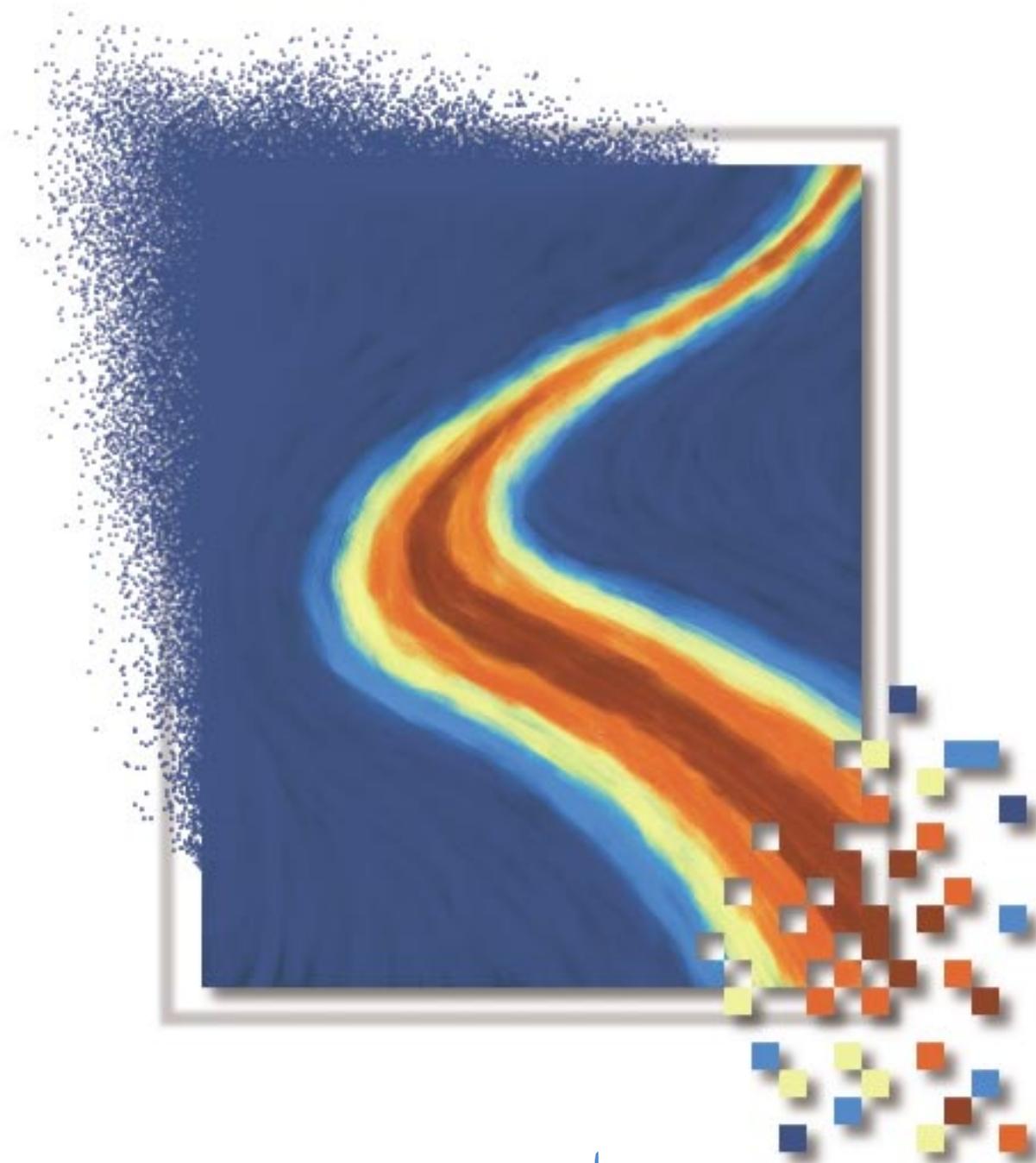


IRIS Education and Outreach Program Plan



Making Waves



Incorporated Research Institutions for Seismology

Education and Outreach Program plan

www.iris.edu

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Executive Summary

Seismology provides a window into the inaccessible Earth and is fundamental for understanding our dynamic planet. It allows us to prospect for and benefit from Earth's natural resources, and to assess and mitigate its earthquake and volcanic hazards. Seismology plays a vital role in monitoring man-made and natural seismogenic events ranging from small industrial explosions to the ringing of the entire Earth. Appreciating and understanding seismology's scientific and societal relevance requires knowledge of geology and physics, often coupled with elements of oceanography, electronic and computer instrumentation, civil engineering, public policy, and other disciplines. Seismology is thus an engaging and quantitative science exhibiting a myriad of connections to broader areas of science and society. As such, it can be illustrative of both the predictive power of simple physics-based models, and of the astounding complexity of Earth systems science.

The Incorporated Research Institutions for Seismology (IRIS) is a National Science Foundation supported consortium of nearly 100 research universities across the United States. Since its 1984 inception IRIS activities have catalyzed unparalleled growth in high-quality seismic data and associated groundbreaking research. IRIS recognizes the potential for professionally coordinated Education and Outreach activities in seismology and associated Earth sciences to significantly advance national awareness, interest, and understanding of science and mathematics.

IRIS E&O activities are designed for audiences ranging from K-16 students to the general public, and are focused where IRIS is well-positioned to make substantive contributions commensurate with its unique position as a large research university consortium incorporating world-class research and data resources. Program goals will be advanced by the E&O staff in close collaboration with a diverse assortment of allies, including IRIS members and their institutions, K-12 teachers, undergraduate institutions, science and news journalists, and science museums. IRIS will also work closely with other national Earth science teaching and research organizations, regional earthquake centers and federal agencies with strong mandates for public education, to maximize joint effectiveness and reduce redundancy. An increasingly important component of IRIS E&O will be contributions to complementary national Earth science initiatives, such as EarthScope, the Digital Libraries for Earth Science Education (DLESE), and the Advanced National Seismic System (ANSS), which offer significant nationwide venues to advance Earth Science interest and literacy.

Leveraging IRIS resources to produce nationally significant results will require substantial and sustained outreach to the wider education community. Important efforts in this direction include a range of K-16 teacher workshops, widely distributed educational modules, and associated tools (including seismographs and educational software for viewing and interpreting seismograms), and a recently instituted IRIS Educational Affiliate membership program for undergraduate colleges and universities. Outreach to the general public will be enhanced through a distinguished lecture program, seismology museum exhibits, improved educational access to and use of seismic data, and other general information initiatives and materials. An essential component of gauging the impact of our efforts in all the above areas will be an assessment plan incorporating internal and external review.

Core Activities and Audiences for the IRIS E&O Program

A Focus on People	
Activity	Audience
Educational Affiliates	Undergraduate institutions
Professional development for undergraduate teaching	Undergraduate faculty
Professional development for Earth scientists working with K-12 teachers	Graduate students and professional Earth scientists
Professional development for K-12 teachers	K-12 teachers
Undergraduate Research Internships	Undergraduate students
Graduate Student Teaching and Communication Workshops	Graduate students
Graduate Student Travel Grants	Graduate students
Efforts to increase diversity throughout our program	K-20 students
Distinguished Lecture Program	Students and faculty at colleges and universities, public
EarthScope/USArray	All Americans
A Focus on Products	
Activity	Audience
Posters and one-page information sheets	Public and K-16
Museum Exhibits	Public and K-16
Seismometers in Schools Program	K-16 schools
Instructional Materials (Teachable Moments resources and other curriculum modules)	K-16
Seismic Data Analysis Tools for the K-16 classroom (AmaSeis, WILBER and VSN Explorer)	Public and K-16
Web access to seismic data and related information	Public and K-16





Chapter 1

Advancing Earth Science Education

Introduction

Seismology is a broad science, fundamental to the study of earthquakes and volcanoes, prospecting and recovery of natural resources, and the evaluation of seismic hazards to buildings, power plants, pipelines, and other infrastructure. Seismology is also about probing the deep inaccessible interior of the Earth through thousands of kilometers of rock, and even about monitoring for clandestine nuclear explosions detonated under some remote desert. This unique blend of basic and applied research in Earth science and physics makes seismology an engaging and highly relevant topic for communicating the essence and excitement of science to students and the public. It is this excitement of scientific discovery and the importance of understanding the complex and dynamic Earth and society's interactions with it that propels us to engage in outreach and education for all Americans.

Earthquakes are a reminder of the power of natural Earth processes and that we are not in full control of our destiny. They challenge us to understand these processes and stimulate interest in learning.

The Incorporated Research Institutions for Seismology (IRIS) is a consortium of United States universities that have research programs in seismology. IRIS is responsible for the development and operation of the infrastructure needed for the acquisition and distribution of high quality seismic data to a global audience of researchers, educators, and the interested public. IRIS infrastructure has facilitated huge advances in our understanding of Earth structure and processes, ranging from global images of our planet's seismic velocity structure to high resolution images of the near surface. Equally important, it has raised the quality of research and increased the opportunities for scientists in the United States and around the world to actively participate in research. With the unparalleled resources in data, data accessibility, computer technology, and scientific expertise among its membership institutions, IRIS can also make substantial contributions to science education. The nationwide distribution of IRIS institutions allows our educational outreach

efforts to incorporate national, regional and local programs. We believe that by drawing on IRIS' strengths we can make significant contributions to science education by promoting a deeper understanding of our dynamic planet through seismology, and by extension, general science.

Providing professional development and resource materials in Earth science and seismology is especially important for teachers in middle and high school grades who teach the bulk of the Earth science concepts that the majority of Americans will ever learn.

IRIS members have increasingly recognized the need to communicate the results of scientific research to the public more effectively, to advance science literacy in our nation for greater understanding of our rapidly changing, and increasingly technological world, and to attract more students to study science. To address these issues, the IRIS Education and Outreach (E&O) program was formed in January 1997. Since its

inception, the E&O program has explored the needs of the different audiences we serve and has developed core activities to address those needs. In 1998, the E&O committee convened a conference with representatives from diverse science and science education disciplines, funding agencies and other Earth science E&O programs to develop a broad vision of how IRIS can uniquely contribute to science education and outreach. The discussions and collaborations that developed during and since this inaugural conference have guided our efforts. Accomplishments over the last four years provide a solid and tested foundation for the new vision and scope proposed in this program plan. In particular, we have been attentive to new science and education initiatives such as EarthScope and the Digital Library for Earth Systems Education (DLESE) (See Chapter 5).

IRIS E&O has chosen, through internal decision-making and the guidance from education and research communities, to provide products and programs for a variety of audiences. Primary audiences for outreach include the general public, K-12 students and educators, and post-secondary students at our nation's colleges and universities (Table 1). However, to be successful, the E&O program must also look inward to tap the huge pool of talent within the diverse ranks of IRIS' nearly 100 member institutions to build an education program of truly national scope and prominence.

The justification for reaching out to diverse audiences is simple. The general public has entrusted scientists to engage in meaningful research for the good of society. Taxpayers supporting such work have the right to expect relevant and timely information that will satisfy their curiosity and allow them to make informed decisions. By providing the public with this information, we contribute to a generally increased level of scientific literacy and help validate the relevance of scientific research to society. The public also has an expectation of excellence in teaching at all educational levels. We can provide opportunities that help the seismology community and K-16 educators engage in more effective teaching in both classrooms and in other, more informal settings. Our efforts will help create a new generation of Americans with a greater understanding of Earth science and seismology, and help us attract the best and brightest to our discipline. Research shows that creative teachers using innovative lessons can stimulate an early interest in science and increase the likelihood of a student choosing a career in science. To stimulate this interest requires high quality educational resources for teachers in K-12 and for college faculty in undergraduate programs. Providing accurate and efficient professional development and resource materials in Earth science and seismology is especially important for teachers in middle and high school grades who currently teach the bulk of the Earth science concepts that the majority of Americans will ever learn.

IRIS will focus on developing people and products through our E&O program by:

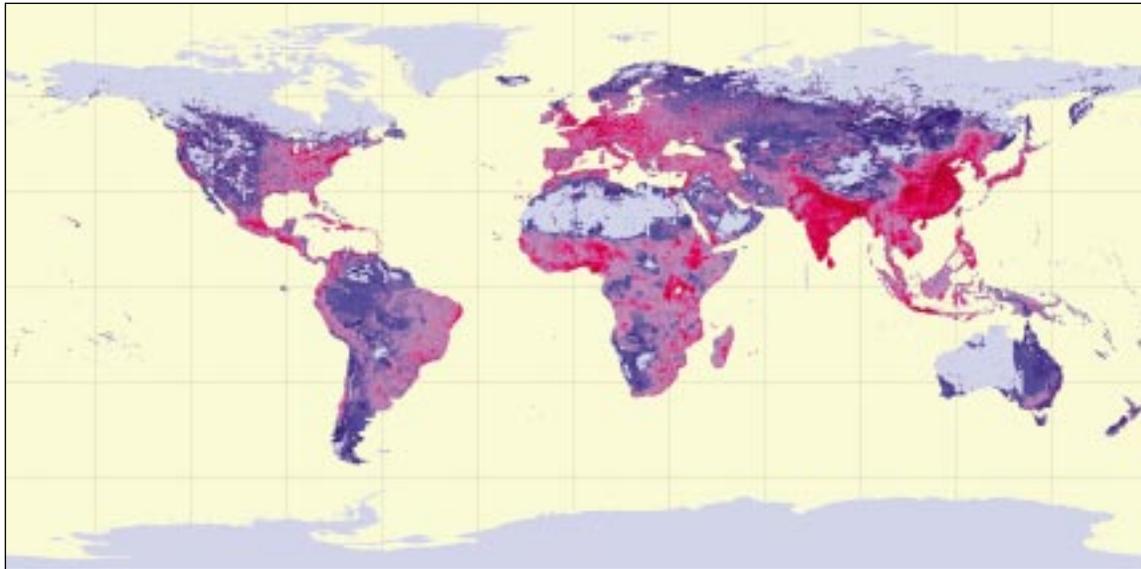
- Providing educational opportunities in seismology and related science, engineering, and mathematics topics that help our target audiences develop new skills and understanding; and
- Developing products to facilitate teaching and learning seismology and related topics in Earth science, engineering, and mathematics.

Table 1: Target Audiences for IRIS E&O Activities

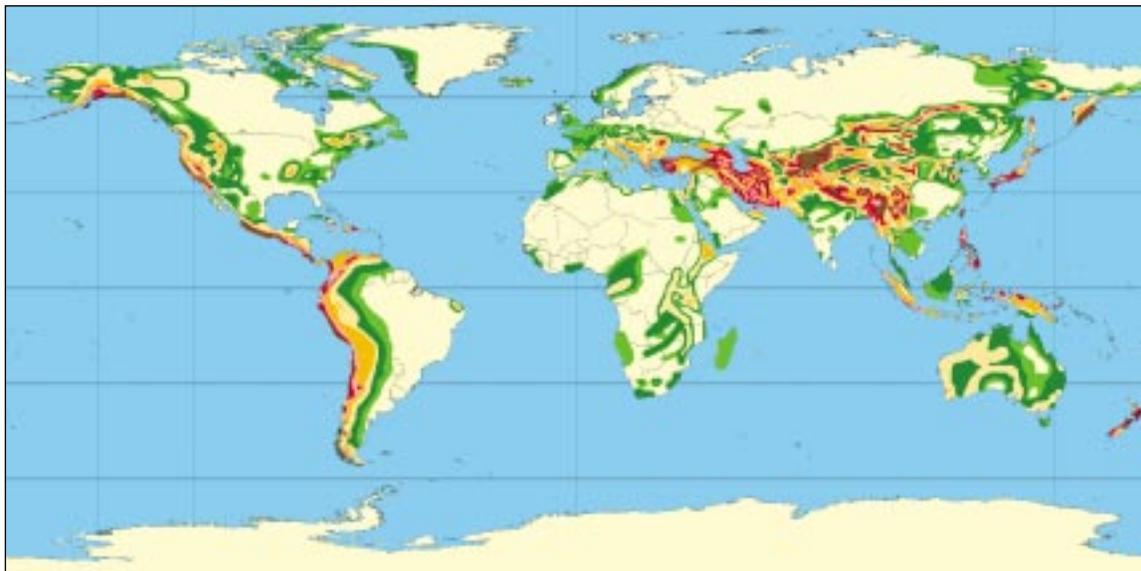
Educational Level/Target Audience	Benefit/Goal
General Public	<p>Increase understanding, awareness, and appreciation of the relevance of science and technology.</p> <p>Provide relevant and understandable scientific information.</p> <p>Build public support of science and Earth science in general, and seismology in particular.</p>
Young Children	Stimulate science interest in young children; many scientists developed their interest in science at a very early age.
K-12 Students/Teachers	<p>Improve quality of science teaching and learning, especially Earth science learning.</p> <p>Capitalize on the natural interest of young students in earthquakes, volcanoes, plate tectonics, and other high profile Earth science.</p> <p>Increase quality and numbers of students entering college with interests in Earth science.</p>
Undergraduate Students/ College Faculty	<p>Improve teaching in introductory Earth science courses and provide future leaders with sufficient understanding of Earth science issues.</p> <p>Increase the number and quality of students selecting geophysics and Earth science as majors.</p>
Graduate Students	<p>Provide graduate students with experiences that improve their skills as scientists and educators.</p> <p>Open doors to a variety of careers.</p>

Educational opportunities currently provided by IRIS include professional development workshops for Earth science professionals and K-12 teachers, where educators learn to teach seismology-related Earth science and physics topics in engaging and effective ways. The E&O program will further stimulate integration of research and education by providing non-specialists with easy access to real and timely seismic data and user-friendly data analysis tools and by providing opportunities to participate in ongoing research projects. This integration can be supported further through the incorporation of real data into inquiry-based science instructional materials.

IRIS has encouraged and supported the involvement of its members and other institutions in a wide variety of education and outreach efforts. The consortium is in a position to help strengthen the efforts of individual members by providing essential resources and coordinating efforts nationwide. We also recognize the crucial leveraging effect of engaging in partnerships with other organizations involved in Earth science education. This approach is key to achieving the vision and goals of the program.



*Global population map. Highest population density is red; lowest population density is light blue.
(C.Scott Walker, University of Arizona)*



*Global seismic hazard map. Highest hazard is dark red; lowest hazard is beige.
(Data from Global Seismic Hazard Assessment Program)*

Locations of high seismic hazard strongly correlate with regions of high population and low economic prosperity, setting the stage for potential earthquake disasters.

In this document we set the stage for IRIS E&O activities, focused on areas where IRIS is well positioned to make substantive contributions. We begin with a brief review of relevant national education reports outlining the present state and national goals of science education and then identify contributions that we can make to help achieve those goals (Chapter 2). We next clarify the role and responsibilities of the IRIS education and outreach program in Chapter 3. Chapter 4 summarizes work that has been accomplished in the past four years and provides an outline of future directions. Important linkages between IRIS and other major national initiatives are provided in Chapter 5. This is followed by a discussion of program evaluation in Chapter 6. Chapter 7 concludes with a list of recommendations for the future of the E&O program.

About IRIS

IRIS was formed in 1984 by twenty-six universities to provide national focus for the development, deployment, and support of modern digital seismic instrumentation and associated data services. Today, membership in the nonprofit consortium numbers over 96 institutions. IRIS supports the research needs of Earth scientists in the U.S. and around the world through four major programs:

- The Education & Outreach Program (E&O)
- The Data Management System (DMS)
- The Global Seismographic Network (GSN)
- The Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL)

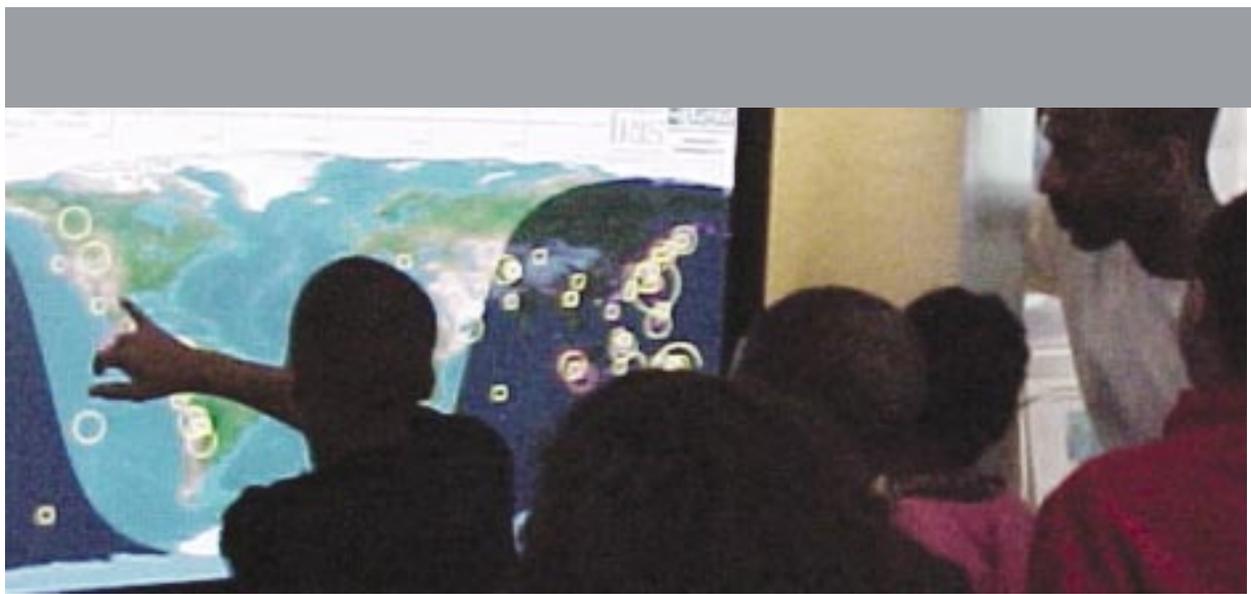
Funding and Management

IRIS is funded by the U.S. National Science Foundation through its Division of Earth Sciences. Management is provided through a small staff with headquarters in Washington, DC. IRIS also has major satellite facilities in Seattle, Washington - site of the Data Management Center, and in Socorro, New Mexico - site of the PASSCAL Instrument Center. IRIS facilities are primarily operated through member universities and in cooperation with the U.S. Geological Survey.

Governance

Each member institution is represented on the Board of Directors. The Executive Committee acts in policy matters on behalf of the Board of Directors. Management is provided by the Corporate Office through the President and Program Managers. Oversight of IRIS programs is provided by associated program Standing Committees.

Voting representation on the Board of Directors and membership on the Executive Committee is limited to Directors representing full IRIS member institutions. Individuals elected or appointed to Standing Committees or other special committees need not be from member institutions. Non-voting members of IRIS include foreign research institutions (Foreign Affiliates) and the newest category, two- and four-year colleges (Educational Affiliates). Additional information on IRIS can be found at www.iris.edu.





Chapter 2

Advancing Science Education and Literacy in the 21st Century

Overview

During the last century, the United States has made dramatic progress in advancing the educational level of its population. Even with population and immigration rates growing rapidly, the level of educational attainment has continually increased such that today about 85% of the U.S. population (age 25+) has completed 4 years of high school or greater, about 65% of high school graduates enter college within one year of high school graduation, and about 25% of the population (age 25+) has completed 4 years of college or greater. These educational achievement rates are as high, or higher, than those of any other country. Furthermore, the U.S. higher education system is widely recognized as one of the best in the world. High school and college graduates from around the world compete for entrance to U.S. colleges and universities and for admission to graduate and professional schools. However, over the past 15 years there has been increasing concern about the performance of graduates from our educational system. Much of the criticism has focused on apparent underachievement in science and mathematics by both high school and college graduates. Another area of concern is the failure to attract sufficient numbers of people to science and technology careers, especially women and minorities. Increasingly, citizens of foreign countries populate our graduate programs in science and technology. In this age of rapid advances in science and technology, there is a great need for all Americans to be scientifically literate to ensure that the U.S. maintains its leadership role in science and the global economy and is able to conduct scientifically informed policies.

IRIS and its member institutions can contribute to solving these problems by:

- Making advances in science and technology knowledge and skills more accessible to all;
- More effectively preparing current and future K-12 teachers to teach science and technology;
- Encouraging and preparing the next generation of scientists and broadening career paths available to them.

In this chapter, we will examine how IRIS can fulfill these goals, taking into consideration the particular challenges facing our audiences.

Informal Education of the Public

Americans draw on many sources for scientific and technical information, although television and newspapers are the primary source that most use to update their understanding of science.



Testing building designs with a shake table.

The Internet is also becoming a major venue for the dissemination of scientific news and is a primary research tool for journalists. While scientists recognize the need for science reporting in the popular press, too often we hear accounts of research represented inadequately or incorrectly. A notorious case in seismology is the Iben Browning 1990 earthquake prediction. Browning predicted that a major earthquake would strike the region of New Madrid, Missouri, on about December 3, 1990. Although nearly all seismologists rejected Browning's prediction and indeed the earthquake did not occur, the prediction became credible to many news journalists; TV, newspaper, and radio coverage caused serious concern among emergency preparedness officials and the general public (Spence et al., 1993). While this was an extreme case of misinformation to and miscommunication by the popular press, it demonstrates the importance of developing

better channels and methods for communicating key scientific information to journalists, and the need to work as closely as possible with news representatives to ensure the accuracy and clarity of the message.

A recent report, (Hartz and Chappell, 1997) summarizes some of the relations between scientists and journalists. This survey of 2,000 journalists and editors and 2,000 scientists and engineers, indicates that neither scientists nor journalists think that the popular press does a generally good job of representing science to the public. The report states: "The results also revealed a serious lack of confidence by both scientists and journalists in the media's understanding of how science is done and how to interpret and convey the results of research studies. That lack of knowledge means that journalists have a hard time reporting scientific and technological discoveries in a readily understandable and useful way. Examples include journalists' frequent confusion about how to interpret statistics, probability and risk. Journalists, furthermore, do not generally understand the peer review process in science, and hence may report findings that have not been subjected to independent review. Further, journalists tend to look for sensational and/or controversial results whereas science usually advances by incremental steps." Clearly, improved reporting of scientific research requires scientists to be able to communicate their work to the non-specialist and for journalists to understand the scientific process. One way that IRIS can contribute to this need is by providing the scientific community with opportunities to develop skills necessary for the effective communication of science to news representatives and to the public.



Demonstrating the concept of a seismograph.

Advances in communications technology have made it easier for journalists and the public to stay abreast of ongoing research and recent discoveries. Technology has also made it possible for the public to partake in the scientific endeavor through seismology programs such as the Public Seismic Network (PSN) of amateur seismologists. IRIS can further expand these opportunities by developing tools and activities that make the existing rich seismic data resources more accessible. In addition, IRIS can also work with museums and other organizations to show the value of seismic monitoring to society. The average American makes approximately two visits per year to science museums, zoos, aquariums, and comparable venues (National Science Board, 1998). These institutions play an important role in life-long science learning, with many also providing substantial K-12 educational programs.

K-12 Education

In 1983, an influential government report was highly critical of U.S. education overall and called for significant reform of educational practice to include more inquiry-based teaching and problem solving ("A Nation at Risk," National Commission on Excellence in Education, 1983). Subsequently, many reports, published papers and oral presentations by educators, news representatives, government officials and business leaders have contained similarly strong criticisms (e.g., "The Third International Mathematics and Science Study," 1999). Attention has focused on science and mathematics, subjects that are increasingly important to technological and economic competitiveness and to the workforce capability. While interpretations of the basic data on student performance are disputed (Jaeger, 1992; Bracey, 1993; Carson et al., 1993), the downturn in the number of students prepared and interested in pursuing careers in science and the confusion among the general population about basic science is indisputably real.

"Four important and enduring reasons underscore the need for our children to achieve competency in mathematics and science: (1) the rapid pace of change in both the increasingly interdependent global economy and in the American workplace demands widespread mathematics- and science-related knowledge and abilities; (2) our citizens need both mathematics and science for their everyday decision-making; (3) mathematics and science are inextricably linked to the nation's security and interests; and (4) the deeper, intrinsic value of mathematical and scientific knowledge shapes and defines our common life, history, and culture. Mathematics and science are primary sources of lifelong learning and the progress of our civilization."

The Glenn Commission, 2000

Of particular importance is the supply of future scientists. The most recent census data suggests that in 50 years, current minority groups will comprise more than 50% of the US population. Today, minority groups represent approximately 31% of the US population (US Census 2000 Tables). The NSF reports ("Opportunities for Enhancing Diversity in the Geosciences," 2000) that underrepresented groups - African Americans, Hispanics, Native Americans (American Indians and Alaskan Natives), Native Pacific Islanders (Polynesians or Micronesians) and persons with disabilities - represent about one quarter of the general population, and earn almost 15 percent of the total bachelor's degrees granted in science and engineering; however, they earn only 4.6 percent of all BS degrees in the geosciences. The percentages for underrepresented groups earning MS and Ph.D. degrees in geosciences are 3.3 percent and 5 percent, respectively, of the total earned. By comparison, underrepresented groups earn 10.6 percent of all MS degrees and 8.2 percent of all Ph.D. degrees in science and engineering. Thus, science, in general, is not attracting underrepresented groups, and the geosciences are doing an especially poor job (e.g. see the special issues on "Minorities in Science" in Science, 1992-1993). The long-term impact of a growing

minority population coupled with low minority recruitment into the geosciences may leave society without the resources to continue advancing our discipline unless action is taken.

Because of its inherent interest to students and its relevance to society, seismology is a topic that can enhance science education in urban and rural environments. IRIS can offer programs that provide teachers with high quality materials and the skills to implement those materials in their classroom.

Across the country, many lower achieving students attend under-resourced rural and urban public schools. Such schools commonly suffer from a shortage of individuals with adequate background and preparation to teach math and science classes and high numbers of minority, recent immigrant and disadvantaged students. These schools have difficulty attracting the best teachers or supplying high quality teaching materials. As a result urban and some rural area schools have low percentages of students with

basic math and science abilities and the students fall significantly behind their suburban counterparts in reading, math and science skills (Education Week, 1/8/98). Science education in rural communities is particularly challenged by the slower rate of introduction of technology compared with that in urban and suburban schools (Education Week, 11/10/97). In many regions specific programs or initiatives are in place or are being developed to improve education in under-resourced schools. Because of its inherent interest to students and its relevance to society, seismology is a topic that can enhance science education in these environments. IRIS can offer programs that provide teachers with high quality materials and the skills to implement those materials in their classroom.

A critical factor in providing high quality science education at the K-12 level is teacher preparation. Recent studies confirm that knowledge of science content, use of effective teaching methods, and consideration of differing learning styles is required for effective science teaching that results in student learning. However, the science content preparation of science teachers varies significantly with grade level; in the 1993-1994 school year less than 2% of elementary level science teachers possessed an undergraduate degree in science or mathematics, compared with 17% and 63% of science teachers at the middle school and high school levels, respectively. (National Science Board, 1998) Knowledge of science content directly affects teaching practices in the K-12 classroom. It has been shown that when covering unfamiliar topics, teachers present the material in a less organized manner, are less likely to encourage active participation, and spend more time on unrelated topics (Carlsen, 1991; Smith & Neale, 1991). Teachers lacking science content preparation also report difficulty in preparing science lessons that meet local, state or national education standards. An additional factor that compounds this problem is that 56 percent of all public school students enrolled in physical science classes in grades 7-12 were taught by teachers without at least a minor in physics, chemistry, geology or Earth science (US Dept of Education, 1996). Content preparation in the Earth sciences is a particularly acute problem.

"Fifty-six percent of all public school students enrolled in physical science classes in grades 7-12 were taught by teachers without at least a minor in physics, chemistry, geology or Earth science."

US Dept of Education, 1996

Data from the National Science Teachers Association (NSTA) Registry indicates that in 1998 more science teachers reported teaching Earth science at the middle or secondary school level than physics or chemistry. However, degrees or certifications in Earth science are much less common among middle or high school teachers than those in chemistry or physics. The smaller number of teachers with degrees in Earth science may be the result of a lack of undergraduate programs that provide adequate teacher preparation in Earth science (Ridky and Keane, 1999). For the reasons



described here, a relatively small number of science teachers have significant training in Earth science. Professional development opportunities for teachers of Earth science (including seismology) are needed to address this shortcoming. In addition, greater collaborations between scientists and science educators are needed to better prepare the next generation of K-12 teachers.

With the publication of "Science for All Americans" (AAAS, 1989), the science education reform movement recognized the importance of science learning for all students and the importance of a scientifically literate populace. Over a

decade of research and publications on science education reform has followed. In 1993, the AAAS published The "Benchmarks for Science Literacy (often referred to as the "Benchmarks"), which are a coherent set of learning goals in science for all students at the K-12 level. Subsequently, in 1996, the National Academy of Science (NAS) published the National Science Education Standards (NRC, 1996), which include recommendations on science content, teaching, professional development, assessment, and educational system practices for grades K-12. These standards outline a framework for reform of science education for the coming decades. Importantly, the Standards recognize Earth and space sciences as one of three major science areas - physical sciences, life sciences, Earth and space sciences - that should be covered throughout the K-12 curriculum. The Standards present exciting new possibilities for pre-college Earth science education because until now Earth science has not been universally taught. In many schools Earth science is being introduced into the K-12 curriculum for the first time, and so, the need to provide improved content preparation in Earth science through pre-service training and in-service professional development is acute.

The 1996 joint statement by the National Academy of Science, the American Association for the Advancement of Science (AAAS) and the National Science Teachers Association, "A Cooperative Era of Reform in Science Education" (Science Education News, 1996), recommends that effective science teaching must:

- be directed at ALL students to ensure science literacy among all Americans,
- embody the nature of science,
- promote science as inquiry rather than an exercise in memorization, and
- embrace the concept that by teaching less, students will actually learn more.

These principles require new and more effective approaches to science teaching at all levels, improved teacher preparation and professional development for teachers, and reorganization of the science curriculum emphasizing important connections to mathematics, technology and other subjects. IRIS can contribute to this effort in Earth science and seismology education.

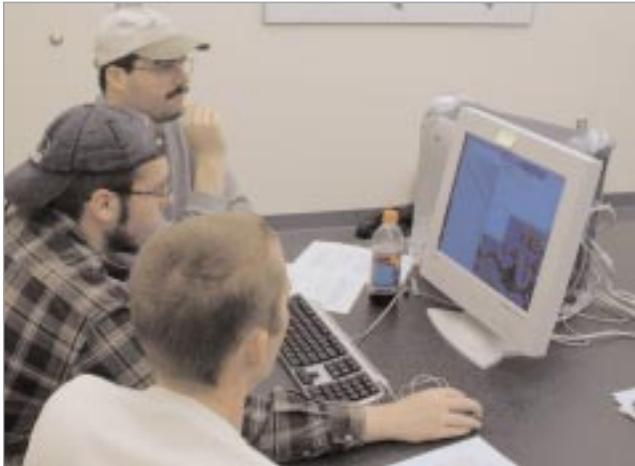
"Many more scientists, mathematicians, and engineers must become well informed enough to become involved with local and national efforts to provide the appropriate current knowledge and pedagogy of their disciplines to current and future teachers."

National Research Council, 2001

Post-Secondary Education

The U.S. has over 3,500 public and private institutions of higher learning, including community colleges, liberal arts colleges and major research institutions. These institutions differ greatly in their educational styles, but all play a major role in the science education of our society. While community colleges and liberal arts schools focus primarily on the education of their students, research universities have a dual role: providing high quality undergraduate education and maintaining their prowess as leaders in research.

A recent report on post-secondary education (Boyer Commission, 1998) has sharply criticized the education performance of American research universities. The report states that while an undergraduate at a research university can receive an education as good or better than that available anywhere in the world, this is not the typical experience. The reasons for this stem from the reward system of research institutions. Despite the oft-quoted claims that equal weight is given to teaching, research and service at research institutions, the reality is that most institutions appoint, promote, and tenure faculty based primarily on research accomplishments (measured by funding success, publication record, national and international influence, and numbers of graduate students).



Ironically, many undergraduate students graduate without experience in research despite the major research programs intrinsic to these universities. Many professors at such institutions are extremely committed to teaching; however inconsistencies between demands on faculty and the reality of tenure requirements mean that teaching can end up as a burden (“teaching loads”) that reduces time available for research. Often, graduate students teach substantial parts of undergraduate classes at research institutions; these graduate students may have little or no teaching experience and in some cases are not proficient in English. To compound the problem, graduate students

and faculty often have little or no training in teaching methodology. Thus, there are obvious opportunities to improve undergraduate science education by involving faculty and graduate students in educational initiatives that increase their knowledge of good teaching practices and by increasing opportunities for integrating education and research in the undergraduate curriculum. IRIS can help by providing faculty and graduate students opportunities to learn about effective teaching methods and providing them with high quality instructional materials in seismology and related Earth science.

In contrast, teaching is recognized as the primary faculty responsibility at liberal arts and community colleges. These institutions share the common problem of providing little or no training for faculty in teaching methodologies. However, they face other challenges in providing excellent post-secondary science education. Faculties at such institutions commonly have heavy teaching commitments, with little or no time to pursue research. As a result it can be difficult to offer research opportunities to students and to incorporate current, cutting-edge research into the curriculum. Yet, good science education at liberal arts and community colleges is critical to a large sector of the work force. For many students, liberal arts and community colleges are stepping-stones to further formal education, with many liberal arts students going on to graduate school, and many community college students transferring to four-year undergraduate institutions. In

addition, community colleges train a significant percentage of future K-12 teachers. Many students from liberal arts and community colleges go on to careers that influence the future of U.S. science education and research such as policy, business, science research and K-16 teaching. Research internships at IRIS member institutions for qualified undergraduates at any U.S. educational institution provide one avenue to assist two-year and four-year colleges and universities in providing a richer learning experience.

A large percentage of students taking introductory Earth science in college are fulfilling a general degree requirement; as a result they may be less interested in the subject matter. However, the broad interdisciplinary nature and obvious relevance of Earth science to everyday life can be used to generate new excitement for science while teaching Earth science content, important related concepts in physics chemistry mathematics, and the scientific method. Improving the quality of undergraduate Earth science education can increase the number and quality of students majoring in Earth science, and enhance the science literacy and understanding of the Earth among the students enrolled in large introductory Earth science courses. IRIS can contribute to this effort.

The challenges facing graduate education are different than those at the undergraduate level. Traditionally graduate education in the sciences has focused on preparing students for careers in research, either at an academic institution or in industry. It is clear that besides preparation for a career in research, a graduate education should also provide an individual with transferable skills and with knowledge of alternative career paths. One of the most fundamental areas in which graduate education can be improved is in helping students to develop excellent abilities in communications – oral and written. Experience with educational programs will be valuable for graduates to develop the communication, organizational and teaching skills needed to have a successful career, especially as a faculty member. IRIS can contribute to this effort with professional development opportunities for graduate students.

“Teacher education in science, mathematics, and technology must become a career-long process. High-quality professional development programs that include intellectual growth as well as the upgrading of teachers’ knowledge and skills must be expected and essential features in the careers of all teachers.”

–National Research Council, 2001





Chapter 3

Defining the Goals

The responsibility of science education for all Americans extends beyond the traditional K-12 classroom. Outreach by scientists and scientific organizations to a broader community is a critical component. Scientists not only have an opportunity to contribute to science education, they also have a responsibility to do so (AAAS, 1989; NSF, 1996, 2000; NAS, 1996; NRC, 1999, 2001). Reaching out to new communities and building partnerships that are mutually beneficial can meet this responsibility. An informed populace, enthusiastic about science and able to distinguish between science and pseudo-science, is also more likely to support future scientific endeavors. Further, by partnering to improve the science understanding of today's students, we are preparing tomorrow's scientists. Early introductions and multiple experiences with scientific investigations are key to developing a broad understanding of science, yet the majority of the populace has little direct contact with scientific research or scientists. Research scientists can contribute by making these science experiences possible in a variety of forms and levels. While involvement in educational outreach beyond the college audience is challenging, IRIS and its members can also reap great rewards from such endeavors.

Outreach is any activity that extends IRIS' reach beyond its traditional research community audience. The basis of any outreach program is education and cooperation to reach common goals. This can take many forms from providing news releases on socially relevant seismology research to preparing the next generation of seismologists. The IRIS education and outreach program begins by educating its own community, the seismology researchers. This role is realized by helping seismologists become more aware of, and able to respond to, opportunities that increase the:

- Pool of excellent undergraduate and graduate students.
- Variety of career options for seismologists and other Earth scientists.
- Public's awareness that supporting Earth science research yields critically needed information to reduce the hazards associated with earthquakes, manage our natural resources and protect our environment and society.

The program will be a catalyst for IRIS members to become more involved in outreach and to develop their own educational outreach efforts.

The IRIS Education and Outreach Program can bring current, exciting and socially relevant science into people's lives.

This chapter highlights our vision and goals for the IRIS Education and Outreach program and identifies avenues that can be pursued to achieve these goals. Education and outreach programs such as this cannot single-handedly resolve national issues or inadequacies in science educa-

tion, nor can they alone result in systemic reform. They can however, make unique contributions through a disciplinary focus and through their immediate access to the scientific community. Perhaps most significantly, the IRIS Education and Outreach Program can bring current, exciting and socially relevant science into people's lives.

The Vision of the Education and Outreach Program

Through seismology and the unique resources of the IRIS Consortium, the IRIS Education and Outreach Program will make significant and lasting contributions to science education, scientific literacy and our understanding of the Earth.

While our understanding of earthquake processes and the structure of the Earth continues to improve dramatically, the challenges of increasing population density and natural disasters, and shrinking natural resources makes seismology critical to maintaining and improving our quality of life. Earthquakes continue to be one of the most deadly natural hazards. Furthermore, although research has identified likely regions of future seismic activity, earthquakes remain essentially unpredictable relative to other natural hazards. When a major earthquake occurs, interest in seismology and related Earth science is stimulated. Similar interest in Earth science and seismology is spawned during times of energy shortages, by concerns for protecting the environment, and by major man-made events with a seismic component (e.g. a nuclear weapons test or terrorist incident). These events provide important "teachable moments" to remind the general public how science and seismology impact their lives.



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Seismology also provides opportunities to teach many science, math and technology concepts and skills to learners of all ages. Teachable moments and more traditional topics in a curriculum provide opportunities to teach seismology-related topics such as:

- Methods of detecting, locating and analyzing explosions and earthquakes.
- Seismic hazard and seismic risk.
- Structural engineering design and related hazard mitigation concepts.
- Prospecting and production of natural resources such as oil and gas.
- The structure of the inner Earth.
- Plate tectonics, Earth history, and the dynamic nature of Earth systems.
- Fundamental concepts in physics from basic wave phenomena and energy, to the design of seismic instrumentation using mechanics, electricity and magnetism.

- Mathematical concepts and skills, including statistical methods, graphing, probability and uncertainty.
- Geography, mapping, and map analysis.
- The role of technology in accessing, processing and using information.
- Critical thinking, problem solving, formulating and testing hypotheses, and making inferences.

Seismology can be used to involve students of all ages in the processes of observation, analysis and inference, and provides an excellent venue for integrating the research experience into broader education. Through IRIS E&O, educators and students can obtain high-quality seismic data, training, instructional materials, and other information resources. The more advanced and highly motivated students can easily collect and analyze their own seismic data through the Seismographs in Schools program and other initiatives. Thus, students can gain an appreciation

of the essence and excitement of science by emulating all of the processes undertaken by practicing researchers, that is, by doing science instead of just reading or hearing about science.

Thus, students can gain an appreciation of the essence and excitement of science... by doing science, instead of just reading or hearing about science.

Our mission and the goals outlined below will help make the vision of our program become a reality with real impact on science and science education in America.

Our Mission to Promote Science Literacy

IRIS Education and Outreach will contribute nationally to science literacy and science education at all levels (K-12, post-secondary, undergraduate, graduate, continuing education & public) with activities and programs focusing on those areas in which IRIS is uniquely qualified to serve by virtue of its data and computer resources, and its widespread and diverse membership. The program will encourage and support the involvement of all IRIS members so that our community's response is comprehensive and inclusive. In addition, IRIS will continue to form partnerships with institutions and organizations that have similar goals and complementary capabilities, to strengthen and coordinate existing and future Earth science education efforts. IRIS will conduct national, regional and local level programs to draw upon the strengths of the wide geographic distribution and the diversity of IRIS' member institutions. Activities at the national level provide the opportunity for coordination and wide visibility and dissemination of resources. Further realization of these programs at regional and local levels is crucial to achieving a lasting, positive impact on educators, students and the general public. Local programs - whether independent or multiplying the effect of national efforts - will foster new links between the research and education communities and will enhance the quality of science education at all levels. We will engage in internal and external evaluations to ensure continuing improvement of programs and products. The program will derive ongoing support from the IRIS NSF Cooperative Agreement and will obtain external funding for large-scale activities and major new initiatives.

A focus on seismology and its impact on society will provide a rich environment for inquiry-based learning in K-16.

Goals

The goals of the IRIS Education and Outreach program are to:

- Continually improve access and usability of IRIS seismological data and research results for all audiences.
- Organize and support efforts to place educational seismographs in K-12 schools and undergraduate institutions.
- Develop and disseminate instructional materials and analysis tools that use seismological observations and data to improve the students' education and appreciation of Earth science in grades K-16.
- Increase the number of pre-service teachers who have a strong foundation in Earth science and are well prepared to teach it.
- Increase the diversity of students that are interested in Earth science and prepared to pursue careers in Earth science.
- Contribute to providing a pool of well-prepared, outstanding students for graduate studies in the Earth sciences to further our understanding of the Earth.
- Prepare undergraduate and graduate students for a variety of seismology related careers and roles in society.
- Provide professional development for teachers and college faculty to improve the science content, teaching methods and student learning of seismology, Earth science and related topics in K-16.
- Provide leadership and an institutional framework for seismology education at the national level and collaborate with major research initiatives, museums, educational institutions and professional organizations having similar goals.
- Increase public awareness and understanding of seismology and related Earth science through both formal and informal education such as museum programs, television, and other educational media.
- Encourage and assist Earth scientists to be more effective communicators of their knowledge and expertise with teachers and students in the classroom, the general public and news representatives.
- Recognize Earth scientists for significant achievements in the areas of education, outreach and public policy.

Achieving these goals will allow all audiences to better understand the role of seismology and related science in their lives. A focus on seismology and its impact on society will provide a rich environment for inquiry-based learning for K-12 students, undergraduates and others.

Furthermore, with improved data access tools, students and educators will be able to more fully participate in seismological research as a part of their education. Schools across the nation will be able to implement the National Science Education Standards so that ALL students learn Earth science concepts throughout their K-12 education. A new generation of Americans will be educated with a greater understanding of Earth science and seismology, and will help us attract the best and brightest to our discipline, to associated fields, and to educational careers. The public will be pro-

We will draw attention to the value of quality education, the effort required to provide it, and reward those who contribute to it.

vided with relevant and timely information and that will allow them to make informed decisions for their own good and the nation's good. As a result, we will increase the level of general scientific literacy and help ensure strong support for scientific research. We will draw attention to the value of quality education, the effort required to provide it, and reward those who contribute to it.

To achieve these goals and improve science education for all Americans, we must implement programs that recognize differing learning styles and that can reach a diverse population. Furthermore, specific programs should be designed to enhance educational opportunities for under-served and under-represented groups and to increase Earth science career opportunities for these groups.

Outcomes

Success of this E&O program requires implementing programs that meet the stated goals and result in real change. It is difficult to know what activities or events trigger change in complex systems such as a society or in an individual's knowledge, however, we look forward to the following changes that should result from our efforts:

- More Americans will have an understanding of the broad applications of seismology and Earth science in their lives;
- Earth science will be more broadly and effectively taught in K-16 schools;
- Seismology will be a frequent topic in Earth science and physics courses;
- More students, representing a more diverse population, will choose careers in Earth science and seismology;
- More people will be capable of participating in monitoring Earth's changes through seismology;
- Public support for Earth science and seismology education and research will increase.

To gauge the impact of our efforts, we will implement an evaluation plan (See Chapter 6) to assess success at achieving our goals.

Achieving these goals will allow schools across the nation to implement the National Science Education Standards so that ALL students learn Earth science concepts throughout their K-12 education.





Chapter 4

Achieving Our Goals

During its first four years, IRIS E&O has developed critical expertise and a better awareness of how to reach our goals. This learning will continue and the initiatives below will serve as a guide rather than a formal mandate. This is especially true for presently evolving major collaborative projects such as EarthScope/USArray and the Digital Library for Earth Systems Education (DLESE) (see Chapter 5).

To reach our goals, we must focus on developing people who can help us make a difference, and developing products that support the efforts of those same people. By engaging the full membership of IRIS in E&O activities, we will capitalize on our numbers, geographic diversity, and especially the wealth of creativity and knowledge within our community. Below we describe our major objectives, focusing first on the people and then on the products essential to the E&O program.

Developing Human Resources: A Focus on People

Providing educational opportunities that help target audiences develop new skills and understanding of seismology and related science and mathematics is an essential element of the E&O program. The specific needs of individual audiences vary but the focus on providing people with the tools, resources and abilities to educate others about seismology and Earth science is consistent and essential for amplifying direct efforts to reach large numbers of students. We will provide several types of initiatives focusing specifically on enhancing our human resources base - an Educational Affiliates program that reaches out to two- and four-year colleges and universities interested in seismology and Earth science education, professional development workshops for K-16 instructors (including graduate students), and career development opportunities for undergraduate and graduate students. A common element behind all of these activities is building infrastructure for providing a high profile E&O effort where education of the public and K-16 students is primary.

College and University Instructors

Educational Affiliate Program: The IRIS Board of Directors amended the by-laws to create the Educational Affiliate membership category during the 2001 Annual Workshop. This new category of membership will expand our E&O audience by creating a restricted membership category for two- and four-year colleges and universities with Earth science departments interested in initiating or enhancing seismology and associated education. Educational Affiliate membership provides these

institutions with opportunities to participate in IRIS educational activities as members and beneficiaries and to serve on IRIS committees.

Educational affiliates will also be offered a discount towards either an AS-1 teaching seismograph or a research-grade seismometer to incorporate into their educational activities. We plan to recruit a select group of affiliate members in 2002 to help us develop the program.

Regardless of the future careers of undergraduate students taking Earth science courses, our goal is to involve the students in discovery learning through seismology and to convey the excitement of scientific research.

Professional Development Workshops: College faculty educate the next generation of business, political, science and educational leaders. Their impact is thus broad and long lasting. Regardless of the future careers of undergraduate students taking Earth science courses, our goal is to increase opportunities for students in discovery learning through seismology and to convey the excitement and importance of science. A significant percentage of two-year and four-year institutions do not have a seismologist or geophysicist on their faculty and may desire instructional materials, content resources, ideas, and expertise to teach seismology-related topics. IRIS E&O will promote contacts between undergraduate institutions and research universities to improve the educational and research experiences for all undergraduates. In addition, we can provide educational resources and professional development opportunities to foster development and implementation of innovative approaches to teaching seismology related topics. Finally, we expect these collaborations to result in more opportunities for faculty to involve undergraduate students in research. (See the Internship Program below). Professional development opportunities at the undergraduate level can provide college and university faculty and graduate students with the tools to achieve these results.

We have approved:

- A motion to change the By-Laws of IRIS to allow Educational Affiliate Memberships.

We have developed:

- Professional development workshops for faculty and graduate students teaching undergraduate students at two and four-year colleges.
- Professional development workshops for faculty and graduate students to learn how to teach seismology to K-12 teachers.

Our workshops demonstrate how to understand and use seismological data, educational software and analysis tools, and seismology and related Earth science content modules to support discovery-based teaching. The workshops also provide illustrations of how active learning techniques can be implemented in Earth science classes.

We have sponsored and led workshops focused on integrating seismology concepts in undergraduate courses at Geological Society of America national meetings since 1999 and approximately 60 faculty have participated. We also offered a workshop for 25 IRIS members demonstrating the variety of educational soft-

ware and tools for analyzing seismic data in 1998. In addition to working with GSA on these workshops, we are also developing collaborations with the National Association of Geoscience Teachers to broaden our impact at future meetings.



Teach-the-teacher workshops are similar to those designed for improving undergraduate education but focus more on providing seismologists with materials and methods for preparing pre-service and in-service K-12 teachers to teach seismology related concepts in K-12 classrooms. IRIS E&O has conducted two 'Seismologists Learning to Teach the Teachers' workshops that prepared 40 IRIS members to train K-12 teachers in educational seismology. Several participants have conducted follow-up workshops in their local area. However, the logistics of organizing such a workshop with local districts can be daunting. Thus, we now encourage seismologists to offer these workshops in conjunction with the larger state and

regional science teacher meetings. In this case meeting organizers handle recruitment and registration and the IRIS leader is responsible for carrying out the workshop. In the future, whenever possible, an experienced workshop presenter from the IRIS community will work with any new presenter to facilitate these workshops.

The approach of conducting workshops nationally leverages the geographic distribution of IRIS institutions to benefit a large number of teachers at a reasonable cost. For example, if each participant in a workshop for 20 seismologists leads two subsequent workshops, this will result in 40 workshops serving 25 teachers each or approximately 1000 teachers. A multi-year program of this kind can reach thousands of teachers. IRIS provides the funding to cover materials and expenses for conducting the teacher workshops. We also encourage the faculty running state and regional workshops to maintain contact with their workshop participants and sponsor activities that bring the seismologists and teachers together again in the following years. Ideally these relationships could generate new local programs, such as research experiences for selected high school students and teachers at IRIS institutions.

We have developed:

- One-Day Earthquake workshops in collaboration with IRIS member institutions at national and regional National Science Teachers Association meetings.

We will expand:

- One-Day Earthquake workshops by establishing collaborations with other science educators.

K-12 Educators

Professional Development Workshops: IRIS can make substantial contributions to K-12 education, in particular through professional development opportunities for teachers that provide in-depth training in seismology and Earth science concepts for teachers. We can use the geographic distribution of IRIS member institutions, data resources and data management facilities to produce teaching materials and to offer programs that benefit large numbers of K-12 teachers. In all cases, the efforts of scientists and member institutions to build and maintain relationships with their local K-12 community are essential.

IRIS E&O has conducted four national workshops and two regional workshops for teachers since 1998, serving approximately 150 teachers who will each impact as many as 150 students per year. Expansion of the One-Day Earthquake workshops, especially teaming with disadvantaged districts, will be an important effort when conducting

We will develop:

- Extended workshops of 2-4 weeks in length to draw teachers nationwide for an in-depth investigation of earthquakes and related topics

outreach during USArray deployments. By also working with science educators who prepare teachers and with school districts that provide professional development to classroom teachers, we can create a very large multiplying effect.

In one-day earthquake workshops, we plan to target school districts implementing NSF systemic initiative grants (Urban Systemic [USI] or Local Systemic Initiatives [LSI]). These districts generally have a comprehensive program of professional development in science and large numbers of minority and disadvantaged students. IRIS E&O will collaborate with districts undergoing major reforms and that are located near IRIS member institutions to provide our workshops as part of the systemic reform program. This is an effective mechanism for reaching the most needy schools, students and teachers with our earthquake instructional materials.

We plan to test this model of outreach by conducting our first workshops in a city such as Los Angeles, St. Louis or Memphis. These areas have significant seismic hazard, and local IRIS institutions that are in a good position to provide workshop follow-up. If our pilot program is successful,



we will pursue supplemental funding to continue the program on a large scale. This program will likely require increasing the number and topics of discovery-based instructional modules available, which can be effectively achieved through partnerships with IRIS member institutions.

We plan to develop multi-week workshops to produce a small number of teachers with the skills and knowledge to use seismological data, seismology and related Earth science content modules, and other IRIS products that support inquiry-based teaching and student research. These teachers will become the ideal candidates for helping IRIS member institutions conduct local workshops associated with deployment of USArray (see Chapter 5).

Undergraduate Students

Career Development: As a result of our workshops for K-16 faculty, more undergraduates will have exposure to and greater knowledge of seismology. This will lay an important foundation for the IRIS undergraduate research internships. Research internships provide opportunities to experience scientific inquiry and explore careers as seismologists. We will seek outstanding undergraduates for this program, focusing on students from our Educational Affiliate member institutions.

IRIS plans to significantly expand the existing pilot undergraduate internship program. IRIS provides funding for interns to present their research at the Seismological Society of America (SSA), Geological Society of America (GSA), or American Geophysical Union (AGU) scientific meetings. We have sponsored 15 interns since 1998 on projects ranging from a PASSCAL deployment in China, to developing instructional materials for K-4 students, to investigating the outer rim of the Chesapeake Bay meteor impact crater with reflection seismology techniques. Nine students have so far presented their research at national meetings.

Graduate Students

Career Development: IRIS and its member institutions have considerable experience in graduate education and in research training. In support of graduate seismology programs, IRIS can improve

graduate education in at least two ways. First, IRIS will work to expand opportunities for graduate students to become more effective teachers by involving them in the development of teaching materials and offering the opportunity to learn new teaching methods in our workshops. Second, IRIS will work to broaden the training of geoscientists to prepare interested graduate students for a wider variety of academic and non-academic careers. These activities represent common interests shared by many Earth science professional societies and we will seek collaborations to maximize our impact in these areas.

We support travel for students to the annual IRIS workshop, where activities include special receptions focused on graduate student opportunities and career development. Future workshop events will focus on the variety of career opportunities available to Earth science graduate students. These sorts of career development activities present significant opportunities for collaborations with professional societies such as AGU, GSA, SSA and AAAS. IRIS additionally supports focused summer internships in seismic instrumentation with the PASSCAL program at the IRIS PASSCAL Instrument Center.

All Audiences

Distinguished Lecture Program: The new Distinguished Lecture Program will improve the dissemination of seismology research results and increase IRIS' visibility with the public and the larger scientific community. These lectures may also be an important component of outreach associated with EarthScope/USArray, as eloquent ambassadors of seismology articulate the broad relevance of important areas of Earth science. This initiative supports all of the IRIS programs by showing a diverse audience the value of seismology to society through education, research, natural hazard mitigation, and public policy. One or more speakers per year will be sponsored to give public lectures to broad audiences at museums, colleges and universities to promote understanding of seismology and its relevance to society. The Distinguished Lecture program will be co-sponsored by the Seismological Society of America (SSA).

EarthScope/USArray Education and Outreach: The scale and complexity of EarthScope's science initiative (see chapter 5) requires a large-scale education and outreach effort. It is anticipated that IRIS will be a major contributor to the EarthScope program. The largest component of EarthScope is USArray, a continent-scale deployment of large networks of seismographs across the United States. We thus anticipate that EarthScope/USArray education and outreach may become a significant focus within IRIS E&O and we have developed an initial plan for EarthScope/USArray E&O that will serve as a starting point for future community planning. The scope of the USArray program provides a further opportunity for IRIS to leverage existing E&O efforts to enhance our national impact in education and outreach. IRIS E&O efforts that provide relevant science information to the public and that make useful information and materials available to educators will

We have developed:

- Research internships for undergraduate students and for K-12 teachers to work with seismologists from IRIS member institutions.
- Graduate Student Travel Grants to provide opportunities for graduate students to attend the annual IRIS workshop and associated E&O workshops.

We will develop:

- Teaching and Communication Workshops for graduate students.

We have developed:

- A plan for structuring the Distinguished Lecture Program.
- A committee of IRIS and SSA representatives to establish the inaugural lectureship for the 2002-2003 academic year.

We will organize:

- A Distinguished Lecture Program, highlighting the contributions seismology and Earth science can make to our everyday lives.

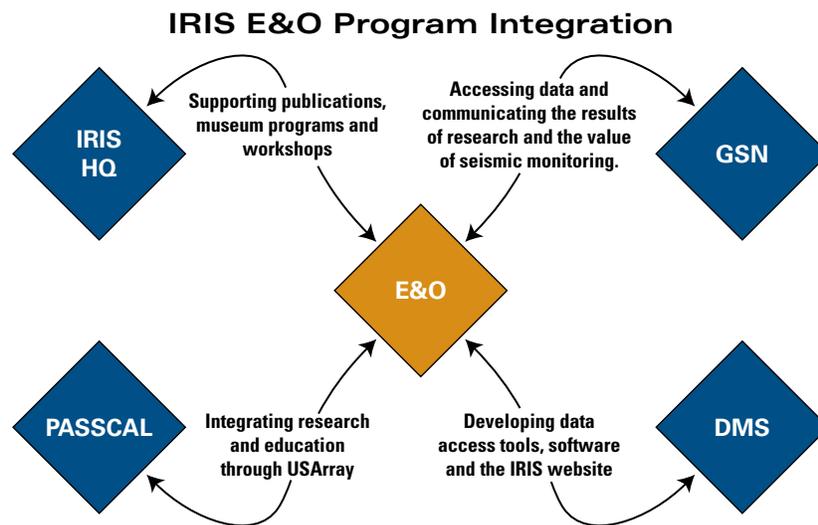
We have developed:

- An initial plan for EarthScope/USArray E&O that will serve as a starting point for future community planning.

be significant contributions. USArray also provides an outstanding opportunity for enhancing the Educational Affiliates program.

E&O efforts for USArray will also provide valuable support for IRIS overall, and the PASSCAL and GSN programs specifically, by further educating the public about the value of seismic monitoring.

Interactions between IRIS E&O and the other IRIS programs have been essential to the development of IRIS E&O. We anticipate that these interactions will become even more important as IRIS E&O waveform analysis software develops.



Developing Knowledge Resources: A Focus on Products

A wide variety of educational products are needed to facilitate improved awareness and understanding of seismology and Earth science among diverse audiences. Over the past four years, we have developed a number of products to fulfill our education and outreach efforts and anticipate developing additional products in the coming years. Our products range from simple information sheets to development of a full-featured seismic data display and analysis system designed for the interested amateur seismologist. Below we describe current products and identify future directions for product development with a special emphasis on the EarthScope/USArray program.

Providing General Information to the Public

IRIS Website: Our products must provide timeless information such as answers to frequently asked questions and timely information about recent seismological events. With Internet access nearly ubiquitous, the E&O web site will provide the primary means of distributing general information and resources. The IRIS E&O web page will provide (1) information on the programs, activities, and opportunities of IRIS E&O; (2) tools for the non-specialist to access and manipulate seismological data (earthquake statistics, maps and seismograms); (3) links to E&O efforts in seismology and the Earth sciences at IRIS member institutions and other organizations; (4) background and topical earthquake information (Teachable Moments and Special Event Pages); and (5) instructional materi-

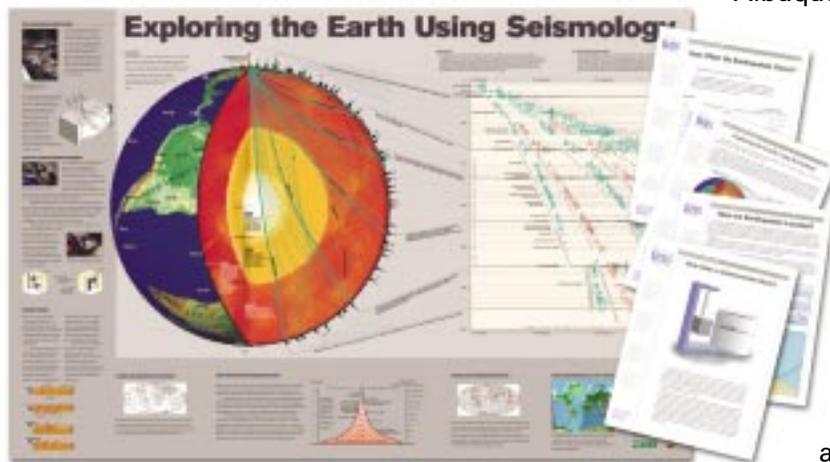
als. The E&O website is continually evolving to incorporate the above elements. The IRIS website represents collaboration between the DMS and E&O to enhance the profile of IRIS and provide greater access to IRIS resources.

One-pagers: One-page informational color overviews of fundamental topics in seismology have been widely distributed through the web and in printed form at national meetings, teacher conferences, and through member institutions. IRIS members play a critical role in suggesting topics and developing the information sheets. When completed, they are printed and distributed by IRIS. Six one-pagers have been completed and another five topics have been suggested.

We have also recently translated the completed one-pagers into Spanish for distribution in Latin America and in Spanish speaking portions of the United States.

Educational Posters: Color posters have been created with science content and ideas on how to use the poster in the classroom. These have been widely distributed as color prints at national meetings, teacher conferences and through member institutions. IRIS E&O has created the “Exploring the Earth Using Seismology” poster illustrating how seismic waves travel through the Earth and how real seismograms vary with location. We are currently working on a “History of Seismology” poster reviewing the development of the science and its impact on society, and on an “Earthquakes, Volcanoes, Impact Craters, and Plate Tectonics” poster, an interpretive map showing locations of these features and other geologic information. IRIS members play a critical role in poster development, with printing and primary distribution provided by IRIS.

Seismology Museum Exhibits: We continue to support the development of new museum displays that build on our successful “Earth in Motion” exhibit. This and other seismology-related museum exhibits and displays were developed by IRIS in cooperation with the USGS’



Albuquerque Seismological Laboratory, individual museums, college and university Earth science departments, and other interested organizations. New design ideas and prototypes for museum displays are being considered.

IRIS has collaborated with the US Geological Survey and the New Mexico Museum of Natural History in developing multiple museum exhibits. The exhibits are both active and interactive: they display the IRIS seismic monitor map and real-

time seismic traces on drum recorders from global seismograph stations; visitors can jump on the floor and create their own “earthquake seismograms” on a drum recorder connected to an integral seismometer. One of our exhibits is on tour with the Franklin Institute’s Power of Nature traveling exhibit. In addition, we have assisted the New Mexico Museum of Natural History,

We have developed:

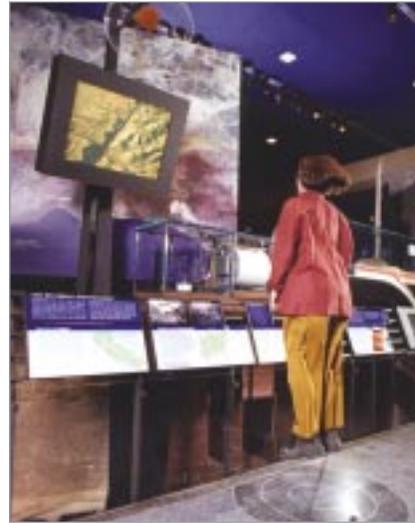
- IRIS Website, including both static and dynamic information
- “One-pagers”; simple one page explanations of important seismological concepts
- Educational Posters
- Seismology Museum Exhibits

American Museum of Natural History in New York, North Carolina State Museum in Raleigh, and Carnegie Museum of Natural History in Pittsburgh in developing permanent displays for their museums. Annual attendance at these museums is approximately 9 million.

Teachable Moments: Web-based background materials on tectonically active regions of the world will provide the public with accurate and timely information about recent seismic events. The information will also be useful to press organizations as background information on a story or as a point of contact for further information relevant to major seismic events. These materials can be the foundation for a “teachable moment” that occurs when world events like a major earthquake or other seismic event bring seismology to the attention of all Americans. Materials will include seismograms, geologic, tectonic, and seismicity maps, historical information on seismic events, and related information.

When a major seismic event occurs, 275 million Americans and hundreds of millions of others around the world want to understand what has happened and how to reduce their own risk. IRIS can be a world leader in

providing timely information to individuals and organizations on current events. IRIS members can play a critical role in development and continued maintenance of this resource. This effort will also bring the research conducted with PASSCAL and GSN data to a very wide audience.



The “Make Your Own Earthquake” exhibit and the American Museum of Natural History in New York.

We plan to develop:

- Teachable Moments - General information guides on tectonically active regions of the world

Materials and Activities for the Classroom

A fundamental step towards improving the quality of seismology and Earth science education is to provide K-12 teachers and college and university faculty with high quality instructional materials. In the past four years, many scientists at IRIS member institutions have developed engaging activities for different grade levels from K-16. Several other organizations and institutions have developed inquiry-based materials (e.g., the American Geophysical Union/Federal Emergency Management Agency’s “Tremor Troops” [K-6] and “Seismic Sleuths” [7-12] and American Geological Institute’s “EarthComm”). However, available materials are not exhaustive in coverage and are particularly lacking in activities that deal with real seismic data. Two obstacles have prevented wide use of seismic data in K-16 education: (1) lack of appropriate display and analysis tools and (2) difficulty of interpreting and analyzing seismograms. IRIS E&O is currently developing, in association the University of South Carolina, a user-friendly display and analysis tool, “VSN Explorer”, to address these obstacles. We will simultaneously be developing materials for classroom instruction suitable for supporting the national E&O effort planned for EarthScope/USArray. These materials will be available through our website, DLESE and at teacher workshops.

New middle and high school level materials will introduce students to seismometry and understanding the basic features of seismograms. They will include activities and experiments using locally collected data from an educational seismograph.

New undergraduate modules will employ seismological data and quantitative problem solving methods using an inquiry-based approach at the advanced high school and undergraduate level.

Two types of courses will be targeted: introductory college-level Earth science courses and upper level college courses that include seismological content. These materials will open access to IRIS data and help promote integration of education and research.

A digital library of teaching materials including images, exercises and software developed and employed by IRIS members will be made available. These archives will also include materials from the Distinguished Lecture Series. These resources will become part of DLESE to facilitate broader distribution.

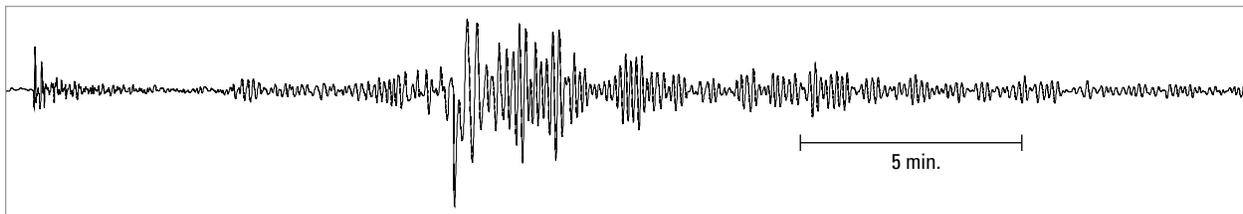
The Seismographs in Schools program places a simple and fully functional educational seismograph in schools, capable of producing useful records of local events and of larger earthquakes throughout the world. The Seismographs in Schools program complements programs already in existence (such as the Princeton Earth Physics Project [PEPP], South Carolina Earth Physics Program [SCEPP], and MichSeis) because it provides a simple stand-alone seismograph that isn't intended for connection to a seismic network. The seismometer that we use, the AS-1, is inexpensive (about \$500) and effective for educational purposes because of its simplicity and ease of management and operation. Basic principles of seismometry are also readily visible in the design. Thus, the seismometer is useful for teaching principles of seismometry and for monitoring.

We are distributing seismographs to selected teachers with a strong interest in integrating seismology concepts in their curriculum. The teachers must have participated in one of the earthquake workshops offered by IRIS or a member institution. We are also developing an AS-1 inspired one-pager and a set of lesson plans to go with the seismometers.



AS1 Seismograph

Currently, there are a number of existing programs promoting seismometers in schools. As a leader in facilitating seismology research and educational outreach, IRIS has provided direct support or collaborated with most of these programs. Coordination and management of educational seismograph programs through IRIS will help ensure their greatest impact, particularly as USArray expands. IRIS E&O is currently working with the US Educational Seismic Network (USES), a group of IRIS member institutions and associates, in developing a framework for nationwide coordination of educational seismograph programs



AS1 Recording at the Marshall School in Minnesota from a magnitude 5.8 earthquake off Vancouver Island on September 14, 2001.

We have developed:

- Discovery-based K-12 teaching materials that cover selected topics in seismology for the K-12 classroom.
- Seismographs in Schools Program

We will develop:

- Additional middle and high school level teaching materials.
- Teaching modules for undergraduate students
- Digital Library teaching resources
- Coordination and collaboration with other Educational Seismograph Programs

(See next chapter). A goal of the coordinated effort is to provide a simplified starting point for schools that are interested in collecting and analyzing seismic data. Thus the long-term expectation is for the AS-1 and other seismographs in schools initiatives to become a unified collaborative program.

Data Products and Analysis Tools

Collecting and distributing seismic data products to the research community is the mainstay of IRIS. As advances in seismology are frequently data driven, these data are often the foundation for making advances in our understanding of Earth. However, sharing those data and the excitement of discovery that they offer with a general audience requires effective tools and an understanding of seismology. People want to know

how a seismometer works and how it can detect earthquakes on the other side of the planet. They want to know what each wiggle on a seismogram means. They want to know when and where the next "big one" will occur and understand volcanic eruptions. While not all of these questions are easily answered, providing non-specialists tools to begin investigating these questions to illuminate the basic scientific research process is a valuable contribution to society. To address this need, IRIS E&O in collaboration with the DMS and GSN have developed a range of products.

We have developed:

- Seismic Monitor, a web-based tool that provides a quick global view of recent earthquake locations.
- AmaSeis, an interactive seismogram analysis program
- WILBER, a web-based tool that provides quick download and viewing of seismograms for selected events.

We are developing:

- Virtual Seismic Network (VSN) Explorer to provide a user-friendly, versatile interface to real-time and archived data.

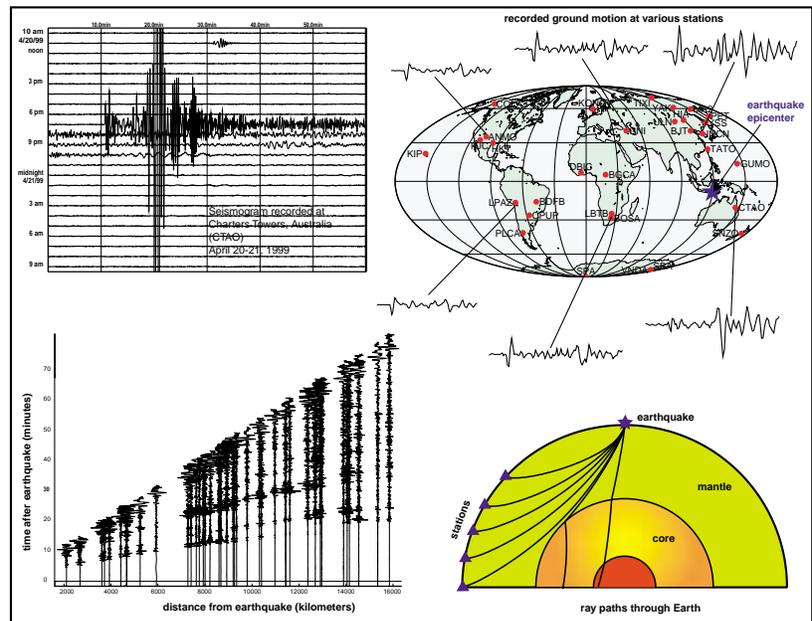
Seismic Monitor is one of the most accessed pages on the IRIS website. It provides a quick view of recent earthquake locations and provides access to global seismic stations. We are currently upgrading Seismic Monitor to be more stable under new browser features and to align with the data structures developing at the Data Management Center. We will be improving some features and adding others, such as the ability to zoom and to personalize the display parameters.

AmaSeis is designed for the analysis of seismograms including the calculation of earthquake magnitude and distance. Event locations can be determined with the help of phase picking and travel time tools when using multiple seismograms from an event. The software can record data from the AS-1 seismometer and display seismograms from other educational seismic networks as well as IRIS DMS data from WILBER (see below). Data zoom and filtering options are also available. Dr. Alan Jones, from the State University of New York at Binghamton, has developed the AmaSeis software under a contract with IRIS. Several IRIS members have provided valuable suggestions and feedback during the development. Future improvements include incorporating the ability to read and write additional data formats, simultaneous viewing of multiple seismograms, and overlaying seismograms onto theoretical travel time curves.

WILBER allows users to view and print maps and images of seismograms. They can also download and analyze data using AmaSeis or Wiggles software. We will also compile a catalog of classic earthquake seismograms that can be accessed through WILBER. WILBER has been redesigned to align with the new data structures developing at the Data Management Center and to provide a more user-friendly interface.

VSN Explorer, a new program currently being developed, will include:

- A versatile, web-based interface that provides real-time displays of seismic data from all over the world. Users will be able to extract, view, filter and print a seismogram.
- Real-time playback of "classic events" including a particle motion animation for three component records.
- Record sections and map displays that show seismograms with true amplitudes and demonstrate variations in amplitude that occur with distance and time.
- Instructional materials and teachers' guides.



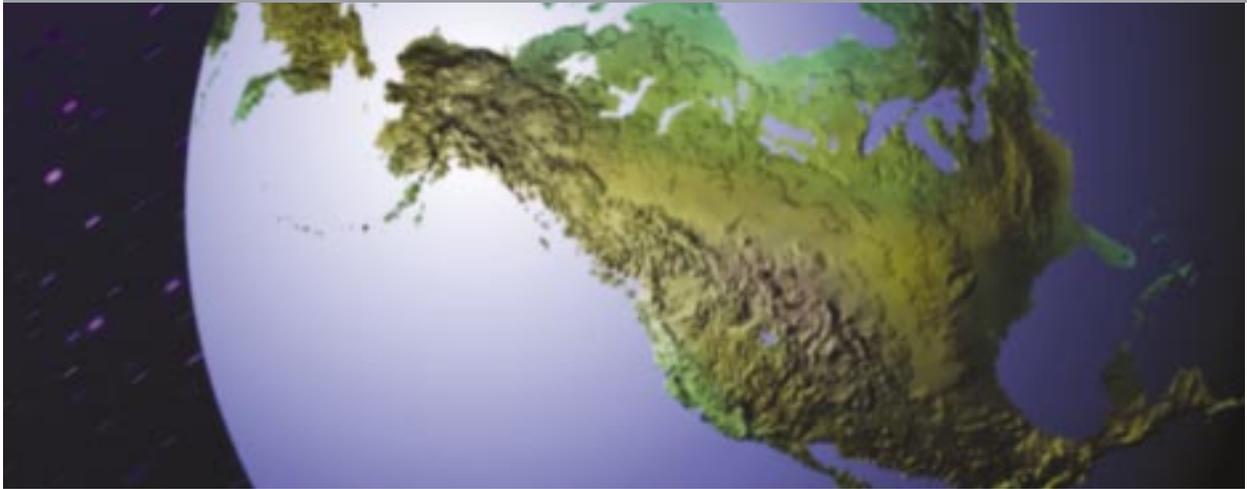
Users will have substantial interactivity to explore and investigate earthquakes, seismology, plate tectonics and related Earth science concepts. This project is being developed in cooperation with the IRIS Data Management Center and the University of South Carolina.

Strategies for Supporting the E&O Goals

As with all programs, IRIS must set clear priorities for E&O and establish management and funding strategies that allow us to achieve our goals. We have four types of funding models for our program initiatives:

- **Funding from the IRIS-NSF Cooperative Agreement:** As a program of IRIS, NSF provides core funding for establishing and maintaining basic E&O functions. These funds have allowed hiring of staff and carrying out the majority of activities reported above.
- **Sub-awards to member institutions:** Some E&O program objectives can be more effectively and creatively carried out by IRIS institutions or individuals with appropriate expertise and innovative ideas than by E&O staff or committee members.
- **Seed Projects and Partnerships:** To jump start new initiatives and stimulate community involvement, IRIS will partner with member institutions in pilot projects or small-scale initiatives.
- **Supplemental funding for large scale new initiatives:** The NSF Cooperative Agreement allows IRIS to seek additional funding from NSF and other funding sources for large-scale projects that are not possible under core funding. To complete these projects, IRIS will develop partnerships with other organizations and member institutions. In addition, IRIS will collaborate with member institutions to obtain external funding to implement successful pilot projects funded through the Seed Projects and Partnerships program on a larger scale.

With these funding strategies, we believe we can maximize our effectiveness, stimulate new and innovative programs, and optimize the involvement of the diverse IRIS community in E&O efforts.





Chapter 5

Supporting National Earth Science Initiatives

Seismology education is fundamentally interdisciplinary and broad. Therefore, natural partnerships for education and outreach exist with many scientific disciplines (geology, physics, mathematics, and computer science, in particular) and with fields that apply seismological knowledge to society (for example, earthquake engineering, emergency management and urban planning, petroleum exploration, environmental monitoring, nuclear test monitoring). While IRIS can make advances in science education through seismology, a concerted effort to link seismology across the scientific disciplines will achieve an even greater impact. We recognize the need to coordinate with other organizations and seek opportunities to collaborate on education and outreach activities where mutual interests exist.

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We view E&O activities that can build on a number of national Earth science research and education initiatives as particularly critical. These initiatives could have profound impact on the profile of Earth science education in this country, and could offer major opportunities for growth of the IRIS E&O effort. We focus here on four examples: (1) EarthScope, a proposed major geoscience research initiative through the National Science Foundation and NASA; (2) the Digital Library for Earth Science Education (DLESE), an NSF-supported geoscience education information system, (3) the U.S. Educational Seismology Network (USES), an initiative promoting seismographs and seismic data for science education in America's schools; and (4) the Advanced National Seismic System (ANSS), a USGS initiative to develop a nationwide network of at least 7000 seismic measurement systems. In the following section, we discuss each of these initiatives in detail, and then discuss opportunities for collaborations with others.

EarthScope

EarthScope is a project of unprecedented scale in the solid Earth sciences proposed for NSF's Major Research Equipment (MRE) program. EarthScope is a distributed, multi-purpose set of

instruments and observatories that will significantly expand the observational capabilities of the Earth Sciences and permit us to greatly increase our understanding of the structure, evolution, and dynamics of the North American continent. EarthScope is being developed jointly by the scientific community and the National Science Foundation, and in partnership with other science and mission-oriented agencies including the USGS and NASA. It includes four components:

-  USArray: a continental-scale seismic array sited in the United States to provide a coherent 3-D image of the lithosphere and deeper Earth.
-  SAFOD: (San Andreas Fault Observatory at Depth), a borehole observatory across the San Andreas Fault to directly measure the physical conditions under which earthquakes occur.
-  PBO: (Plate Boundary Observatory), a fixed array of strain meters and GPS receivers in western North America to measure real-time deformation on a plate boundary scale.
-  InSAR: synthetic aperture radar images of tectonically active regions providing spatially continuous strain measurements over wide geographic areas.

Collectively, EarthScope facilities will produce synoptic images of the solid Earth providing a framework for broad integrated studies across the Earth Sciences including research on earthquakes and seismic hazards, magmatic systems and volcanic hazards, mantle dynamics, regional tectonics, continental structure and evolution, and fluids in the crust.

IRIS can provide leadership for developing educational materials specific to USArray that make the EarthScope science more accessible to teachers and students.

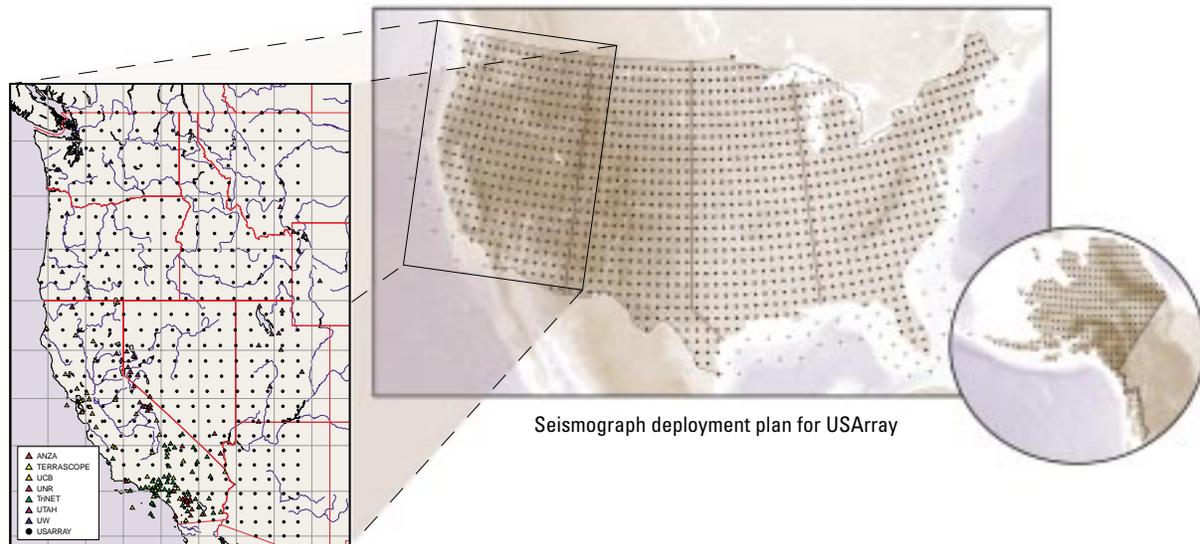
IRIS has been heavily involved in the development of EarthScope and may be the lead organization for operating USArray. Thus IRIS E&O has a clear role in shaping community involvement in educational applications of USArray data and

science. In addition, two other components of EarthScope, SAFOD and PBO, also carry a strong seismology component and may provide additional opportunities for E&O activities.

IRIS can contribute to the E&O component of EarthScope and USArray through a coordinated program that:

- Plays a key role in organizational workshops for the Earth science community in planning and development of education and outreach efforts (the first of these was held in January, 2002).
- Develops awareness, interest, and support for EarthScope activities among the communities and schools surrounding USArray and PBO sites during the planning and deployment stages.
- Develops partnerships with schools in the communities surrounding EarthScope sites to facilitate school involvement in educational activities using real-time data display and analysis software.
- Develops educational materials specific to USArray that make the EarthScope science more accessible to teachers and students and teach about seismology, and the geology, tectonics and seismic hazards of the region.
- Disseminates scientific results from EarthScope at a level appropriate for K-12 schools, community and four year colleges, and the general public.

We envision that many of these activities will involve collaboration with the USESN initiative, IRIS member institutions, the US Geological Survey, and other interested organizations and programs.



Digital Libraries for Earth Science Education (DLESE)

DLESE is conceived as an information system dedicated to the collection, enhancement, and distribution of materials that facilitate learning about Earth systems at all educational levels. DLESE supports Earth system education by: (1) developing collections of high-quality materials for Earth science instruction at all levels providing access to Earth data sets and imagery, and developing the tools and interfaces needed to enable their effective use in education, (2) developing discovery and distribution systems to efficiently find and use materials encompassed by the DLESE network, (3) providing support services to help users find, use, and create learning materials, and (4) developing communications networks to facilitate interactions and collaborations across all interests of Earth systems education.

DLESE is a distributed resource built by the community. Collections, services, and tools are being developed and maintained by numerous partners rather than being housed at a single centralized facility. To coordinate the DLESE effort and integrate library collections, services, and policies, a governance structure and central program office, the DLESE Program Center (DPC), have been established. The DPC, located at the University Corporation for Atmospheric Research, is engaged in both the community and technical aspects of library construction and management.

IRIS' role (in DLESE) is to increase access to seismological data sets and allow non-specialists to perform simple seismic data analysis for educational purposes.

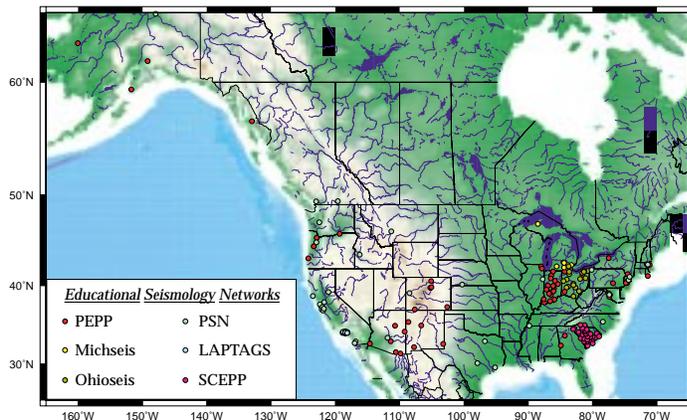
IRIS E&O is taking a leading role in providing seismic data access to DLESE through its initial involvement in the Geosciences Digital Library (GDL) program and now through its involvement in the National Science, Mathematics, Engineering and Technology Digital Library Project (NSDL). IRIS' role is to increase access to seismological data sets and allow non-specialists to perform simple seismic data analysis for educational purposes. This effort is being addressed with

improvements to WILBER and development of the VSN Explorer. IRIS is also charged with developing instructional materials that use seismic data. We will address this goal by building partnerships with member institutions to develop classroom activities tied to WILBER, the VSN Explorer and the Teachable Moments materials.

U.S. Educational Seismology Network

The USESN is a newly developing national initiative that brings together under a single aegis a number of disparate programs that support deployment and use of seismographs in schools. The mission of the USESN is to promote the use of seismographs and seismic data for science education and to provide an organizational framework for coordination of educational seismology around the country. The primary goals of the USESN initiative are to:

- Promote installation and effective use of school-based seismographs and seismic data;
- Provide advice and technical assistance in the form of instructional guides and information sharing for purchase, deployment and operation of school seismographs.
- Disseminate, in coordination with other organizations, high-quality classroom materials that promote educational seismology; and
- Provide an organizational framework for coordination and advocacy of educational seismology around the country.



Because of the confluence in the goals and ongoing activities of IRIS E&O and the planned USESN activities, IRIS E&O plans to provide initial support to the USESN as an IRIS E&O activity. We expect that the USESN will build on the IRIS Seismographs in Schools and Educational Affiliates programs, providing an avenue for a national educational seismograph initiative to grow substantially. Similarly, the VSN Explorer will provide display and analysis tools that allow non-seismologist data users to access the wealth of IRIS research quality data and data archived from educational seismographs.

Advanced National Seismic System

The Advanced National Seismic System is a USGS initiative to develop a nationwide network of seismic measurement systems that will make it possible to provide: (1) emergency response personnel with real-time earthquake information, (2) engineers with information about building and site response, and (3) scientists with high-quality data to understand earthquake processes, seismic strong motion, and solid Earth structure and dynamics. Development of this network is led by the US Geological Survey, with close linkages to other organizations such as IRIS, the Seismological Society of America, the Consortium of Organizations for Strong Motion Observation Systems (COSMOS), the Earthquake Engineering Research Institute (EERI), state geologic surveys, and emergency management agencies. ANSS and EarthScope will provide complementary opportunities for outreach to local communities, and IRIS E&O will work with the ANSS products committee as plans develop for an education and outreach program.

Collaborations with Other Earth Science Education Efforts

Many other scientific organizations are developing and promoting diverse educational materials and programs that involve earthquakes and seismology. By coordinating and collaborating with these organizations, we will maximize our impact and make greater advances towards our goals. These organizations include:

- National Earth science organizations such as the American Geophysical Union (AGU), the American Geological Institute (AGI), the Seismological Society of America (SSA), and the Geological Society of America (GSA);
- Federal agencies with strong mandates for public education, such as the United States Geological Survey (USGS), the Federal Emergency Management Agency (FEMA), and the National Oceanic and Atmospheric Administration (NOAA); and
- Regional earthquake research centers such as the Southern California Earthquake Center (SCEC), the Mid-America Earthquake Center (MAEC), the Northern California Earthquake Data Center, (NCEDC), the Multi-disciplinary Center for Earthquake Engineering Research (MCEER), the Pacific Earthquake Engineering Research Center (PEER),

IRIS has had a long-standing collaboration with the US Geological Survey on seismic station operations (with GSN and PASSCAL) as well as data distribution through the DMC. IRIS has extended that relationship by including USGS scientists on the E&O and other committees, and by collaborating with the USGS on the museum exhibits program. The USGS has developed effective

outreach materials focusing on national seismic hazards that we incorporate extensively in our outreach. We plan to build on their contributions with our Teachable Moments materials. Similar collaborations can occur with others. For example, organizations such as SCEC have taken leadership roles in education, internship, and knowledge transfer in local regions. AGU, AGI, GSA and FEMA have developed curriculum materials on earthquakes and a broad range of Earth science topics. Organizations from related scientific disciplines have also mounted effective education and outreach programs that include relevant scientific content. These include the American Association for the Advancement of Science (AAAS), the American Chemical Society (ACS), the American Physical Society (APS), the National Aeronautics and Space Administration (NASA), the University Consortium for Atmospheric Research (UCAR), and the National Academy of Sciences (NAS). IRIS E&O can provide people and products to complement the efforts of other organizations.

We will strive to establish effective collaborations with the wide spectrum of organizations involved in Earth science E&O activities.

Summary

The IRIS program has made a strong commitment to bring high-quality educational materials related to seismology into schools and communities through its E&O activities. These educational opportunities are heightened by the presence of a number of major research initiatives that have the potential to significantly advance the visibility of state-of-the-art scientific research in our country. The possibilities are magnified by the presence of both new educational reform initiatives and new educational resources that can make these scientific data and scientific results available and relevant to the broader educational community. It is an exciting time for science education and outreach. At the same time, we recognize that these efforts will be most effective if they are thoroughly coordinated with activities of other scientific and educational organizations.





Chapter 6

Evaluating Our Progress

Program evaluation is critical for effective decision-making, strategic planning, and the optimal use of the available resources. In this Program Plan, we have outlined a series of goals for IRIS's Education and Outreach efforts and a range of activities to meet those goals. With a well-designed evaluation plan, we can document and measure how well the program's services and products address the stated goals. Using this information, we can review the appropriateness of our goals and objectives and be ready to refine the program. Program evaluation relies on routine assessment, or gathering of information, about the program activities. At the most basic level of assessment, we will document the range of activities, the goals that they address, and the demographics of participants in the E&O program. Table 1 shows the E&O goals, the activities planned or underway and the diverse audiences they address.

Each year the Program Manager, in collaboration with the E&O Committee, will conduct an evaluation of overall program activities. This evaluation will focus on measuring the outcomes and overall impact of the entire program and provide key information for guiding future directions. Important questions to address in these evaluations include:

- How well do the individual activities support the mission and goals of the IRIS Consortium and the E&O program?
- Is the E&O Program providing IRIS with opportunities for continued growth and development?
- Does the balance of activities adequately address the needs of the communities and audiences that IRIS most wants to serve?
- Is the quality of services and products adequate to address the program goals?
- Does IRIS E&O have the necessary skills, personnel, and other resources to adequately conduct the ongoing activities and proposed activities?

Evaluation of the overall program requires knowledge of the needs of the audiences served and the impact and quality of individual activities. The goals and current activities of the E&O program are based on perceived and stated needs of different audiences. With continued work in seismol-

ogy outreach, these needs may change and the impact of our activities may change. Evaluation studies will identify the needs of targeted audiences, how those needs are changing and how well individual activities are effectively meeting them. This information can then be used to develop, manage and improve individual products and services.

The evaluations must examine the nature of the programs themselves, as well as all intended and unplanned outcomes over time. The range of assessment tools will include surveys, interviews and focus groups, as well as usability studies for software and web interfaces, and content peer review and field-testing of the instructional materials. With a program this large and diverse, it is important that the evaluation process place minimum demand on project participants, and recognize the time and cost-effectiveness of different types of assessment. Table 2 outlines modes of assessment that can be used to measure the success of individual activities as part of an overall program evaluation.

Due to the diversity and scale of this program, it is recommended that IRIS hire a professional evaluator who understands the needs of the project's sponsors and IRIS' ability to fulfill them. A professional evaluator can impartially assist with development of assessment tools, evaluation of the data and compilation of reports that document program activities and outcomes. In addition, an External Review Committee (2-3 people) should conduct a thorough review of the E&O program every three years.

Sample Responses From a NSTA Workshop Evaluation Summary

Participant Evaluation of Workshop (23 Participants)

5 = Strongly Agree (SA); 4 = Agree (A); 3 = Undecided (U); 2 = Disagree (D); 1 = Strongly Disagree (SD).

	5-SA	4-A	3-U	2-D	1-SD
1. The instructors displayed a clear understanding of workshop topics.	23	0	0	0	0
2. The workshop was well-organized.	22	1	0	0	0
3. I can apply information/skills learned in this workshop.	21	2	0	0	0
4. As a result of this workshop, I will definitely implement some additional seismology and/or Earth science topics in my teaching.	22	1	0	0	0
5. Overall, the workshop instructors were among the best teachers I have known.	19	4	0	0	0
6. Overall, this workshop was one of the best that I have ever attended.	21	2	0	0	0
7. What were the most significant parts of the workshop to you?					
<ul style="list-style-type: none"> • The materials are relevant & useful. The hands on activities are fun and educational. • Exchanging ideas with other participants in addition to the activities I learned at the workshop. • I have very limited materials available in my class. Now I have a low cost earthquake activity that I will use this during the spring term this year. • Using the software to find data about earthquakes. • Enjoyed explanation & presentation of mantle lithosphere, P, S & surface waves as well as way of demonstrating these to students. • The tongue-depressor building test. Been looking for a good way to start an earthquake building project for several years. 					
8. Etc....					

Table 1: Goals and corresponding E&O activities that contribute to achieving goals

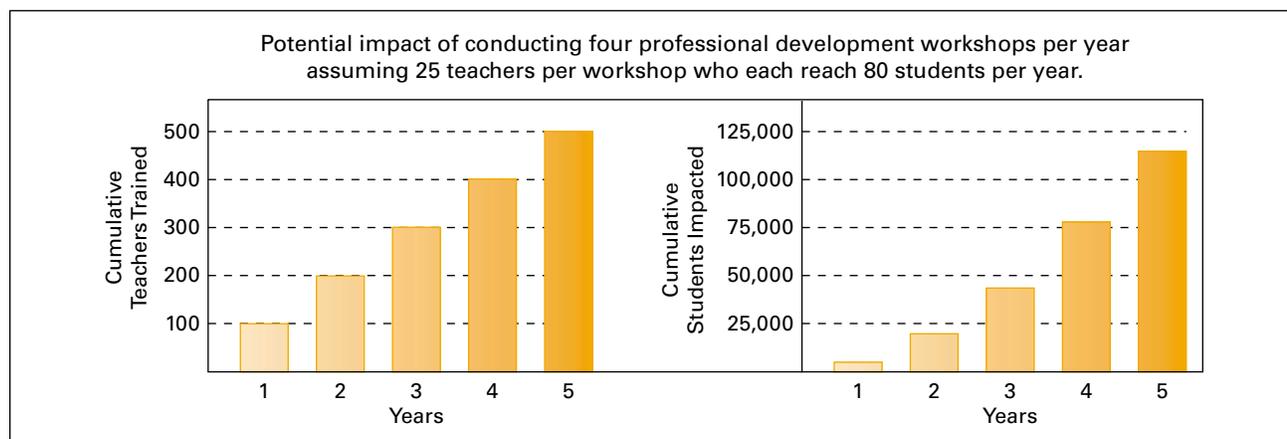
Goal	Pathway	Audience
Improve access and usability of IRIS seismic data and research results.	WILBER, VSN Explorer, Teachable Moments resources, EarthScope/USArray, Distinguished Lecture Program, museum exhibits, posters, One-pagers, Seismic Monitor	All Americans
Organize and support programs to place educational seismographs in K-16 schools.	Seismometers in Schools program, USESN, VSN Explorer, WILBER, AmaSeis, Teachable Moments resources, instructional materials, EarthScope/USArray	K-12 schools and undergraduate institutions
Develop and disseminate instructional materials and analysis tools that use seismological observations and data.	Seed Partnerships and Projects program, new inquiry-based lessons and activities, Teachable Moments resources, posters, One-pagers, Seismometers in Schools program, EarthScope/USArray	Kindergarten through graduate school students and teachers
Increase the number of pre-service teachers who have a strong foundation in Earth science.	Seismologists teaching the teachers, workshops for undergraduate faculty, One-Day Earthquake workshops, Educational Affiliates	Undergraduate and graduate students and faculty
Increase the number and diversity of students that are interested in Earth science and capable of pursuing careers in Earth science.	One-Day Earthquake workshops, Undergraduate Research Internship Program, workshops for undergraduate faculty, EarthScope/USArray, instructional materials and seismological data analysis tools	Kindergarten through undergraduate students and teachers
Prepare outstanding students to pursue graduate studies in Earth sciences and to fill a variety of careers and roles in society.	Undergraduate Research Internship Program, workshops for undergraduate faculty, Graduate Travel Grants.	Undergraduate and graduate students
Provide professional development for teachers and college faculty to improve instruction in K-16 classrooms.	One-Day Earthquake workshops, workshops for undergraduate faculty, Educational Affiliates	K-12 teachers and undergraduate faculty
Provide national leadership and an institutional framework for seismology education.	EarthScope/USArray, USESN, DLESE, museum exhibits, Distinguished Lecture Program	All Americans
Recognize Earth scientists for their achievements in education and public policy that lead to an increase in scientific literacy.	Distinguished Lecture Program	Professional Earth scientists
Increase public awareness and understanding of seismology and related Earth science.	One-pagers, posters, maps, web based information, museum exhibits, Distinguished Lecture Program	All Americans
Encourage and assist Earth scientists to be more effective communicators of scientific concepts.	Communications workshops for Earth scientists; Teachable Moments resources; WILBER, the VSN Explorer and associated instructional materials.	Graduate students and professional Earth scientists

Table 2: Evaluation strategies for IRIS E&O programs (A Focus on People)

Activity	Audience	Measures of Success
Educational Affiliates	Undergraduate institutions	Number of affiliate applications; level of involvement in IRIS activities; participant surveys.
Professional development for undergraduate teaching	Undergraduate faculty	Participant surveys; follow-up interviews with participants; classroom testing and evaluation of materials and software.
Professional development for Earth scientists working with K-12 teachers	Graduate students and professional Earth scientists	Participant surveys; follow-up interviews with participants; classroom testing and evaluation of materials; documentation of workshops provided to K-12 teachers by participants.
Professional development for K-12 teachers	K-12 teachers	Participant surveys; follow-up interviews with participants; classroom testing and evaluation of materials.
Undergraduate Research Internships	Undergraduate students	Participant surveys and follow-up interviews for student and sponsor; tracking career paths of undergraduate participants.
Graduate Student Teaching and Communication Workshops	Graduate students	Participant surveys and follow-up interviews; survey of career choices.
Graduate Student Travel Grants	Graduate students	Number and demographics of applicants and recipients; survey of career choices.
Efforts to increase diversity throughout our program	K-20 students	Number and demographics of participants in all of our activities.
Distinguished Lecture Program	Students and faculty at colleges and universities, public	Speaker and participant surveys; IRIS member surveys of program impact, feedback from sponsoring venues.
EarthScope/USArray	All Americans	The diversity of programs involved will require a broad based assessment.

Table 3: Evaluation strategies for IRIS E&O products (A Focus on Products)

Activity	Audience	Measures of Success
Posters and One-page Information Sheets	Public and K-16	Peer review; product demand; user surveys.
Museum Exhibits	Public and K-16	Visitor surveys; attendance at museums; peer review.
Seismometers in Schools Program	K-16 Schools	Demographics of participants, follow-up interviews of participants; evidence that the instrument has improved teaching of Earth science or seismology in schools.
Instructional Materials (Teachable Moments resources and other curriculum modules)	K-16	Peer review; field-testing; product demand; user surveys.
Seismic Data Analysis Tools for the K-16 classroom (AmaSeis, WILBER and VSN Explorer)	Public and K-16	Peer review; field-testing; product demand; user surveys.
Web access to seismic data and related information	Public and K-16	Peer review; product demand; user surveys.







Chapter 7

Recommendations

This report ends with a series of recommendations for major new and continuing efforts by the IRIS Education & Outreach Program. These recommendations are guided by the stated goals of IRIS E&O and consistent with the ongoing and future activities presented in this program plan. These recommendations should be implemented in close coordination with the other IRIS programs and, where possible, in collaboration with other organizations involved in Earth science E&O. The core activities can be funded within IRIS' Cooperative Agreement with NSF. As the program grows to implement new initiatives such as an expanded professional development program, and IRIS' contribution to EarthScope/USArray, supplemental grants will be required to fund additional staff and resources.

We view these recommendations as a 5-year strategic plan, although many of the recommendations may still be appropriate for many years beyond. However, implementation must retain the flexibility for shifting emphasis based on changing conditions and technology, new opportunities that arise, and response to program evaluation.

Implementation must retain the flexibility for shifting emphasis based on changing conditions and technology, new opportunities that arise, and response to program evaluation.

IRIS, through its E&O staff, E&O Committee and general membership should vigorously pursue the following major efforts:

- *Rapid development, testing and dissemination of the concepts embedded in the Virtual Seismic Network (VSN) Explorer software and related instructional materials:* This software and associated instructional materials are the key to leveraging the valuable digital seismic datasets that are at the heart of IRIS. While these data are, today, generally available to researchers, the availability and use by a wider audience depends on the development of better data access, analysis and display tools. The VSN Explorer is a key element of plans for undergraduate and K-12 education, educational seismographs programs, EarthScope/USArray E&O, IRIS contributions to the Digital Libraries for Earth Science Education (DLESE) project, and all other efforts that involve the use of digital seismic data by non-seismologists. Combining the VSN Explorer with inquiry-based instructional materials opens the door to fully integrating education and research.

- *Expansion of the Seismographs in Schools program through support for the U.S. Educational Seismology Network (USES N):* One of the major challenges of the E&O program is to increase public awareness of the relevance of seismology and Earth science and to contribute to enhancing science education at all levels. The VSN Explorer will contribute significantly to these goals. In addition, the Seismographs in Schools Program provides motivation for learning seismology and related Earth science and opportunities for the integration of education and research. Targeting of under-resourced schools and traditionally underrepresented minority groups, through contacts and collaborations made at earthquake workshops in Urban Systemic Initiative cities, should be a significant goal of the Seismographs in Schools Program. The Seismographs in Schools Program is aimed primarily at K-12 schools; however, educational seismographs are also a part of the new Educational Affiliates program that is designed to increase IRIS' connections to undergraduate institutions. The efforts of the USESN will assist schools in choosing the most appropriate resources for their individual needs.
- *Dissemination of E&O products through DLESE:* The IRIS E&O program has been involved from the beginning in the DLESE program. Our data sets and software will be an important part of this digital library. IRIS should continue to be an active participant and contributor to this program and utilize DLESE to provide effective and broad dissemination of materials.
- *Teachable Moments (significant event) initiative:* This project has the potential to periodically engage, in a highly effective and meaningful way, a large number of people at various educational levels. We expect the project to be initiated as a collaboration with IRIS member institutions to take advantage of member expertise and with time to provide useful background about many seismic zones around the world. These materials can be used for effective education and outreach to the public and students after significant events.
- *Preparation for, and initiation of, EarthScope/USArray education and outreach:* the opportunities for E&O in conjunction with the EarthScope/USArray program are enormous, but so are the challenges of designing and delivering a coordinated and successful effort. Planning and developing that effort must be a priority so that when USArray is deployed, the E&O program

The national scale of EarthScope/USArray creates the potential for impacting all Americans and for involving a larger portion of the IRIS, and other Earth science, communities in outreach.

is ready to capitalize on this unique opportunity to broaden our audience and visibility. The national scale of EarthScope/USArray creates the potential for impacting all Americans and for involving a larger portion of the IRIS, and other Earth science, communities in outreach. IRIS should continue working to engage more scientists in E&O activities to meet the needs of the extensive

EarthScope/USArray E&O opportunity. The next step in this process will be to build on the first national workshop devoted to EarthScope E&O planning and organization.

- *E&O program assessment and evaluation:* The E&O program should undertake substantial and ongoing assessment to measure the outcomes and progress of the elements of the program. Overall evaluation by the E&O committee and by an external evaluator should also be utilized to help provide direction and refinement of the program and document its effectiveness.

The following ongoing IRIS E&O efforts should be continued:

- *Professional development workshops:* Workshops are an important mechanism for encouraging use of IRIS data, software and other E&O efforts, and for obtaining feedback and ideas from participants. The E&O program has developed a series of workshops for non-seismology faculty involved in undergraduate teaching and for K-12 teachers. Perhaps the most important workshops are those that teach IRIS seismologists how to conduct workshops for K-12 teachers in their own communities, thereby leveraging the expertise and geographic distribution of the IRIS membership. The new extended workshops for teachers should have significant benefit and help capitalize on the opportunities presented by Earthscope/USArray. We recommend that the current workshop effort expand to accommodate the USArray extended workshops and to pilot the workshops in school districts with Urban Systemic Initiatives. Expansion of these programs would occur by generating supplemental funding.
- *Improvements to the IRIS E&O web site:* This web site is the continuously visible face of IRIS E&O efforts. Through this site, we engage and inform our target audiences. The web site will become the focus for data delivery to non-seismologists with the development of VSN Explorer. Current plans call for improvements to Seismic Monitor and the WILBER interface and the delivery of pre-filtered, printable seismograms from “classic events” for teaching. An ongoing effort to improve the usefulness and usability of this web site is essential to achieving the overall E&O goals of IRIS.
- *Museum displays:* Museum displays are a highly effective and visible part of the current E&O program. The museum display program has been very successful and should continue to foster relationships between IRIS and major museums and should target the development of at least one new museum display each year.
- *Products:* Seismology education and outreach products, including posters, maps, earthquake updates, instructional materials, and software and web-based tools, have been important components of the IRIS E&O program. We recommend that development of these materials be continued at near the current level. However, development of instructional materials for use with the VSN Explorer, the Seismographs in Schools program and USArray. will require additional resources and effort.
- *Undergraduate internship program:* The undergraduate internship program is an important component of the IRIS Educational Affiliates program. It also serves a need for undergraduate opportunities in IRIS member institutions. The number of internships offered should be maintained at the current level. Improvements in the administration of the internship program should be made to ensure that it maximizes available opportunities and maintains a highly talented applicant pool each year. The internship program should also specifically target a diverse student population.

Seismology education and outreach products, including posters, maps, Earthquake Updates, instructional materials, and software and web-based tools, have been important components of the IRIS E&O program.

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