broadly announce a timetable of EarthScope events of all types to encourage participation and promote awareness.
- Create media packets and conduct press conferences.
- Create resources for mobile outreach programs, conferences, and meetings.
- Maintain a dynamic web site that will offer diverse audiences throughout the world a variety of opportunities to observe and participate in EarthScope.
- Create video segments and generate interaction with the public and media representatives.
- Identify high-visibility spokespersons at the national and local levels to disseminate the EarthScope message.
- Establish a Speaker's Bureau at the local, regional, and national levels.
- Distribute information products (maps, news articles, brochures, posters, fact sheets) on EarthScope project plans and results using packaging strategies that address multiple needs and audiences.

The national EON office will take primary responsibility for this effort but will require significant cooperation and contributions from the EarthScope science community and local EON alliances. The community believes strongly that the EarthScope information resources must reflect the experiment's breadth of research and accomplishments and serve a diverse community of users.

Profile: EON Dynamic Web Site

A dynamic web site maintained by the national EON office will offer diverse audiences opportunities to observe and participate in EarthScope's cutting-edge research. Visitors will gain an understanding of existing programs, opportunities, and possibilities presented by EarthScope. The web site will be the primary outlet for the most current news about activities and discoveries, resources for teaching and learning Earth science, and other information. Through animations rendered in 3-D space, visitors to the site will learn how movements along faults are shaping the mountains and valleys of the western part of our continent and how this occurred in the past along what is now the East Coast. Other models might use geochronologic and petrologic data to reveal how pieces of North America were stitched together over geologic time. As the hundreds of USArray seismometers are deployed from west to east across the country, people can observe their progress and use the data recorded to answer scientific questions and to test hypotheses. Portals tailored to different audiences will enable appropriate levels of access to sites containing geological and geophysical data and models showing the formation of North America.

Each researcher conducting EarthScope-funded research or educational activities can develop and maintain an up-to-date web site for their project. The national EON office will provide researchers with a template and basic support for site development. The uniform template with the EarthScope identifier will quickly inform the visitor that the work on a particular site is part of the EarthScope initiative. This network of EarthScope resources will allow scientists to keep informed of colleagues' progress between national meetings and will hopefully trigger new collaborations among scientists, technical professionals, and educators not directly involved in EarthScope. As scientists reap the benefits of their high-profile research, they will also begin to appreciate the importance of communicating with the public and working closely with EON.

The Internet is the fastest and easiest venue for dissemination, and it has the potential for reaching the broadest audience. Given the enormity of information on the Internet, EarthScope must also use many other mechanisms such as radio, television, print, and video to create a national identity and raise awareness of the resources offered on the Internet. EON will work closely with national and local media outlets to ensure timely news releases of discoveries, publicize upcoming events, and contribute new information relevant to current issues. EON can also support booths and displays at national and regional conferences where target audiences gather in large numbers, and assist local alliances at local conferences. The national office and local alliances can develop partnerships with other groups that disseminate EarthScope resources as well. The greatest dissemination, however, will come at the grass roots level through the local EON alliances and the programs they implement.

Goal 2: Establish a sense of project ownership among scientific, professional, and educational communities and the public so that a diverse group of individuals and organizations can and will make contributions to EarthScope.

Why is this needed?

EarthScope depends on broad participation from the Earth science community to realize the goal of an integrated and new view of Earth. It also depends on the science and science education communities across the country to become involved in EON and to provide educational and outreach activities in their area. As the network of EON collaborators broadens, the best ideas and plans for educating and communicating with large numbers of people will emerge, resulting in a higher quality and greater diversity of activities and resources. Finally, EarthScope is dependent on public interest and cooperation with deployment.

How to Accomplish This

- Establish a management plan that promotes broad participation in EON and is responsive to the community and to changes in EarthScope over time.
- Create strong collaborations and channels for communication among the EarthScope facilities, data centers, and the national EON office.
- Promote two-way open communication to identify opportunities and mechanisms for the community to contribute to EON.
- Provide customized products and services that inform, educate, and facilitate local community involvement in the EarthScope experiment.
- Provide a set of services (e.g., templates, protocols, evaluation) that enable local EON alliances to develop resources for EON.
- Develop advance teams and materials to facilitate instrument deployment and siting.
- Establish partnerships with individuals and organizations that sponsor, support, or otherwise aid in development and implementation of essential activities and products that meet our education and outreach goals.

To create a broad community network requires a clearly defined organizational structure that is understood by people within and outside the community. EON's management structure will be flexible in order to respond quickly to changes in EarthScope and will foster community efforts to contribute to EON.

The national EON office has been proposed as a core function within EarthScope and as such, it can develop close collaborations with the facilities to promote EarthScope. The national EON office must also build partnerships and collaborations with education efforts of professional societies such as GSA and AGU, other scientific facilities such as COMPRES, SCEC, IRIS, and UNAVCO, and geological surveys at the state and federal levels.

Working closely with the facilities and local alliances, the national EON office will develop resources in support of deployment and connect the national deployment teams with local alliance leaders. To promote the identity of EarthScope and en-

Scenario: Project ESComm Brings EarthScope to the Community

Hiroo, a local educator assigned to the ESComm Learning Center, is preparing for a family science night focusing on EarthScope technology. The Center, located in the community library, serves as both a formal and informal learning resource.

The students have been using EarthScope data and models in their school science program and now will work with their families to solve a new puzzle. Family science night gives the children a chance to show what they have learned, and provides an opportunity for families to learn science together. In tonight's program, the students and their families will retrieve USArray seismic data using the Internet. There are few earthquakes in this area but they do have an active mine 100 km to the southeast and are not too far from a military base just to the northwest of town where soldiers engage in mock war games. The puzzle for the students and their families is to determine which recordings on the local seismometer are from the mine and which are from the military base. In addition, a professor from the near-by university is present to give an update on EarthScope activities and how the EarthScope discoveries can address problems in the local community.

The ESComm program brings students and their families together to conduct experiments that reveal how Earth works, keeps the community informed of EarthScope activities locally and nationally, and fosters a sense of community ownership and a positive learning environment for citizens of all ages. Surveys conducted weeks after the family science night show that the participants have increased their use of the library computing facilities and are monitoring the seismic records with their children.

sure the quality of EarthScope educational products and programs, the national EON office will provide products and services to local EON alliances and partners such as templates for classroom exercises, evaluation or peer-review of resources, and protocols for developing new EarthScope resources. Local alliances will inform their communities about deployment activities in their area and use the deployment activities to initiate informal and formal education programs in their community. As people become aware of EarthScope, we want them to participate and contribute to EarthScope in ways most appropriate to their interests and abilities.

Goal 3: Promote science literacy and understanding of the EarthScope experiment among all audiences through informal education venues.

Why is this needed?

Rapid advances in science and technology make it difficult for the public to keep informed and to understand how to address Earth-related problems facing them every day. Where we live, how a community develops its land, what natural resources we consume and produce are decisions that require knowledge and understanding of science (Earth science in particular) and technology. EarthScope has a clear role in educating society about how Earth works, geologic hazards, and natural resources.

EON can also provide leadership in raising the profile of science and technology careers. At a time when the need for scientists, engineers, and technical professionals is continually increasing, the interest and knowledge of these fields among the youth of our nation has waned. Working through informal education venues and community programs, we hope to engage the public in the wonders of science and technology through EarthScope and highlight career opportunities in these fields.

The questions scientists will investigate in EarthScope are consistent in tone and scope with the questions about Earth being asked by lay people, students, educators, and government officials. Thus, they are ideal for translating the science of EarthScope into core content for the EON efforts.

Scenario: Boy Scouts Teach Community about Local Geology and Earthquake Hazards

Boy scouts in Troop 4 in upstate New York are working with the local EarthScope facilitator, earning their Geology and Communications badges. They took a field trip to the mountains in the area and investigated ancient glacial features as well as folds and faults in the rocks. They learned first hand about how rocks slowly deform over geologic time. During a troop meeting, they constructed a working seismograph and recently recorded a small earthquake. The young scientists combined their data with other EarthScope seismic data and determined the earthquake occurred in the area visited during their field trip. This is an unusual spot for an earthquake. The EarthScope facilitator taught the scouts how modern geologic processes like the melting of the great ice sheet in this area 11,000 years ago can reactivate the ancient folds and faults and trigger these earthquakes. The troop also studied the effects of the earthquake and developed a booklet to help people know what to do to prevent or reduce property damage and personal injury. The scouts reproduced and distributed the booklet at key locations and gave presentations on the knowledge they gained from the project.

Fact Sheet Ideas

- How old are the continents?
- How and why did the continents and ocean basins form?
- Can we predict earthquakes?
- Why do earthquakes occur in the middle of our continent?
- What makes some volcanoes more dangerous than others?
- How long does it take to build a mountain range?
- Can one earthquake trigger another?
- How do volcanoes work?
- Are there natural resources that we have yet to discover?
- What determines where natural resources are formed?

How to Accomplish This

- Compose news and other educational articles for traditional media and the Internet that reveal the inquiry process behind EarthScope experiments and teach basic science concepts.
- Develop resources, inquiry activities, videos and movies, permanent displays, and programs to engage and educate a broad and diverse audience at informal education venues such as museums and parks.
- Create resources to engage families in science and promote life-long learning such as educational television segments on EarthScope discoveries, a roadside geology travel log, or natural history and geology maps of popular vacation sites.
- Create resources and implement mobile outreach programs for schools, libraries, community centers, state fairs, conferences, and other meetings that promote EarthScope, Earth science, and careers in science.
- Initiate projects that involve community organizations, clubs, and schools in the installation of equipment and investigation of the technology, data, or related educational resources provided by EarthScope.
- Provide tours at EarthScope facilities and research centers.
- Create EON web pages with Frequently Asked Questions and print Fact Sheets.

Goal 4: Advance formal Earth science education by promoting inquiry-based classroom investigations that focus on understanding Earth and the interdisciplinary nature of the EarthScope experiment.

Why is this needed?

In recent years, many national studies have advocated systemic reform of the K-16 science education enterprise (NRC, 1996). One such report published in 2000—*Before It's Too Late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century*—underscores the need for America's students to improve their performance in mathematics and science to successfully meet the challenges of our scientific and technologically dominated society and to ensure that the United States remains competitive in an integrated global economy. Within this broad reform, Earth science education is undergoing its own transformation—changing from a discipline that has emphasized facts and properties about Earth to one that explicitly acknowledges the importance of inquiry, and promotes the study of Earth as a dynamic system. The reform in Earth science education is well articulated in *Shaping the Future of Undergraduate Earth Science Education* (Ireton et al, 1997) and *Blueprint for Change: A Report from the National Conference on the Revolution in Earth and Space Science Education* (Barstow and Geary, 2002).

A significant number of scientists and science educators involved in EarthScope are engaged in efforts to reform Earth science education. While the EarthScope community is not in a position to lead a reform effort, EarthScope does offer a unique and valuable opportunity to contribute to systemic reform of Earth science education and deliver high-quality learning experiences for the next generation of citizens and scientists. EarthScope education and outreach can reinforce high-quality Earth science education by providing: (1) a national focus, (2) opportunities for educators

EarthScope science goals and the fundamental principles that EON will advance are aligned with the National Science Education Standards (NRC, 1996) and the AAAS Benchmarks for Science Literacy (AAAS, 1993).

- Evidence, models, and explanation.
- Constancy, change, and measurement
- Evolution and equilibrium
- Systems, order, and organization
- Science, technology, and society
- History and nature of science

Specific Earth science content standards addressed by EarthScope science are:

- Energy and the Earth System
- Origin and evolution of the Earth system
- Structure of the Earth system
- Earth's history
- Properties of Earth materials
- Changes in Earth and sky

to become involved in the EarthScope experiment at a variety of levels, (3) a structure to coordinate and disseminate local reform efforts, and (4) a means through which the Earth science educational community can acquire the skills and resources to create and disseminate learning materials developed from state-of-the-art Earth science exploration.

How to Accomplish This

- Make EarthScope data, technology, and discoveries comprehensible, useful, and exciting to K-16 students in ways that promote effective instructional strategies and research opportunities.
- Provide professional development that prepares a large number of K-16 educators throughout the country to use EarthScope data and discoveries in the classroom.
- Develop a cadre of liberal arts two-year and four-year colleges to act as bridges between research universities and K-16 schools and students.
- Develop teacher-scientist and student-scientist partnerships that provide opportunities for teachers and students to participate in the EarthScope experiment, for example, in deployment, field data acquisition, and analysis.
- Recruit and train EarthScope graduate teaching fellows and faculty in effective teaching and outreach methods so they can support local EON efforts.
- Develop accurate modeling, simulation, and four-dimensional animation tools to help students understand spatial and temporal Earth processes.
- Create opportunities for schools to acquire resources and equipment that enable them to participate in EarthScope.
- Develop creative and engaging problem-solving modules that help students develop an integrated understanding of Earth processes and that use EarthScope data to formulate solutions to real problems.
- Engage the geoscience education research community to assess the effectiveness of curricula and programs.
- Build partnerships with organizations conducting complementary education and outreach efforts to extend the impact and awareness of EarthScope and EON.

Scenario: National EarthScope Teacher Training Academy

Imagine university science educators and EarthScope scientists organizing and conducting a national EarthScope Teacher Training Academy for master teachers. Each year, 30 creative science teachers from across the country who have exhibited leadership in their field are selected through a competitive process to attend the three-week-long Academy. The 30 teachers, or "EarthScope agents," learn about EarthScope science, geological and geophysical data and discoveries, and work in partnership with a science educator and scientist to develop investigations that use EarthScope data in classrooms. After the workshop, each EarthScope agent mentors other teachers and disseminates the EarthScope materials, activities, and information in another three-week Academy in their home state, following the format of the national model. The impact of the EarthScope Teacher Training Academy program is potentially significant. When the 30 master teachers provide training for 900 other teachers, EarthScope resources and programs could reach 27,000 new students each year.

Goal 5: Foster use of EarthScope data, discoveries, and new technology in resolving challenging problems and improving our quality of life.

Why is this needed?

The study of dynamic processes on the surface and deep within the Earth will provide critical information for a wide variety of other scientists and technical professionals charged with mitigating hazards and ensuring supplies of natural resources to our country. Scientists working on EarthScope research need a mechanism to ensure that their research results, and the basic data products reach the people and organizations that need it. EON can facilitate connections between the scientists and the end-users of EarthScope data and results to ultimately help taxpayers reap the benefits of their investment in Earth science research and EarthScope.

How to Accomplish This

- Create professional development activities for Earth science professionals and other end users of EarthScope data and discoveries, such as science journalists, risk assessors, engineers, urban planners, and professional geoscientists.
- Provide communication tools and resources to assist coordination among the broad EarthScope communities.
- Develop products and promote standards of practice that reflect EarthScope results and their application in Earth science, engineering, planning, policy, and education sectors.
- Identify and disseminate information about successful implementations of EarthScope data and research results that improve quality of life or reduce the risks associated with natural hazards.
- Create a series of fact sheets that promote successful partnerships with practicing professionals, policy makers, industry, and others who benefit from the practical application of EarthScope research.
- Create a database for tracking current and new partnerships throughout the lifetime of the EarthScope experiment and use it to stimulate interest in additional partnerships.

Scenario: Local Surveyors Meet EarthScope PBO

The PBO deployment team is busy making plans for work in a very rural area of Idaho. There are a few GPS stations already in the region but there are few university contacts to help build connections to the local communities. The team has distributed fact sheets that summarize research and investigations in EarthScope to local surveyors, engineering firms, and civic groups to generate interest among local scientists and technical professionals who might benefit from EarthScope. One of the flyers documents the partnership between the Southern California Integrated GPS Network and the surveying community for long-term maintenance of GPS receivers, which serve as highly precise reference stations for surveying. Through this effort the PBO team hopes to build partnerships that smooth the deployment process and result in a long-term agreement with the county to maintain the site.

Scenario: Extending the EarthScope Community

Geraldo, the chief scientist for the local water management board, is struggling to develop a long-range plan for the water management area in his arid, western city. The community is growing rapidly and he needs to determine the impacts that this growth and continued pumping from the local aquifer might have on the ground surface. There are signs of subsidence in the basin, but they could be due to the prolonged drought, or over use of the aquifer, or something else. He has read the new study that shows the largest fluctuations in the Los Angeles basin elevation occur on an annual cycle corresponding to the precipitation, although there is also long-term subsidence in the basin due to prolonged water withdrawal. Characterizing the problem of subsidence is more complicated than he expected. Maybe he could use satellite interferometry and GPS to aid his work in the same way scientists used data from those instruments to monitor Los Angeles basin subsidence. But first he needs to learn more about the techniques and who has the expertise.

A search on the Internet quickly takes Geraldo to the www.earthscope.org web site. From a recent EarthScope News article, he learns that geophysicists are teaming up with hydrologists to conduct integrated experiments in several western basins to answer similar questions. The article has links to the web site of the key scientists where he gets more in depth information about how the GPS, seismic, and interferometric data combine to give a complete picture of basin response over short and long time periods. A bit more searching reveals a list of EarthScope partner institutions and a complete list of scientists funded to conduct EarthScope research. Two nearby universities have scientists participating in EarthScope and one university scientist is interested in conducting a seismic experiment with a flexible array in his area. A few phone calls later, Geraldo has an appointment to meet with the university scientists to determine whether they could extend the EarthScope investigation in ways that could help answer his questions.

The national EON office will initiate efforts to partner with individuals and groups that offer opportunities to use EarthScope data, models, and results in applications of many types. Example applications include hydrologic basin analysis, mineral exploration, hazards research, and establishing baselines for surveying. Working at the national level, we can begin to identify the broad range of target audiences for this knowledge transfer. Fact sheets developed by the national EON office will serve as models for new partnerships to broaden EarthScope's impact, aid the permission process during instrument deployment, and demonstrate the value of the EarthScope experiment to society. As new partnerships form and are successful, new fact sheets that describe the partnership's impact will be created. The database created for tracking current and new partnerships will be evaluated each year to assess progress in developing successful partnerships, and the results will be included in the annual EarthScope report.

Evaluating Progress

With a new venture such as EarthScope EON, involving new participants and spanning the country in an unprecedented network, it is essential that careful assessment be conducted at every stage to ensure that the program is responsive to audience needs and is effective in achieving its goals. The purpose of this section is not to detail the formal evaluation plan but to suggest a framework for how such a plan can be developed and implemented. Naturally, the evaluation process will evolve to meet changing programmatic needs as we carry out EarthScope EON's goals.

Evaluating a program with the complexity of EON and the diversity of stakeholders will require the services of an independent external evaluator from the outset. To evaluate EarthScope EON products, the national EON office and the EON Advisory Board will examine a number of existing review processes (e.g., within Digital Library for Earth Systems Education, NASA, the *Journal of Earth science Education*, and the *Journal of Geoscience Education*) and develop a mechanism based on the experience of these and other organizations.

The EarthScope EON evaluation strategy will have four overlapping stages:

1. Stakeholder needs assessment will determine a base level of knowledge among various audiences and will identify specific needs to be addressed. Working closely with the national EON office, the professional evaluator(s) will gather this information through document reviews and interviews with representatives of the key target audience groups.

2. Evaluation design will consider the types of evaluation methodologies and logic models EON will employ, based on decisions of what should be evaluated (Quality and/or quantity of products? Usefulness of services? Cost-effectiveness? Net causal impact?) and why the evaluation is needed (Improve the disciplines of education and outreach? Accountability to agency management and stakeholders? Improve service delivery and program effectiveness?).

3. Performance measurement of product development and implementation will involve collecting accountability information for stakeholders, tracking intended and unintended outcomes of the program, and providing information vital to program improvement and achieving pre-established goals. This information can be useful for management of activities, resources, and partnerships.

4. Programmatic assessment of the overall success in achieving EON's stated goals and identification of what was successful, what failed, and why. This step is broader than performance measurement as it addresses the long-term, overall effect of the education and outreach program as a whole, and has implications for other large-scale education and outreach programs that can learn from EON's example.

In short, the evaluation process will answer certain key questions: What are we trying to achieve and why is it important? How successful are we in conveying the science and applications of the EarthScope experiment to our target audiences? How robust are our partnerships? What can we do to improve our program? How effective is EarthScope EON in achieving the desired outcomes? What difference was made?

EON Structure

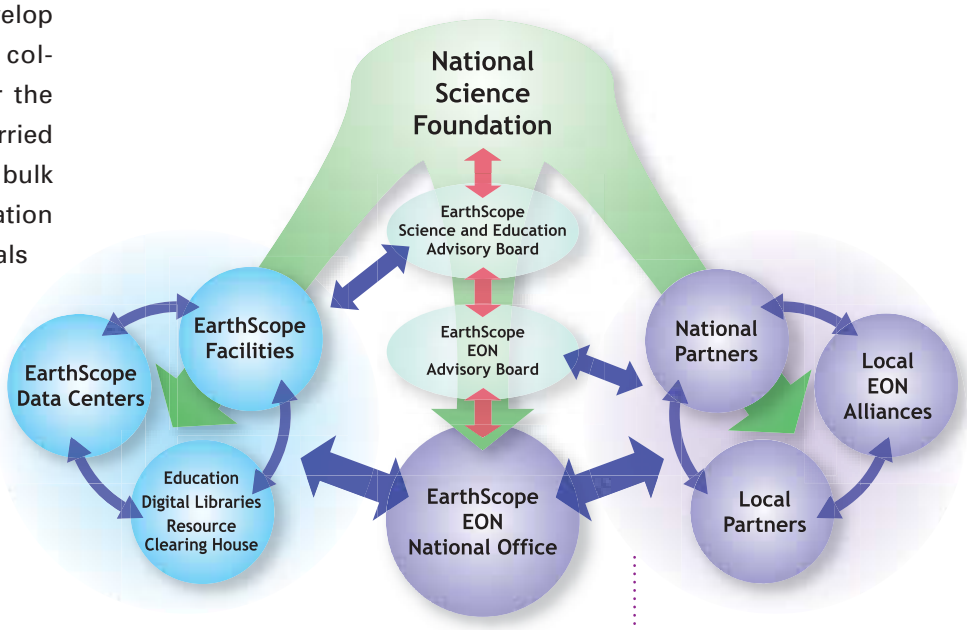
One of EarthScope's challenges will be to initiate and sustain a continental-scale education and outreach effort over the next 10-12 years. This effort must include developing and disseminating information and resources, implementing new educational programs, and supporting instrument deployment. To realize this vision of a coordinated and distributed education and outreach program requires a clear understanding of the roles of all potential contributors and an articulation of mechanisms available for coordinating their activities. The contributors fall into four categories: the national EON office, local EON alliances, EON partners, and EarthScope facilities.

A set of resources required to launch the EON effort and support the basic education and outreach efforts of the community will be developed by the national EON office. Similarly, the national office may develop and implement some programs in collaboration with national partners or the EarthScope facilities that are best carried out in a national forum. However, the bulk of the development and implementation efforts will be carried out by individuals and groups within the EarthScope community that have the best ideas and methods for achieving the EarthScope EON goals. The community recommends establishing a new program to fund these efforts through individual proposals at NSF, however, funding will also be sought from other federal and state agencies or private foundations.

EON management, as discussed in the next chapter, will take two forms. NSF has created the EarthScope Science and Education Advisory Board, which will serve in an oversight capacity for the national EON office and the overall EarthScope program. In addition, the EON Advisory Board, which will have representation of the broad EON and scientific community, will guide the overall EON effort and advise the national EON office.

Below we define the specific roles and relationships of these entities within the EON structure.

Basic Structure of the EarthScope EON Effort



The National EON Office

The national EON office is the focal point for EarthScope education and outreach efforts and the broader EarthScope community. It has the primary responsibility for creating opportunities for the community to achieve EON's goals. The national EON office will also work closely with the facilities, the EON Advisory Board, and NSF's EarthScope Science and Education Advisory Board to achieve the overall goals of EarthScope. The rich variety of activities related to this responsibility are described in detail below. To carry out this role, the EON office will have a small staff and core budget for its primary functions.

Role

The national EarthScope EON office is primarily responsible for creating resources and programs that establish a national public identity and presence for the EarthScope experiment and the EON efforts. It is also responsible for promoting, facilitating, and coordinating the contributions of the local EON alliances, EON partners, and EarthScope facilities. Activities that will be performed by the national EarthScope EON office include:

Resource development and dissemination for a national EON presence. The national EON office will be responsible for developing, implementing, disseminating, and maintaining materials related to EarthScope EON at the national level. These include: (1) an EarthScope EON web site, (2) nationally relevant education and outreach materials for use by local EarthScope alliance members, and (3) materials needed to gain financial and intellectual backing for the EarthScope EON effort as a whole. As a result of these efforts, the national EON office may have staff with specialized expertise (e.g., a graphic artist) who can be made available for small projects that support the local EON alliances or facilities.

Public relations. The national EON office will be charged with actively promoting EarthScope EON activities at all levels to EarthScope scientists, policy makers, technical professionals, funding agencies, and the public (e.g., assisting with instrument deployment).

Solicit participation of local EON alliances and partners in EON. In its role of facilitator and coordinator of the distributed EON efforts, the national EON office will actively solicit individuals and groups to participate in EON by notifying them of deployment schedules in their region and funding opportunities available at NSF and other agencies. The national EON office will work to identify and encourage existing groups to form alliances. While NSF and the EON Advisory Board will work together to set new directions for EON, the national EON office will work with NSF to help the community respond to these new directions with effective proposals. The goal of these efforts is to encourage a large and diverse community of scientists and educators to contribute to EON and to coordinate their efforts.

Brokering services. The national EON office will act as a brokering service between those individuals wishing to create and disseminate new content resources and other individuals conducting the science around which the content will be based. The office will also work with the DLESE and other national science digital library initiatives to

disseminate locally developed EarthScope materials and best practices to national Earth science audiences.

National workshops and the annual meeting. The national EON office will conduct workshops appropriate for national audiences in collaboration with national partners and/or the EON Advisory Board. These include workshops to help local EON advocates develop alliances and programs of their own, workshops to create resources for EarthScope EON, workshops directed toward helping educators, science writers, and other technical professionals use EarthScope results, and an annual meeting of EarthScope EON stakeholders and contributors.

Program evaluation. An important role of the national EON office is to determine measures of success and how well the EON community meets them. A program evaluator working with the national EON office can develop evaluation strategies and assessment tools vital to documenting the impact of the national program and can also provide guidance and assistance to local EON alliances in this area.

Support for EON Advisory Board. The EON Advisory Board is the primary mechanism through which community ownership of the EON endeavor occurs. It is also an important mechanism for the national EON office to receive community feedback on its efforts. Part of the role of the national EON office is to support the EON Advisory Board by organizing and conducting meetings of the Board and its subcommittees. Based on community input, the EON Advisory Board may make recommendations for key initiatives to be carried out by the national EON office. For recommendations that go beyond the core responsibilities of the national EON office, the EON Advisory Board will seek approval from the EarthScope Science and Education Advisory Board.

Mechanism for funding the national EON office. The workshop attendees recommended that the national EON office be awarded a core level of funding through a competitive proposal process at NSF. The award period should be consistent with that of the EarthScope facilities to enable a coherent effort over the life of the experiment. For activities beyond the core, the national EON office can seek additional funding through proposals to federal and state agencies and private foundations, as necessary.

Local EON Alliances

Local alliances, composed of groups of individuals with broad science and education expertise, will carry out EON's goals at the local level. Local alliances will include representatives from alliances' specific target audiences and experts in the development of education and outreach for those audiences. Thus, an alliance could include teachers or teachers' organizations, science writers or media representatives, school districts, colleges and universities, state geological surveys and emergency management offices, and informal science providers such as museums and nature centers.

Role

Local EON alliances have the primary role of implementing programs, building local partnerships, and customizing, developing, and disseminating EON resources. Individuals and groups forming local EON alliances will be designated as Local Alliance Members. Local alliances also have an important role in providing support for deployment as appropriate and ensuring knowledge transfer to key groups and organizations that could directly benefit from EarthScope science and education programs. Local EON alliances can take on many sizes, shapes and responsibilities but must address, at a significant level, multiple EON goals and serve multiple target audiences. A more detailed description of the structure and criteria for local alliances is presented below.

Local EON alliances assume the task of implementing the EON programs within their communities by working with teachers, students, the general public, informal educators, colleges, universities, and other stakeholders. Through this model, EarthScope EON can leverage and encourage the development of strong local activists that use the resources of EON to meet the needs of local communities. Examples of some of the activities that could be undertaken at the local level include:

Adopting, using, and disseminating materials developed by EarthScope through national initiatives. EarthScope facilities and the national EON office are expected to develop tools, data products, and educational resources appropriate for use by local EON efforts. Using these resources, in their original form or with modifications to reflect the local setting, the local EON efforts will accomplish significantly more than a single national entity can.

Resource development and dissemination. In addition to using materials developed at the national level, many potential EON participants are interested in developing primary material for their specific communities or national audience. In this context, materials could represent any of a variety of EON-related products and activities, such as brochures, educational resources, workshop materials, and museum display information. Materials development is encouraged, however, it must build upon the wealth of existing high-quality curricula and meet national education standards and norms. The national EON office can act as a clearinghouse for field-testing and disseminating these materials.

Conducting workshops. The strength of the EON model is its ability to support a workshop program that has a national scope,

yet seeks to enact change at the local level. With financial and material support (e.g., with content resources from the national EON office), local alliances can provide workshops to a variety of local audiences. These workshops could encompass professional development for educators, museum professionals, and engineering and planning professionals or could focus on fostering careers in Earth science.

Building K-16 partnerships. A concerted effort is required to effectively integrate EarthScope into educational programs at all levels. At the local level, EarthScope EON will support the development of local mentors interested in reaching out to K-16 Earth science educators. There are many high-quality, inquiry-based curricula that teach Earth science concepts related to EarthScope. The local EON alliances can work with school districts to adopt these resources and could also provide support for teachers' professional development. In addition, the local EON alliances could develop, in partnership with the school district, supplemental resources that demonstrate the curricular connections to EarthScope and extend curricular units.

Mechanisms for funding local EON alliances. Funding of the local EON efforts will be handled through individual proposals submitted directly to federal and state funding agencies and private foundations. Workshop participants recommend that new NSF funding be made available to support these proposals. Proposed efforts should reflect the goals outlined in this program plan and EON's changing needs as the network develops.

Scenario: IndigenES — Indigenous EarthScope Teams

Juan Carlos, a professor at the local Tribal College learned about EarthScope at a recent national conference and sees a real opportunity to serve his people and advance science education and research. A number of USArray and PBO instruments are slated to be installed on tribal lands and the EarthScope community needs his assistance. The tribal lands have infrequent, but unnerving, seismic activity that is monitored by distant instruments operated by the USGS. The USArray instruments promise to reveal smaller events traditionally not detected by the USGS.

Gabriella, a professor at a major research university, is the leader of a local EON alliance. Gabriella and Juan Carlos developed a plan that encourages the Native American students to take a leadership role in educating their tribe about the benefits of EarthScope to their community, and to help with siting and deployment on their lands. Juan Carlos and Gabriella also devised a research experience that will involve the students in analysis and modeling of data collected through EarthScope. The students will research historic records of seismicity for the region and develop, in their native language, fact sheets explaining the cause of the local earthquakes and the geology of their lands. The students, in partnership with the tribal cultural preservation office, will also research tribal oral histories to determine if any historic geologic events revealed by EarthScope correlate with stories from the elders. These "Indigenous EarthScope (IndigenES) Teams" will help their people gain a sense of project ownership while they participate in the EarthScope experiment. The goal is to provide a unique research experience that blends science with the native culture while facilitating local deployment of EarthScope experiments and public education about Earth.

Structure of Local Alliances

A flexible local alliance model will be employed to make maximum use of existing resources and structures. We anticipate that a flexible model will attract proposals from groups motivated by a wider set of needs than will a more restrictive model, and it will enable alliances to focus their efforts on what they do best and to serve the audiences and geographic area most appropriate for their alliance goals. The physical extent of an alliance's coverage could be defined by government (e.g., state-based), physiography (e.g., Colorado Plateau), or economic infrastructure (e.g., New York metropolitan area). However, flexibility must be balanced by a set of design criteria that support program coherence and ensure EON's goals are achieved through an integrated community effort. Local alliances that integrate their efforts with existing structures and leverage existing resources will be most effective. For example, a Colorado Plateau alliance focusing on K-12 education might align its activities with the standards of the states in which it operates and build collaborations with universities and other stakeholders in the region.

Local alliances may form to develop resources for EON, implement EON programs, or both. Funding for resource development will be needed throughout the life of EarthScope. However, funding for implementation of EON programs by a local alliance should be more closely tied to deployment of EarthScope instrumentation or complementary geologic campaigns and might extend from six months or a year prior to the field experiment or deployment until six months or one year after the experiment ends. This will allow the local EON alliance to assist with deployment and provide a rich education and outreach program tied to the experiment.

Criteria for an Effective Local EON Alliance

While local EON alliances may vary greatly in size, geographical extent, and role in the overall EON program, they will be most effective when they address, at a significant level, multiple EON goals and serve multiple target audiences (public, K-16 students or educators, technical professionals, and policy makers) using EarthScope data and science. For example, local alliances might propose to carry out one of more of the following components of the EON program:

Table 1: Examples of Local EON Alliances

Geographic Extent	Needs Served Optimally	Examples
Shared government (e.g., state-based)	Common standards, need to deal with same legislative bodies	• Serving all of Texas • Serving the Navajo Reservation
Shared geology (regional)	Work together on common Earth Systems themes, share data that pertains to an inter-school project	• Serving the Four Corners area of the Colorado Plateau • Serving the Appalachian Mountain region along the entire East Coast
Shared economy	Shared media and transportation systems, making it easy to organize centrally located events and run field trips	• Serving New York or another major metropolitan area

- Promoting Earth science education in K-12 classrooms.
- Conducting outreach and public relations.
- Supporting instrument deployment.
- Using EarthScope data in inquiry-based K-16 learning activities.
- Providing informal education opportunities.
- Improving undergraduate education.
- Training of college and university faculty and graduate students.
- Promoting the participation of underserved groups.
- Training of technical specialists (engineers, planners, science writers, policy makers).
- Knowledge transfer to technical specialists.

To make optimal use of existing resources and contribute new ones to the EON community, it is critical for local alliances to:

- Leverage their efforts by enlisting the involvement of multiple stakeholders.
- Avoid duplication of effort in the region being addressed by other local alliances.
- Contribute resources to the EON effort that can be used nationally either in their original form or with modifications.

This distributed development strategy for EarthScope EON is designed to leverage the pre-existing capabilities of local communities and motivate them to explore diverse and creative means of aligning their efforts to the goals of the EarthScope EON program. Existing groups in a region that have a structure and educational philosophy consistent with EarthScope's mission will be encouraged to join the EarthScope EON effort. These potential collaborations based on mutual benefit can advance the entire program substantially.

Scenario: New York State EarthScope Education Consortium

A group of teachers is using a Geographic Information System at a local summer workshop in the Adirondacks to study issues related to the siting of USArray instrumentation in the mountains. This is one of the events that the New York State EarthScope Education Association is sponsoring on a state-wide basis in anticipation of local deployment of USArray. Some of the aerial imagery and digital maps the participants are studying depict in great detail the mountains where many of their students are now spending their summer vacation hiking, camping, and fishing. The teachers are excited about the prospect of using this technology, integrated with EarthScope science, to engage their students in inquiry-based explorations of the Adirondacks. Students can look forward to discovering ancient faults that govern the locations and shapes of the lakes and streams that they are now exploring on foot, and evaluating evidence that the ancient bedrock beneath their homes may be rising and increasing the elevation of these mountains. They will also consider how high-precision GPS can shed light on the rate of this rise and provide data for calculating future elevations of the Adirondacks based on various models of uplift and erosion rates. These young citizens and future decision-makers will create maps of proposed USArray site locations based on their analysis of slopes, depth to bedrock, access, and the need to minimize impact on wilderness areas. Results will be presented to their parents.

EON Partnerships

A critical component of creating and sustaining EON is establishing formal and informal partnerships with a range of organizations active in areas of importance to EarthScope education and outreach. Partnerships will facilitate sharing resources and expertise for the benefit of both EON and the partner. This will allow new EON activities to efficiently leverage and build upon existing programs, extending the reach and impact of our efforts.

Organizations may become formal partners in EarthScope through a Letter of Agreement that outlines the mutually beneficial elements of the partnership. For example, a state geological survey could have a Letter of Agreement with EarthScope EON and the facilities to provide geological data in GIS format to be used for education, research, and instrument deployment. Similarly, an arrangement can be made with the National Park Service for developing exhibits in visitors' centers at selected parks. These types of partnerships can be developed at both the national and local levels. Other partnerships may arise through other means such as joint funding opportunities.

Role

Partnerships may be formed with groups that are involved in either science or education. Partnerships with other national scientific and educational communities could contribute knowledge and educational resources (e.g., USGS, COMPRES, state geological surveys), provide ready-made infrastructure for dissemination (e.g., National Geography Alliance, DLESE, American Geological Institute, Geological Society of America, American Geophysical Union, museums), or speed development of new resources (e.g., IRIS, UNAVCO). Partnerships can bring together a dedicated group of professionals at the national or local level who are capable of bridging the gap between scientists and educators by distilling the science into valuable and needed resources. Many potential partners have been identified in planning workshops and one of the first jobs of the EarthScope national EON office will be to begin establishing partnerships with these organizations. A list of potential partners is included in Appendix 2. As EarthScope EON develops, the number of partnerships will naturally increase, as needs and opportunities are determined.

The most effective initial collaborations will be with organizations where there is significant overlap in mission, where there are clear benefits to both parties, and where the partnership assists in translating data and science into education. Partners may be able to provide in-kind support or access to expertise including educational resources, technology, or communications. EON will be able to reciprocate by providing new EarthScope-focused resources, data, and technology. Partnerships may result in materials development or local or national implementation, or a combination.

Many national education efforts with resources valuable to EarthScope desire to implement their programs on a local scale. The local EON alliances can provide help with the local implementation and dissemination they need. Examples of a few of the activities that could be undertaken at the national and local levels include:

Scenario: Geologic History of the Jemez Caldera

Rasheed and Lisa are undergraduate students in a tectonics course taught at a university in New Mexico. They and their classmates have been assigned to interdisciplinary teams that will investigate the origin, evolution, and current dynamics of several of the main features of the Rio Grande rift system. Rasheed and Lisa are focusing on the formation of the Jemez Caldera from a petrologic and geochemical standpoint. Other students are examining seismic profiles of the caldera provided by an EarthScope flexible array, while still others are using ages of the rocks in the caldera to establish timing of events. All of the students assisted in the deployment of the flexible array. While doing so, they gathered samples of every rock type along the profile and have begun the petrographic analysis of them. Their professor provided some articles from popular science journals to help them get started. She has also pointed them to the Digital Library for Earth System Education, which has a special collection of EarthScope resources, including digital maps of seismicity, current plate motion and rates of deformation, seismic profiles showing subsurface features, and a geologic map of the area. There are also animations of the formation of the caldera and information on the status of magma chamber under the caldera. With these resources Rasheed and Lisa will develop an integrated model of the caldera and its geologic history. They will use EarthScope geological and geophysical data sets overlain on GIS databases of infrastructure and lifeline maps to assess societal risk. At the end of the semester, Rasheed and Lisa, along with their classmates, will hold a town meeting and deliver a short oral presentation to the undergraduate geology club.

Establishing a speaker's bureau. A number of organizations (e.g., AAPG, SEPM, SSA, IRIS, JOI, NAGT, AWG, Sigma Xi) sponsor speakers to address scientific and general audiences. EON could develop a partnership with one or more of these organizations to facilitate broad education of the scientific community or the general public.

Partnerships with school districts and teacher organizations. NSF currently funds dozens of Local Systemic Initiatives to reform the science curriculum in large, urban school districts. Partnerships on the local level that take advantage of these programs could have significant impact on the Earth science curriculum in the schools. A partnership between a local alliance and the district might involve university scientists and graduate students working with master teachers in the district. At the national level, EON can work with organizations such as the National Earth Science Teachers Association or the National Science Teachers Association to develop quality resources for the classroom and facilitate their dissemination and implementation.

Faculty and graduate student professional development. The National Association of Geoscience Teachers (NAGT) and others have experience offering faculty professional development workshops aimed at broad incorporation of current pedagogy, methods, and content into geoscience in-

Scenario: Museum Partnerships

A group of families is crowded around the EarthScope display in a new museum, with children waiting their turn to create their own earthquake. The locations of today's earthquakes blink on the giant display of the United States and rotating drums record the reverberating aftershocks of this morning's offshore earthquake. At the touch of a button the screen shifts to an animation of 5 million years of changing coastlines and topography of the North American continent. A boy switches the images back and forth as he deduces the connection between today's earthquakes and the geologic history and shape of North America. The exhibit builds upon the IRIS museum display, uses data from USArray, PBO, and SAFOD, and incorporates visualizations developed by EarthScope scientists, UNAVCO, EarthScope EON, and the museum.

struction. EON can form partnerships with NAGT and similar organizations to sponsor workshops on teaching Earth science using EarthScope data and problems. The integrated nature of EarthScope science provides a great opportunity for students to investigate Earth processes from both a geological and geophysical perspective and to learn more about the geophysical causes of some of the geologic features they observe. Many smaller universities have no geophysicist on the faculty and thus do not teach geophysics at the undergraduate level. Consequently, many geoscientists know what happens as a result of plate tectonics, but they may know little about why it happens. Workshops focusing on a geological problem that is familiar could provide faculty with the resources to begin introducing more geophysics in their undergraduate curriculum.

Dissemination of resources. Partnerships with DLESE, the National Geography Alliance, and the National Science Teachers Association, for example, could go a long way to disseminate resources generated through EON to a wide audience.

Museum and park exhibit development. A tremendous amount of experience in communicating science to the public is available at major museums and parks. Informal education of the public is an area in which few EarthScope scientists have any expertise. A partnership with a major museum or park, or with a national organization such as the Association of Science and Technology Centers, could result in new opportunities for scientists to learn about the field of informal education and use that knowledge and the partnership to develop high-quality EarthScope exhibits.

Radio and television. Partnerships with radio and television organizations can result in weekly or monthly science stories that reveal Earth secrets and update the public on EarthScope.

Mechanism for funding EON efforts carried out by partners. We anticipate that partners with EON will seek funding to support collaborative efforts with EON through the same competitive proposal process at NSF as the local alliances. In some cases the partners may be collaborating with the national EON office and in others with a local EON alliance. Proposed partnerships should be encouraged to use EarthScope data and scientific discoveries to carry out key components and goals of the EON program.

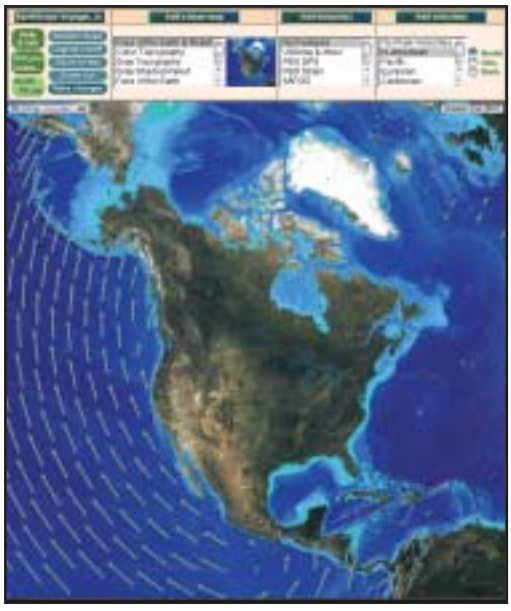
EarthScope Facilities and EON

EarthScope facilities are those entities awarded the responsibility to build, operate, and maintain the hardware and information technologies directly related to acquiring and disseminating EarthScope data. As currently envisioned, there will be three EarthScope facilities supported through a Major Research Equipment and Facilities Construction (MREFC) agreement with NSF—USArray, SAFOD, and PBO. However, facilities also include the data centers discussed in the EarthScope Science Plan, which will contain a wide variety of complementary geological and geophysical data and data products to support the EarthScope experiment. Each of these facilities will be housed within a larger host organization that will most likely be a partner of EarthScope and EON.

Role

The MREFC EarthScope facilities have a narrow and specifically defined role to gather, store, and disseminate data in support of EarthScope. Within this role, there are two areas in particular where the facilities and EON mutually benefit from collaborations: public relations in support of deployments, and development of data analysis and visualization tools. EON can help the facilities with public relations in their deployment mission while creating opportunities for local EON alliances to engage in more substantial education and outreach. Conversely, the EarthScope facilities are well positioned to enable access to, and use of, EarthScope data streams, data products, and tools for data analysis and modeling. By collaborating with EON, the data products and tools could be made accessible to a much wider audience. Appendix 1 provides a discussion of the anticipated technology and tools needed for EON. Some of these can be developed with the help of the facilities, others can be carried out by the EON members. Below we describe the types of tasks that could be supported by the facilities. Support of these tasks may require additional staff that could be shared among the facilities and the national EON office.

Development of information technology directly for the EON effort. EarthScope facilities will develop, implement, and maintain information technology related to acquiring, processing, and distributing data for the scientific community. This is a core mission of the facilities and is essential for the success of the EarthScope scientific enterprise. The facilities will collaborate with EarthScope scientists and organizations to develop and refine these capabilities. In a similar manner, the facilities may collaborate with education and outreach experts to adapt and, where



needed, develop new technology that will facilitate access to data streams and data products for the broad audiences EON will serve. These technologies may include specialized products for earthquake engineers, planners, and policy makers or visualization tools and Earth models for students. These products must be easily incorporated into learning materials developed by the education and outreach experts in the EarthScope community, and should also conform to a set of standards with regard to format and metadata across the three facilities.

Education and outreach in support of operations. EarthScope facilities can seek support to conduct educational and outreach efforts directly related to their operations. For example, SAFOD may develop a visitors center on site and PBO or USArray may wish to create video segments documenting their work. However, facility-based education and outreach generally will not extend to education and outreach activities related to the science and discoveries that come as a result of the experiment.

Mechanism for funding the facility-based EON efforts. For those education and outreach efforts that extend beyond the MREFC funding, we anticipate that the facilities will seek additional funding through the competitive proposal process at NSF. As in the case of partners and local alliances, programs that use EarthScope data and science to carry out the key components of the EON program will be most effective.

Scenario: Creating an EarthScope Hazards Map

"Let's put the geophysical institute here," suggests Joan to Tarik, as she points to the level area on the topographic map displayed on the monitor. Tarik agrees, observing that, "even though the bluff would afford a good view of the mountains from the offices, it would pose a significant seismic hazard. If an earthquake does occur, it would be a real bummer to find the building damaged and unsafe to enter as we ran to the door in hopes of looking at the seismograph." With the "Building Structure Tool" they place the outline of the geophysical institute in the preferred location and set its height to four stories. Joan and Tarik are enrolled in Dr. Azziz's Natural Hazards course at a university in the eastern United States where, although devastating seismic events are rare, large ones have occurred in historic time, along with numerous smaller events. As a homework exercise, the two students are using EarthScope's Hazmap software to display seismic, structural, InSAR, and topographic data from the EON web site. Their assignment is to redesign a nearby city to mitigate the effects of natural hazards, such as earthquakes, subsidence, and floods. "Let's make this area a park and steer development to places with more solid substrate," Tarik recommends as he points to an area surrounded on three sides by a meander in the river. "The InSAR data shows gradual subsidence here, probably because this area was once a marsh." Using the "Land Parcel Tool," they create an outline for the new park. "Let's look at the skyline again," Joan suggests. As they rotate a 3-D scene of the newly designed city, they both agree that it would be wonderful to actually experience living there.

EON Management

EON will be guided through both formal and informal reporting structures. Formally, NSF will oversee the work of the national EON office and the EON program overall using the EarthScope Science and Education Advisory Board and a possible visiting committee for the national EON office. The EarthScope Science and Education Advisory Board serves a critical role in keeping EON well connected to the EarthScope scientific experiment. The role of the EarthScope Science and Education Advisory Board is being set by NSF and will not be discussed further here. As the role of this Science and Education Advisory Board develops, and EarthScope comes to fruition, we expect that this nascent management model will also develop and evolve.

The community has identified a strong need for effective representation of EON concerns within EarthScope's management structure. The EON community recommends forming an EON Advisory Board to take on this role and to guide EON from a community perspective. This EON Advisory Board may include representatives of partner organizations, EON alliances, target audiences, and the EarthScope scientific community. It will also include representatives of the facilities as *ex officio* (non-voting) members.

The EON Advisory Board will carry out the following responsibilities, in some cases, with the help of the community and the national EON office.

Represent the EON community within the EarthScope management. The EON Advisory Board will represent the EON community in the EarthScope management structure and will report to the EarthScope Science and Education Advisory Board. To carry out this role, the EON Advisory Board, along with the national EON office and local alliances, will gather information from the community on EON needs, and identify new directions for EON efforts. The EON Advisory Board will also set policy in areas such as resource quality assurance and program evaluation. Community input will be gathered through discussions on the EarthScope EON electronic discussion group (at www.dlese.org) and through an annual meeting of the EON community.

Advise the national EON office. The national EON office efforts will play a critical role in establishing activities and creating materials that support the efforts of local alliances throughout the country. Thus, it is essential that the community have adequate input into the activities and resources developed by the national EON office. The EON Advisory Board will work with the community to ensure that critical needs are brought to the attention of the national office and are appropriately addressed.

Establish subcommittees as necessary. Subcommittees will assist and advise the EON Advisory Board on particular matters, undertake projects appropriate to the focus of the committee, and provide a mechanism for gathering community input. Subcommittees may include Public Relations, Deployment, Informal Education, Formal Education, Data and Technology, and Knowledge Transfer among others. As EON evolves, these subcommittees may also evolve to focus on emerging opportunities and new challenges. The EON Advisory Board will name the chairs of any subcommittees and appoint an EON Advisory Board member as a liaison on the subcommittee. Membership on the

subcommittee will be chosen by the chair and approved by the EON Advisory Board. Subcommittees charged with specific tasks can be established and dissolved at the request of the EON Advisory Board.

Convene an annual meeting of the EON community. An annual meeting for the EON community will provide opportunities for defining new directions, conducting targeted training, and stimulating collaborations and partnerships. The EON Advisory Board will be responsible for defining the goals and setting the agenda for the annual meeting while the national EON office will be responsible for the logistics and organization of the meeting. All funded EON alliances will be encouraged to include funds in their budgets to attend the annual meeting. Support to attend the meeting could also be provided through the national EON office for individuals desiring to become active EON partners or to form local EON alliances.

Solicit formal partnerships. In some instances, it will be beneficial for EON to have a formal relationship with a partner. The EON Advisory Board will establish a mechanism for local EON alliances and the national EON office to make recommendations for formal partnerships. If the EON Advisory Board approves a recommendation, the national EON office will formalize the partnership with a Letter of Agreement.

Establish guidelines for review of EON resources. The community will create many new resources promoting EarthScope and representing the EarthScope community. The EON Advisory Board will establish a review process to ensure resources using the EarthScope logo and name are consistent with the goals and identity adopted by the community.

Promote use of EON resources and participation in EON. To encourage sustainability and growth of EON and ensure EON's goals are met, the EON Advisory Board will establish policies that govern participation in EON.

Establishing the EON Advisory Board. An EarthScope Education and Outreach Steering Committee currently exists. This committee is charged with bringing the community to the point at which EON can be launched. When this task is accomplished, the new EarthScope Advisory Board will be established to take EON into the development stage. The current EarthScope Education and Outreach Steering Committee will appoint a nominations committee to solicit candidates for the EON Advisory Board. A slate of candidates that is representative of the diverse community participating in EON will be developed and put forth to the community for approval. Voting for the slate of candidates rather than individuals will more effectively ensure broad representation.

Conclusions

EarthScope is a monumental enterprise to investigate the dynamics and evolution of the North American continent. In recognition of this unique opportunity to fully integrate science research and education, representatives from the education, science, and EarthScope facilities communities developed the Education and Outreach Network program plan presented here. EarthScope data and scientific discoveries will form the core of a major education and outreach program that reaches all Americans, young and old. Just as the experiment is national in scope with designs to accommodate regional and local scientific problems, the EarthScope education and outreach efforts will be both national and local. This large-scale program can be realized with leadership from a national EON office and an EON Advisory Board, and with significant contributions from multiple local EON alliances, partners, and the facilities.

EON's mission is to ensure the EarthScope experiment creates as its legacy a public more knowledgeable of basic Earth science concepts and that has a deep understanding of the scientific and societal contributions made by the EarthScope experiment. EON will address this challenge by developing programs and disseminating products that use EarthScope's data, models, technology, and discoveries and that support existing Earth system science and outreach programs. We will form partnerships with museums and parks to create exhibits and educational programs for the public and with K-12 schools to support systemic reform efforts. We will establish programs that promote research experiences for K-16 students and faculty in K-12 schools and undergraduate institutions. Finally, we will develop products that facilitate wide use of EarthScope data and results by technical professionals working to improve our communities and our lives. In all of these efforts, we will focus on increasing interest in Earth science careers, especially among minorities and other under-represented groups.

The EON program design addresses two other issues important to every education and outreach effort: sustainability and assessment. Establishing partnerships between EarthScope EON and existing organizations and programs with similar goals and philosophies will address sustainability. Building upon existing programs will provide the infrastructure for EON efforts to gear up quickly and continue well beyond the life of the experiment. EON program design also incorporates a plan for careful assessment to be conducted at every stage to ensure that the program is responsive to audience needs and effective in achieving its goals. Through these efforts, EarthScope will have great impact on all American's understanding of how Earth works, and EarthScope will have a legacy that lasts for many generations.

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Appendix 1:
Technology and Tools in Support of These Goals

Advanced technology applications are at the heart of EarthScope and EON. They will support data collection and sharing, communication and education, and scientific discovery. Detailed descriptions of some key technologies and tools desirable for a first rate education and outreach program follow.

Internet Portal

An Internet Portal, functioning as a "virtual resource center" with hyperlinks to the ever-expanding EarthScope knowledge base and other complementary web-based resources, is an essential EON feature. Such a resource, updated frequently, would constitute a "one-stop-shopping" learning network for all target audiences. It would also be invaluable in supporting high-quality professional development for EON members—educators, K-12 teachers, scientists, and technical professionals. Activities and resources that we envision for the Portal include:

- An online professional journal that encourages mathematics and science teachers to engage in publishable research and to share new teaching strategies with colleagues, both nationally and internationally.
- Access to freely available resources such as ArcExplorer, Seismic Eruptions, Seismic Waves, Mr. SID Viewer and GeoViewer, Image2000, and Jules Verne Voyager.
- An interactive venue for conversations, meetings, and idea sharing; links to digital libraries and databases like DLESE and the Eisenhower National Clearinghouse.
- Technology and tools (available for a variety of computer platforms) to enable EarthScope stakeholders to access, analyze, visualize, and interpret multifaceted EarthScope data and geologic information.
- User-friendly access to real-time EarthScope data and experiences.

Videoconferencing and Distance Learning

Because of the scale of the EarthScope experiment and the distributed nature of the facilities and instruments, some EON participants may be isolated from new information and professional development opportunities by geography or they may lack sufficient resources for travel to workshop destinations. To this end, we will encourage EON members and EarthScope partners to investigate opportunities to use currently installed technology—Internet, satellite, and videoconferencing—to create multi-media, distance-learning environments for appropriate education and outreach activities. Videoconferencing, for example, could be used to share innovative instructional strategies, link scientists with teachers in training workshops or with students in classrooms, and deliver tutorials on curriculum materials that meet federal and state education standards to teachers.

Scenario: Roadside Geology Explorations

The Mutombo family is preparing for vacation. They have a new car navigation system equipped with a DVD stereo/video system that displays a map library, encyclopedia, and graphical locators. They will no longer argue about where they are on the map, but questions about "When will we get there?" will take on new meaning. Latifa Mutombo just bought the new EarthScope Roadside Geology Explorations DVD, which uses the car's GPS navigation technology to provide continuously updated geologic and natural history information customized for their trip. As they travel down the highway they can view maps, images, short videos with narratives, and other information on the geology and natural history of surrounding landscapes. As they near a crossroad, the system identifies short diversions from the main road to points of interest. It also informs them of notable local events such as earthquakes and floods, and of specific points of interest, such as good fossil-collecting sites. The information on the DVD is derived from publications by EarthScope scientists, federal and state geologic surveys, National Park Service guides, and Bureau of Land Management and Forest Service maps. It is also possible for the Mutombo family to gather the most recent updates to the information using a real-time cell phone / satellite link to the EarthScope data center. Recently automobile clubs, travel agencies, and local chambers of commerce, have teamed up to deliver the same information at kiosks or in print form to tourists lacking this technology, and the rail and airlines are investigating how to enhance travelers' experiences in a similar way.

Web-casts would also be used to allow target audiences to experience EarthScope science and to provide them with an understanding of the technology used to collect data. For example, SAFOD web-casts could be used to showcase drilling technology and provide real-time monitoring inside the fault zone that will contribute to understanding earthquake nucleation and propagation.

Visualization

Understanding spatial relationships is crucial to developing a conceptual understanding of Earth processes. EarthScope will investigate the use of visualization technologies to facilitate the display of three- and four-dimensional EarthScope data in electronic media and on virtual reality display devices. Sophisticated systems include the wide-screen, immersive environment of the new Visualization Center at the Scripps Institution of Oceanography at the University of California, San Diego, which allows groups of researchers to collaborate in real-time on large Earth science data sets displayed as three-dimensional images projected on high-resolution wall-sized screens. Less complex, more affordable methods include the PC-based CAVE virtual reality environments like GeoWall, developed by the Geowall Consortium, which uses projection systems to visualize Earth structure and dynamics. It is based on technology developed at the Electronic Visualization Lab at the University of Chicago that allows low-cost PC-based graph-

ics workstations to link to an Access Grid node in order to project three-dimensional stereoscopic computer graphics.

Visualization tools are useful for all EON target audiences, but in particular for informal science education (i.e., museum exhibits), for college- and university–level education, and for professional development for technical users of EarthScope data. Although not yet commonplace, the rapid pace of development of cost-effective, immersive virtual reality environments suggests that they will be widely available during the course of the EarthScope experiment. Visualization images and technology that convey the scientific and technical concepts of the EarthScope experiment in ways never before seen by many of our target audiences will help them develop a keen appreciation for the program.

Geographic Information Systems (GIS) can integrate EarthScope data with geographically referenced information and serve as a data management, analytical, or display tool. For example, GIS can be used by local planners and emergency response managers to integrate lithologic and EarthScope data with land use, cultural, economic, and human factors to depict the inferred relative stability of the land surface during an earthquake and to assess the level of risk associated with specific areas. GIS can also serve as a visualization tool, and in the context of this example, can produce animations showing predicted consequences of an earthquake. EON should offer training in GIS, visualization tools and applications, and data interpretation.

Maps, Media, Models, Animations, and Simulations

EON will prepare traditional two-dimensional representations of spatial data such as maps (i.e., regional earthquake maps) and profiles, and assemble collections of materials that promote an understanding of EarthScope science and technology—videos, printed materials, educational toolkits, and imagery supplemented with photographs of ground scenes to enable ground-truth studies. We will also encourage the development of animations, models, and simulations. These may include four-dimensional reconstructions of tectonic provinces and plates similar to those developed by Tanya Atwater at the University of California at Santa Barbara and the PLATES project at The University of Texas Institute for Geophysics; hazards models and ground shaking simulations; and animations that illustrate geologic processes, again similar to examples developed by Atwater. We will explore the incorporation of systems modeling packages such as STELLA (Systems Thinking Experiential Learning Laboratory) and offer opportunities to compare observations based on EarthScope data with computer simulations such as simulations of deformation from groundwater withdrawal, volcanoes, and earthquakes.

Appendix 2:

Anticipated EarthScope EON Partners

A significant number of organizations have indicated an interest in being a partner in EarthScope EON. As EON develops, we will formalize these partnerships to facilitate sharing of resources and expertise for the benefit of both EON and the partner. The list below is a partial list of future partners, which we expect to expand as EarthScope gets underway. You can learn more about partnerships with these groups on the EON web site at www.earthscope-eon.org/eo/partners.html.

- **American Geological Institute**
  www.agiweb.org
- **American Geophysical Union**
  www.agu.org
- **Association of American State Geologists**
  www.kgs.ukans.edu/AASG/AASG.html
- **Association of Presidential Awardees in Science Teaching**
  www.ehr.nsf.gov/pres_awards/assocs2.shtm
- **Center for Earthquake Research and Information**
  www.ceri.memphis.edu
- **Coalition for Earth Science Education**
  www.ceseweb.org
- **COMPRES**
  www.compres.stonybrook.edu
- **Digital Library for Earth System Education**
  www.dlese.org
- **Federal Emergency Management Agency**
  www.fema.gov
- **Geological Society of America**
  www.geosociety.org
- **GeoWall Consortium**
  www.geowall.org
- **The Incorporated Research Institutions for Seismology**
  www.iris.edu
- **Mid-America Earthquake Center**
  mae.ce.uiuc.edu
- **Multidisciplinary Center for Earthquake Engineering**
  mceer.buffalo.edu
- **National Association for Black Geologists and Geophysicists**
  www.nabgg.com
- **National Association of Geoscience Teachers**
  www.nagt.org
- **National Earth Science Teachers Association**
  nestanet.org
- **National Geodetic Survey**
  www.ngs.noaa.gov
- **National Geographic Society Education Foundation**
  www.nationalgeographic.com/foundation
- **National Oceanic and Atmospheric Administration**
  www.noaa.gov
- **National Park Service**
  www.nps.gov
- **National Science Teachers Association**
  www.nsta.org
- **Pacific Northwest Seismograph Network**
  www.geophys.washington.edu/SEIS/PNSN/welcome.html
- **Revolution in Earth and Space Science Education**
  www.earthscienceedrevolution.org
- **Science Teachers Association of New York State**
  www.stanys.org
- **Seismological Society of America**
  www.seismosoc.org
- **Society for the Advancement of Chicanos and Native Americans in Science**
  www.sacnas.org
- **Southern California Earthquake Center**
  www.scec.org
- **Space Science Institute**
  www.spacescience.org
- **UNAVCO, Inc.**
  www.unavco.org
- **United States Geological Survey**
  www.usgs.gov

Appendix 3:
Acronyms

AAAS .....American Association for the Advancement of Science
AAPG .....American Association of Petroleum Geologists
AGU .....American Geophysical Union
AWG.....Association of Women Geoscientists
COMPRES.....Consortium for Materials Properties Research in Earth Sciences
DLESE .....Digital Library for Earth System Education
EON.....EarthScope Education and Outreach Network
FEMA .....Federal Emergency Management Agency
FOSS.....Full Options Science Systems
GIS .....Geographic Information Systems
GPS .....Global Positioning Satellite
GSA.....Geological Society of America
InSAR.....Interferometric Synthetic Aperture Radar
IRIS.....The Incorporated Research Institutions for Seismology
JOI.....Joint Oceanographic Institutions, Inc.
MREFC .....Major Research Equipment and Facilities Construction
NAGT .....National Association of Geoscience Teachers
NASA .....National Aeronautics and Space Administration
NPS .....National Park Service
NRC.....National Research Council
NSDL.....National Science Digital Library
NSF .....National Science Foundation
NSTA.....National Science Teachers Association
PBO .....Plate Boundary Observatory
SAFOD .....San Andreas Fault Observatory at Depth
SCEC .....Southern California Earthquake Center
SEPM .....Society for Sedimentary Geology
SSA .....Seismological Society of America
UCAR .....University Consortium for Atmospheric Research
UNAVCO .....formerly University Navstar Consortium, now UNAVCO, Inc.
USGS .....United States Geological Survey

Appendix 4:
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