The IRIS Consortium:

Twenty Five Years of Support for Seismological Research 1984–2009

25 YEARS

The IRIS Consortium
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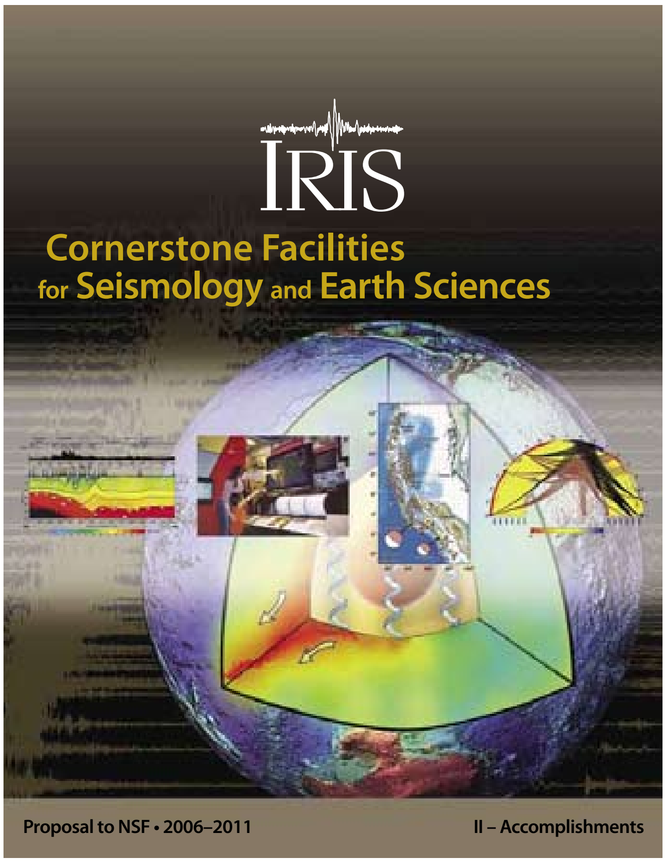
IRIS



Cover of the proposal that formed the basis for the 2006-2011 Cooperative Agreement between IRIS and the National Science Foundation.

A facilities program to support Research and Education in the Earth Sciences through the collection and distribution of seismological data for studies of:

- Earthquakes
- Earth Structure
- Earth Dynamics
- Verification of the Comprehensive Nuclear Test-Ban Treaty

IRIS NSF

Contents

Introduction

This report was prepared in January 2009 as part of a review being carried out mid-way through the third year of the fifth five-year Cooperative Agreement (2006-2011) between the National Science Foundation (NSF) and the Incorporated Research Institutions for Seismology (IRIS).

This report is intended to complement other materials and mechanisms through which NSF carries out ongoing review of IRIS and its programs. These include:

- **Five-Year Proposals:** The IRIS programs for development and operation of facilities for seismological research have been funded through five-year Cooperative Agreements with NSF. Each of these has been based on a comprehensive proposal that presents the scientific rationale for IRIS core programs; the proposed evolution of the facility; budgets for capital improvements, operations and maintenance; and the governance, organizational and management structure under which the consortium and facilities will be operated. In addition to a detailed description of the IRIS facilities, these proposals have included a lengthy section of "one-pagers" that presents the results of numerous investigations documenting recent scientific results based on the use of IRIS data and resources.

- **Annual Program Plans and Budgets:** As part of the procedures specified in the Cooperative Agreement, every year IRIS is required to provide NSF with an Annual Report, Program Plan and Budget that describes the activities and expenditures for the past year and the proposed activities and budget for the following year. This proposed plan is developed by IRIS, within the context of the five-year plan, based on input from the program Standing Committees and approval by the IRIS Board of Directors. Approval by NSF is the basis for incremental funding of IRIS programs on an annual basis.

In addition to the annual and five-year reviews by NSF, the IRIS programs undergo continual evaluation and evolution through input from the university research community and Consortium members. This community review and oversight takes place through the IRIS committee structure, and member participation at Annual Workshops and special meetings. The activities of the Consortium and the state of the IRIS facilities are communicated to the membership through the IRIS web site, and Annual Report.

In this review, emphasis is placed on the history and evolution of the Consortium and its programs, and the structure for involvement of the membership and broader research community in the governance and management of IRIS. This document does not contain detailed descriptions of either the technical aspects of the facilities or the scientific results that have emerged from their use. For those interested in more information on these topics, the IRIS web site, www.iris.edu (see Appendix III), contains extensive information on the status and use of the facilities, and the publications and bibliography listed in Appendix IV document the scientific rationale and results.

IRIS Articles of Incorporation

May 8, 1984

Purposes:

- To promote and conduct geophysical investigation of the earth's interior using seismic and other geophysical methods;
- To promote the exchange of information and knowledge and to create, foster, and encourage cooperative efforts between the members of the Corporation and other organizations, research workers, students and other institutions involved in the area of the study of earth sciences;
- To solicit, raise and receive funds for the advancement and furtherance of the foregoing purposes; and
- To do any other acts that may further the general purposes of the Corporation as set forth herein.

Mission Statement

The mission of the IRIS Consortium, its members, and affiliates is to:

- Facilitate and conduct geophysical investigations of seismic sources and Earth properties using seismic and other geophysical methods.
- Promote exchange of geophysical data and knowledge, through use of standards for network operations, data formats, and exchange protocols, and through pursuing policies of free and unrestricted data access.
- Foster cooperation among IRIS members, affiliates, and other organizations in order to advance geophysical research and convey benefits from geophysical progress to all of humanity.

Adopted by the IRIS Board, June 2006

IRIS – Then and Now

Formation and Incorporation

The idea for the IRIS Consortium grew from the merging of two independent interests identified by the academic seismology community in the early 1980s. One group was interested in an upgraded global digital seismic network that would expand and modernize the aging and under-funded World Wide Standard Seismographic Network (WWSSN). The other group was interested in developing a new generation of portable seismic instruments for seismological studies of the continental lithosphere. Both of these initiatives were guided by reports from a series of important studies carried out by the National Academy of Sciences and its Committee on Seismology on future instrumentation and data needs in seismology and the Earth sciences (Figure 1). Additional encouragement came from a key report from the Committee on Science, Engineering and Public Policy in 1983 that identified "five research areas in which significant dividends can be expected as a result of incremental federal investment in FY1985" including "seismic investigations of the continental crust" and "a global digital seismic array."

After a year of intense activity that included numerous workshops and planning meetings, the US seismology community joined together in 1984 to form a new consortium to develop and implement plans for an ambitious new set of facilities to support a wide range of seismological research. The IRIS Consortium was formally created as a not-for-profit corporation in the State of Delaware on May 8, 1984 with a broad mandate, as stated in the Articles of Incorporation, to pursue the development of new resources to support seismological and geophysical investigations (see box on opposite page).

One of the first activities of the corporation was to develop a ten-year proposal that laid out the seismology community's vision. In December 1984, IRIS submitted to the National Science Foundation the "Rainbow Proposal" entitled *Imaging the Earth's Interior: Detailed Studies of the Earth and of the Seismic Source with New Global and Transportable Arrays* (Figure 2). This proposal requested $107 M for the initial five years, and $281 M for the full ten years of activities, which included the development of a Global Digital Seismic Array, a Mobile Array for continental lithosphere studies, Central Data Management and Distribution Facilities, and a Major Computational Facility (see box on page 4).

Figure 1. A series of important studies by the National Academy of Sciences and its Committee on Seismology in the late 1970s and early 1980s culminated in reports that provided the scientific and technical basis for new observational and data facilities in seismology and Earth sciences.

IRIS Proposal to NSF, 1984
Imaging the Earth's Interior
Executive Summary

Our Earth's interior remains one of man's major scientific frontiers. Inaccessible for direct observation beneath a 10-15 km drilling range, Earth's lower crust, mantle and core are seen primarily through illumination by seismic waves.

In a major departure from the traditional single investigator approach to research support, the seismological community has, in 1984, created a consortium of research institutions for the purpose of implementing critically needed national facilities necessary to support seismological research on Earth's interior in the coming decades. IRIS, the Incorporated Research Institutions for Seismology, a non-profit Delaware corporation, was founded May 8, 1984. By the first meeting of the Board of Directors on May 13 there were twenty-six members of the Corporation. As this proposal is submitted, membership includes forty universities, a representation of nearly all U.S. universities with seismological research programs.

A university consortium of such size and degree of participation represents a unique and remarkably unified commitment to the common research goals addressed by IRIS. A list of member institutions and representatives is given in the Foreword.

This proposal is for support of the ten-year IRIS program for the implementation of four major national facilities for seismology,

- A Global Digital Seismic Array, featuring real-time satellite telemetry from one hundred modern seismographic observatories
- A Mobile Array comprised of one thousand portable digital seismographs to be used for studies of the continental lithosphere
- Central Data Management and Distribution Facilities to provide rapid and convenient access to the data sets for the entire research community
- A Major Computational Facility, capable of supporting the analyses of these new data

The IRIS program is set out in Table 1.1 in a ten-year plan, with budget estimates assuming major capital equipment acquisition in the initial five years. Steady-state operation of the four IRIS elements is estimated to require a minimum of some $17M per year in facilities maintenance and operation, plus $7M annually in equipment acquisition, and a $8M yearly increment in funds for associated research support to individual investigators. The estimated ten-year cumulative cost to bring the IRIS initiative into full operation is $281M, of which nearly 30% represents capital equipment.

Actual expenditures may well exceed this estimate. For example, a fully supported computational facility with Class VI or greater capabilities can alone cost $15M per year. Other NSF programs and other agencies will very likely support major enhancements to the basic IRIS plan.

The IRIS plan offers an NSF response to two of the five research areas identified by the Foundation's Research Briefing Panel on the Solid Earth Sciences initiatives, "...in which significant dividends can be expected as a result of incremental federal investment in FY1985." IRIS represents a consortium made up of an overwhelming majority of the research universities in seismology supporting new initiatives in these areas.

IRIS was created to implement major new national facilities which will provide the tools of earth scientists into the next century, and to develop an effective management for this collective use by the research community. This proposal represents the positive response of the seismological community to clearly-defined needs, and it offers NSF an action plan to develop these exciting areas of the solid earth sciences.

IRIS Today

Twenty five years later, in 2009, IRIS has grown from its 26 original members to a consortium of 109 Members, two US Affiliates, ninety Foreign Affiliates and seventeen Educational Affiliates (Figure 3). Three of the initial four major national facilities outlined in the 1984 Rainbow Proposal have been nurtured by IRIS and the community. The rapid evolution of supercomputer facilities obviated the need for a dedicated seismological computational facility, and IRIS data resources focused on centralized data management. With the addition of the Education and Outreach Program in 1998, the IRIS core programs currently consist of:

1. **Global Seismographic Network (GSN):** A permanent worldwide network of over 150 broadband seismological observatories.
2. **Program for the Array Seismic Studies of the Continental Lithosphere (PASSCAL)**: A program of portable instruments and arrays for use by individual scientists for high-resolution experiments in focused areas,
3. **Data Management System (DMS):** A data system for collecting, archiving and distributing data from IRIS facilities, as well as a number of other national and international networks and agencies.
4. **Education and Outreach Program (E&O):** A program designed to integrate research and education by making our data and science accessible to non-seismologists through a variety of innovative programs.

In addition, USArray, has been built on many of the resources developed under the core IRIS programs to become the seismological component of EarthScope, a continent-scale geophysical observatory constructed during 2003-2008 with funds from the NSF Major Research Equipment and Facilities Construction (MREFC) account.

The GSN, PASSCAL and USArray are complementary programs and the primary tools for acquisition of new data. The GSN, along with other cooperating networks, provides a baseline resolution of approximately 1000 to 2000 km on the continents and oceanic islands worldwide. Denser deployments of the PASSCAL and USArray instruments allow investigations of focused targets with resolution on the order of hundreds of kilometers down to the sub-meter scale. The DMS and E&O are also complementary programs and the primary means of distributing data for research and education. By combining and distributing data from different sources, the DMS allows individual investigators to assemble data products tailored to their research objectives. The DMS also serves as a forum to coordinate international cooperation, set data and software standards, and promote data exchange.

As these core facilities have grown, so has the demand from the seismological community for the services and products that they provide. IRIS facilities, products and services are now essential for the progress of a large proportion of seismological research funded by the NSF, USGS, DoD, and other US government agencies with programs in the Earth sciences and nuclear monitoring. IRIS facilities and data are also making new styles of scientific investigation possible. A constant goal of IRIS is to improve operation and efficiency of the existing core IRIS facilities.

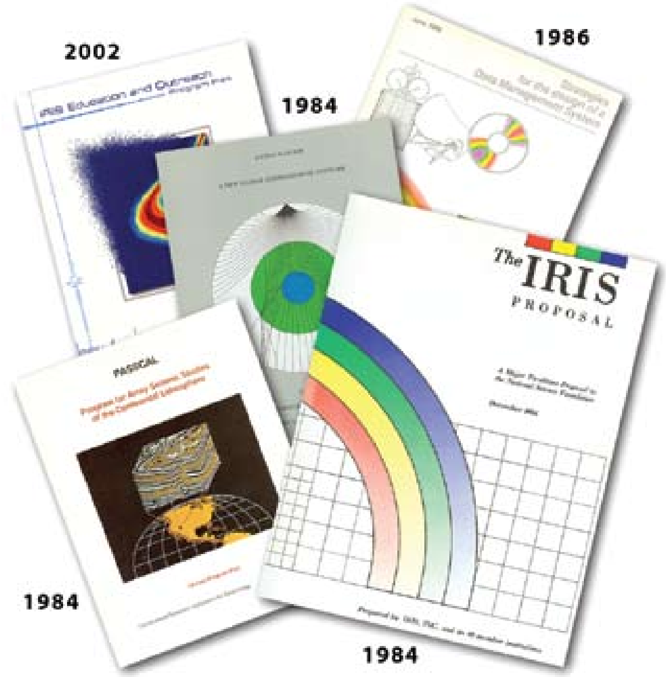


Figure 2. The 1984 "Rainbow Proposal" from the IRIS Consortium to the National Science Foundation built on intensive workshop and Program Plans developed in 1983-84 related to the development of a new Global Seismographic Network and a complementary Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL). Preliminary plans for data management were included in the 1984 proposal and expanded in the 1986 Program Plan for the IRIS Data Management System. Education and Outreach was added as a core IRIS program in 1998 and further defined in the 2002 Program Plan.

From the beginning, IRIS facilities and products have also been used for educational purposes. Educators use seismograms or earthquake data obtained from the DMS in the classroom, construct public displays of "live" seismological data from the GSN, and introduce students to field work and research through participation in PASSCAL deployments. Following the advice of reviewers of the 1996 IRIS proposal, and recognizing the opportunity that IRIS has to facilitate the use of many types of seismological data for educators, in 1998 IRIS established the Education and Outreach (E&O) Program to better address the need for educational materials and services. The E&O Program integrates seismological data with educational programs and public outreach, making IRIS data available and usable, not only for research seismologists, but also for educational institutions and the interested public. The E&O Program also plays an important role in translating scientific results on Earth structure and dynamics into terms meaningful and accessible to the general public. E&O provides outreach to the public through museum displays and lecture series, trains teachers and undergraduate faculty on the collection and analysis of seismic data, and encourages student participation in seismological research through an intern program.

IRIS and EarthScope

The role of the IRIS Consortium in the broader seismological and geophysical research communities in the United States has continued to expand. IRIS has become an organization that successfully facilitates collaboration and cooperation among seismologists and other Earth scientists. As a consortium of universities, IRIS has been able to develop, present and promote initiatives that have broad support in the academic Earth science community. To that end, in 2003 IRIS joined with a broad sector of the Earth science community in the development of EarthScope, a major NSF-funded initiative that includes a new generation of facilities for seismology, geodesy, magnetotellurics and fault zone studies. EarthScope combines enhanced geodetic observations in the western United States (Plate Boundary Observatory, PBO), a continental scale seismic array (USArray) and in situ studies of an active fault zone (San Andreas Fault Observatory at Depth, SAFOD) to provide fundamental new insights into earthquake processes and the structure, evolution and deformation of North America. In 2008, the IRIS Consortium, UNAVCO, Inc., Stanford University and the US Geological Survey completed the observational systems that form the foundation of EarthScope. EarthScope is intended to continue for an additional ten years, providing continuous data from permanent GPS and seismic installations and continuing to support the transportable component of USArray as it continues to traverse the lower 48 states and Alaska.

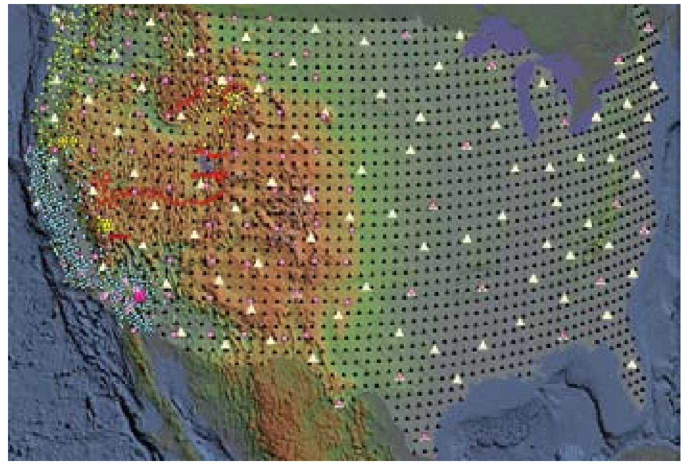


Figure 3. Map showing the EarthScope geophysical stations in the conterminous US including PBO geodetic (circles) PBO strain (diamonds) and USArray TA (black triangles) and Reference Array (white triangles).

The USArray component of EarthScope consists of continental-scale, portable seismic and magnetotelluric arrays that will map the structure and composition of the North American continent and the underlying mantle at high resolution. Through its four elements—the Transportable Array, the Flexible Array, Magnetotellurics and the Reference Network—USArray is able to capture images that span the continuous range of scales from global, through lithospheric and crustal, and from regional to local, complementing and extending the reach of the GSN and PASSCAL facilities. USArray has been implemented through extensions to the existing four IRIS core programs, and represents an approximate doubling of the IRIS infrastructure in terms of number of instruments and data volume. An exciting aspect of USArray is that virtually every educational institution in the United States has the opportunity to take an active role in the investigation.

Consortium Activities and Support

As a Consortium, IRIS serves as a forum for exchanging ideas, setting community priorities and fostering cooperation. The IRIS mission statement (box page 2) was adopted by the IRIS Board of Directors in June 2006 to formalize the broad goals of the Consortium. In addition to community outreach through its committee structure, IRIS uses workshops, publications (Figure 4) and the web as means to engage the broader community in advancing this mission. The IRIS Workshop (now held every two years, alternating with the EarthScope National Meeting) is usually held in June with an attendance of approximately 200. The workshop is a forum to review the IRIS facilities and to assess the state of key areas within the science. Seismological and interdisciplinary topics are included in science talks and poster sessions. Many of these sessions have focused on regions of current PASSCAL and GSN studies, with a special emphasis on linking the seismological studies with other geoscience disciplines. Other science sessions have proposed new directions for the evolution of IRIS programs or the development of new initiatives. For example, sessions on USArray and the Plate Boundary Observatory at Workshops in 1995 and 1998 (followed

Figure 4. The 109 full members of the IRIS Consortium now represent most universities in the United States with "major commitment to research in seismology and related fields." A full list of the institutional members and their representatives on the IRIS Board is included in Appendix I.

by IRIS Newsletter articles in 1998) were part of the early stages in the development of EarthScope. The Workshops also include program reviews, tutorials, demonstrations and "Special Interest Groups" (SIGs) to provide IRIS staff and committee members the opportunity to present program activities and explore new directions. Some workshops have been preceded by one-day short courses on data management, instrumentation, software and teacher training. In addition to the IRIS Workshop, special topical workshops are supported on an *ad hoc* basis.

The IRIS Newsletter, published two to three times per year from 1990 to 2007, and the DMS Electronic Newsletter, which began in 1999, report on the activities of IRIS and related organizations and present articles on recent developments in seismology (find both at http://www.iris.edu/hq/publications/newsletters). The IRIS Annual Report, with a distribution of more than 2000, summarizes each year's activities for Consortium members, funding agencies and the public. The Education and Outreach Program publishes a variety of supplementary curriculum materials for use by teachers, including posters and topical one-pagers (both English and Spanish versions are available, http://www.iris.edu/hq/programs/education_and_outreach/publications). Even the IRIS five-year proposals, in addition to their role in the NSF review process, have been used as a way to engage the community in setting priorities and reviewing recent accomplishments in seismology and the geosciences. The extensive collections of one-page science summaries in the past two proposals have been used in classrooms and graduate seminars as broad summaries of current research in seismology.

In 2008, IRIS was requested by NSF to engage the Consortium membership and representatives of the broader Earth science community in development of a Long Range Plan for Seismology. The resulting plan, entitled "Seismological Grand Challenges in Understanding Earth's Dynamic Systems" (www.iris.edu/hq/lrsps), presents significant research challenges, and the resources required to support them, that will help define future directions for research in earthquakes and Earth structure supported by NSF and other federal agencies. The IRIS web site (see Appendix III) serves multiple purposes: acting as a portal to IRIS data and services; providing links to other resources and organizations in seismology; and outlining the activities of the Consortium. An IRIS bulkmail service is used to keep registered users informed of IRIS activities, employment opportunities and items of special interest to the seismological community.

There have also been ways in which IRIS, through the breadth of the Consortium membership and the reach of its global programs, has been influential in impacting areas of seismological research that extend beyond its core facilities. As embodied in the IRIS mission statement, one of the goals of the Consortium is to "Promote exchange of geophysical data and knowledge, through use of standards for network operations, data formats, and exchange protocols, and through pursuing policies of free and unrestricted data access."

- *Standards for instrumentation and data formats:* In the early stages of the IRIS programs, careful consideration went into the specification of design goals for seismometers and data loggers and standard formats for data exchange.

Figure 5. IRIS publications include the Newsletter, Annual Reports, educational "one pagers" and posters, proposals and reports. High-resolution versions of the educational materials are available on the IRIS web site and printed copies are provided free of charge to teachers.

Instruments from a number of manufacturers, produced to meet the specifications of the IRIS GSN and PASSCAL design goals, have become the de facto standard for broadband equipment worldwide. This has greatly increased the quality of global seismological information and facilitated the exchange of data. IRIS involvement in the establishment and on-going activities of the international Federation of Digital Seismograph Networks (FDSN) has also facilitated the exchange of global data. PASSCAL and USArray have served as models for similar large-scale programs for portable seismology recently emerging in Europe, Japan and China, and a number of national networks (including Russia and China) have benefited from interactions with both GSN and PASSCAL.

- *A culture of "open data":* The IRIS adherence to a policy of free and unrestricted exchange of data as substantially changed the culture of data sharing within the seismological community in the US and worldwide. More than 8000 stations have now contributed data to the IRIS DMC, some formally as designated stations of the FDSN, other stations and networks through more informal agreements with IRIS. Following the 2004 Indian Ocean earthquake and tsunami, there has been a significant increase in the number of IRIS Foreign Affiliates. Each of them, as a requirement of membership, has been asked to endorse the IRIS Mission Statement and this has further increased the international commitment to open data exchange.
- *Nuclear test monitoring:* Working with the Natural Resources Defense Council, UC San Diego and the USGS, IRIS played a major role in establishing agreements with the Soviet Academy of Sciences to allow the installation of modern seismic stations, as part of the GSN, throughout the Soviet Union in the late 1980s. For the first time, seismic data were available from large parts of Eurasia that had been previously closed to foreign scientists. IRIS has continued to play an important role in calling for open release of data from international treaty monitoring networks and there is growing collaboration between the GSN and the International Monitoring System (IMS) being established by the Comprehensive Nuclear Test Ban Treaty Organization in Vienna. Of the 170 seismic stations included in the IMS, 46 GSN stations are designated as auxiliary stations.
- *Education and Outreach:* Since the formation of IRIS, the National Science Foundation has significantly increased its efforts to forge links between research and education. The IRIS E&O program is a direct response to NSF's requirement for researchers and facilities to engage in the development of educational materials and demonstrate the societal relevance of NSF-funded activities. Beyond the specific activities of the E&O Program, however, IRIS has been successful in increasing awareness among Consortium members of the value of involvement in educational endeavors, not only to satisfy NSF requirements, but also to help develop a future US student population with strengths in basic science and interests in pursuing careers in seismology and the Earth sciences.
- *International and inter-agency collaboration:* Many of the facilities established by IRIS are inherently multi-use. Global and portable seismic networks find application in earthquake and tsunami monitoring, hazard assessment, nuclear explosion monitoring, climate change studies and resource exploration and management. IRIS and the FDSN have been leaders in encouraging international collaboration in network development and data exchange, and through the GSN, US investments have contributed significantly to the development of the International Monitoring Systems for the CTBT. The linkages between US-based research and mission agencies (NSF, USGS, NOAA, DOE, DOD), that have been established during the development of IRIS facilities, serve as a relatively rare example of inter-agency collaboration in support of multi-use facilities.
- *International Development Seismology:* Many research programs using PASSCAL instruments provide scientists in developing countries with their first introduction to modern digital instrumentation. The US Principal Investigators on these projects are often interested in working with their local collaborators on these experiments to develop long-term sustainable networks for use in regional and national earthquake hazard investigations, but lack to the resources to continue interactions after the end of their NSF research grants. Experience with the Africa Array project in southern Africa has shown how a collaborative effort between research scientists, local educational institutions and mission agencies can leverage scientific investments in support of development activities. In November 2008, the IRIS Board of Directors created a Committee for International Development Seismology to explore the prospects of obtaining support from development agencies and international aid sources, to assist Consortium members in establishing programs for training, technology transfer and network operations in developing countries.

Facility Operation and Maintenance

The National Science Board's "2020 Vision for the National Science Foundation" issued in December 2005 included:

Enabling Strategy 1: NSF will provide the infrastructure, including advanced instrumentation, facilities, cyberinfrastructure, and cutting-edge experimental capabilities, which enable transformative research.

This strategy is carried into the September 2006 "National Science Foundation Strategic Plan" as an outcome goal for research infrastructure:

"Build the nation's research capability through critical investments in advanced instrumentation, facilities, cyberinfrastructure and experimental tools".

These documents reflect a growing awareness, especially in the Earth and environmental sciences, of the need for NSF to balance its support of basic research with a commitment to establish and maintain the observational and data-management tools required to stimulate and support research and exploration. At the same time, by including Learning as a key element in its Strategic Plan, NSF underscores its commitment to:

"Cultivate a world class, broadly inclusive science and engineering workforce, and expand the scientific literacy of all citizens."

Under Cooperative Agreement with NSF, the IRIS Consortium has established core facilities—the tools of seismology—that have become an essential part of the fabric of domestic and international research in seismology and the Earth sciences. Through careful planning and constant re-evaluation, these tools have evolved and grown in response to the changing needs of the research community. The IRIS facilities were established with a commitment to high-performance in quality of instrumentation, data resources and user services. IRIS continues that tradition of excellence, extending the facilities to higher resolution; establishing a pathway to an enduring, long-term commitment to global observations and preservation of data resources; and encouraging public and educational involvement in the excitement of seismological discovery.

A substantial investment has been made in IRIS facilities, in both hardware and software. Less tangible, but equally important, has been the investment in the human resources that make IRIS an effective and efficient organization. One of the most significant activities of the mature IRIS organization is the operation and maintenance of the capital investments that have been made in establishing its facilities. A significant challenge for IRIS and the seismology community in the future will be to maintain the support required to continue operation of the full facility (both *infrastructure* and *learning*) to support the exploration of new ideas essential for a healthy future of research in seismology and the Earth sciences.

With support from NSF, other US agencies and numerous national and international partners, IRIS has built a successful facility that in many ways directly realizes the vision that was articulated twenty years ago in the original IRIS proposal. IRIS, in partnership with the USGS, operates a Global Seismographic Network that in terms of geographical station distribution (at least on land) reaches the goals of the network as originally planned. Instrument acquisition for PASSCAL now meets its original goals, and in many ways the PASSCAL program has exceeded its initial expectations in terms of the services it provides in supporting a large variety of field experiments. The DMS has evolved into an archiving and data distribution center for IRIS and other seismological and geophysical data, with a capacity that far exceeds that originally planned. USArray and EarthScope have built on the resources established under the IRIS core programs and, in collaboration with UNAVCO and USGS, established a geophysical observational system for the US portion of North America that is unprecedented in density and scope.

When IRIS was established, only a half-dozen research institutions in the US could support the facilities required for cutting-edge observational seismology. The technical requirements for maintaining instruments, fielding experiments, and handling large data sets prohibited all but a fortunate few from having access to high-quality data sets and state-of-the-art instrumentation. Today, a new generation of scientists has been empowered by IRIS. Every scientist and student with a connection to the Internet now has access to data from global, regional, and local networks around the world. Any individual investigator can now propose an experiment without the burden of establishing an in-house technical capability. The past infrastructure barriers to seismology have been torn down — making our science and data available to new audiences of researchers and educators.

Consortium Structure and Governance

Structure and Roles

The IRIS governance and management structure is an interface between the scientific community, funding agencies and the programs of IRIS. The structure is designed to ensure close involvement of the research community in the development of IRIS facilities, to focus scientific talent on common objectives, to encourage broad participation, and to effectively manage IRIS programs. Community involvement in the governance and management of IRIS has been a key to the success of the Consortium. Each year, over 80 scientists from more than 50 research institutions participate in the management of IRIS through its ten regular committees, plus *ad hoc* advisory groups. These scientists work with a professional staff led by the President, Director of Planning, Director of Program Support and Special Projects, Director of USArray, Director of Finance and Administration, and four Program Managers to administer IRIS programs.

As a **consortium of research universities**, IRIS looks to its members to provide advice and direction on IRIS activities. Through on-going interactions with scientists at member institutions and through formal structures such as workshops, annual meetings, symposia and newsletters, the research community interacts with IRIS and, through the Consortium, expresses its evolving needs to funding agencies. From the enthusiasm and experience of its members, IRIS derives excitement and vision to guide the role that IRIS can play in supporting Earth science and encouraging forefront research.

As a **major facilities program** for NSF, IRIS works closely with the NSF Division of Earth Sciences to develop a program focused on the support of facilities on which NSF-funded seismological research is based. Through a series of Cooperative Agreements, NSF has provided funding with which IRIS, on behalf of the research community, operates and manages GSN, PASSCAL, DMS, E&O and USArray. Since many operational aspects of the IRIS programs are closely integrated with activities at the US Geological Survey and other federal and international programs, joint IRIS/NSF coordination with these activities is also essential to maintaining an effective program.

As a **corporation**, IRIS provides the legal and fiscal structure through which NSF can interact with IRIS for the stable operation of its facilities, and a mechanism for developing programs and bringing the wishes of it members to fruition. Through its professional staff, committees and sub-awardees, IRIS provides continuity in institutional and personnel resources for operational and developmental activities.

Consortium Membership

IRIS is a 501 (c) (3) not-for-profit corporation, incorporated under the laws of the State of Delaware in 1984. As specified in the IRIS By-Laws, educational and not-for-profit institutions chartered in the U.S., with a major commitment to research in seismology and related fields, may become Members of IRIS. Two- and four-year colleges and universities with a commitment to teaching undergraduate Earth science, including seismology, may become Educational Affiliates. Research institutions and other not-for-profit organizations both inside and outside the US engaged in seismological research and development, which do not otherwise qualify for IRIS membership, may be elected Affiliates or Foreign Affiliates. The IRIS by-laws were modified by the membership in June 2004 to transition from a structure in which all member institutions held seats on the Board of Directors to one in which the executive powers of the corporation are undertaken by a nine-member Board of Directors elected by representatives of the Member Institutions. Under this new structure, the Members Institutions retain significant powers, including revisions to the by-laws, election of the Board and calling of special meetings. The Board of Directors now meets three times per year, to receive reports of programmatic activities, guide the development of on-going programs and new activities, approve annual program plans and budgets, appoint members to supporting committees, monitor the fiscal state of the corporation, participate in the development and review of new proposals and transact other activities that require Board action. The Annual Meeting of the full Membership takes place in December during the American Geophysical Meeting in San Francisco. Consortium activities also take place at the IRIS Biennial Workshop, usually held in June, and partial travel support is provided to encourage participation by representatives from member institutions. Appendix I contains a list of the current Board of Directors, 109 Member Institutions of the Consortium, 2 U.S. Affiliates, 92 Foreign Affiliates and 17 Educational Affiliates.

Committee Structure

It is the nine-member **Board of Directors of IRIS**, acting on behalf of the Member Institutions, that serves as the major decision-making forum for IRIS. It sets goals and policies, reviews and approves program plans and budgets, appoints members to advisory committees and directs the activities of the President and staff. The Board of Directors has created three sub-committees drawn from its membership—Budget and Finance, Membership and Legal Affairs—that are responsible for coordination of key Board functions. The Board also appoints membership to the Nominations Committee to prepare a slate for the annual election. The Board appoints and receives information and advice from four Program Standing Committees, a USArray Advisory Committee, a Planning Committee and a Program Coordination Committee. Appendix I shows the organization of these committees and lists current and past membership. The **Planning Committee** develops new initiatives and coordinates IRIS activities with related programs in fields such as earthquake hazard mitigation and nuclear monitoring. The **Program Coordination Committee** integrates activities that cross-cut the individual programs and is charged with developing a coordinated program budget each year for presentation to the Board. A special **Instrumentation Committee** was recently created to report to the Coordination Committee on pan-IRIS instrumentation issues. Four separate **Standing Committees** provide detailed oversight of the four core programs: the Global Seismographic Network (GSN), the Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL), the Data Management System (DMS), and the Education and Outreach Program (E&O). A **USArray Advisory Committee** provides oversight of USArray activities. The Chairs of all Standing committees, the USArray Advisory Committee and other Board level committees participate in Board meetings on a non-voting basis. In addition, the President and the Board of Directors can appoint special advisory committees and ad hoc working groups for specific tasks. It is the role of all appointed committees to develop recommendations for the Board, which in turn, evaluates and acts upon such recommendations on behalf of the Member Institutions.

The Board of Directors meets at least three times per year to review the status of IRIS programs, to approve annual budgets and to develop long-term program directions. Each of the four Standing Committees and the USArray Advisory Committee meets twice per year to review program-specific activities and makes recommendations for improvements and future developments. The Coordination Committee meets prior to the Board's spring budget meeting to coordinate presentation of the next year's plan and budgets for approval by the Board of Directors. IRIS committee meetings are often combined with site review visits to the various program facilities, specifically: the Data Management Center in Seattle, Washington; the PASSCAL Instrument Center in Socorro, New Mexico; the GSN facility at the University of California, San Diego; the USGS partnership facility at the USGS Albuquerque Seismological Laboratory in Albuquerque, NM; and the IRIS headquarters office in Washington, DC.

One of the greatest strengths of IRIS continues to be the strong engagement of a broad sector of the scientific community in the governance and management of the Consortium and facilities. Appendix I shows the IRIS committee structure and the breadth of community involvement over the past 25 years. Membership on the Board of Directors is restricted to individuals from Consortium Member Institutions, but the Standing Committees, other committees and working groups can draw from any institution and a number of scientists from government agencies and labs participate, enriching the input to the committees and enhancing interagency collaboration. More than 200 individuals have served on IRIS committees since 1984, with more than 80 engaged in active, pro bono service each year. Tables in Appendix I show how the membership on each committee has evolved over time. While a number of committed individuals have been exemplary in their dedication through continued service over the years, often on multiple committees, there has also been an explicit effort to engage new committee members, especially younger scientists. Most members of the Board of Directors are elected after initial participation on one of the Program Standing Committees, providing them with an in-depth knowledge of the way in which the facilities are operated. The constant feedback and advice from a community of active scientists has been essential to the success and evolution of the programs and facilities operated by IRIS.

Program Planning and Review

The primary instrument for IRIS support has been a series of five-year cooperative agreements between IRIS and the National Science Foundation. These awards are based on proposals which review the current state of the facility and outline the goals for activities for the next five years. Separate 5-year awards are used to support the core programs (through EAR/I&F) and USArray/EarthScope, with other, smaller awards to support polar programs and part of the E&O activities. All IRIS proposals and annual program plans and budgets are approved by the Board of Directors, after development through a systematic process designed to distill the collective scientific interests and priorities of over 100 member research institutions.

The mode of NSF funding for the IRIS facilities—five-year Cooperative Agreements with Annual Program Plans and Budgets—has provided a level of both stability and flexibility that has allowed the facility resources to evolve in response to changing scientific needs and technical developments. For example, the PASSCAL program has continuously worked with its Standing Committee to assess the balance of different types of instrumentation (short-period vs. broadband) based on community input and the demands of an evolving portfolio of NSF funded research projects. Over the past 25 years, PASSCAL has also increased the level of professional support provided for field programs and data management, in response to requests from PI's. The GSN has been able to remain flexible in the installation of key stations, using Standing Committee recommendations on the balance of continent vs. island based stations; or borehole vs. vault installations; and responding to political opportunities and logistic challenges. The Data Management System has had to evaluate the balance between software development, user services and maintenance of the archive.

The IRIS programs have also made on-going adjustments to respond to international developments. As hardware and data procedures established by IRIS have become de facto standards, there have been increasing opportunities for international collaboration in areas such as station installation, data exchange and field experiments. In all of these areas, decisions to adjust priorities in the evolution of the facilities have been directed by the Program Standing Committees and Board of Directors, based on consideration of their scientific and technical merits.

As a special project under the NSF Major Research Equipment and Facilities (MREFC) EarthScope program, USArray, especially during the initial 5-year construction phase, was subjected to more stringent NSF project management and budgetary constraints than had been used for oversight of the I&F awards for support of the core programs. In both the implementation and management of USArray, however, efforts have been made to ensure that maximum benefit was gained from previous IRIS experience and that close integration was achieved between USArray and all core program activities where appropriate. The structure that has evolved for USArray management and community input to its development has proven to be synergistic and successful. As USArray proceed into the O&M phase for EarthScope, interactions with the core programs, especially in the areas of field support, data management and product development are expected to continue and improve.

In addition to the five-year cycle of reviews carried out as part of the NSF proposal process, the structure of IRIS management, and the organization within specific programs, have also received periodic review and evaluation by internal and external committees. For example, a review of the IRIS management structure by an ad hoc committee of former Executive Committee chairs in 1997 led to the formation of the IRIS Planning and Program Coordination Committees as a means of encouraging long-term strategic planning and interactions among programs. A competition for the IRIS Data Management Center resulted in the Center being moved from an interim location at the University of Texas to its current location at the University of Washington in 1991. A competition for the PASSCAL instrument center lead to the consolidation of the previous two centers at Stanford and Lamont to a single new location in 1998 at New Mexico Institute of Mining and Technology. The DMS Standing Committee conducted a self-study to review the DMS structure and activities and presented a strategic plan to guide the development of future DMS functions. The GSN was reviewed in 1998 when the White House Office of Science and Technology Policy appointed a special panel of the National Science and Technology Council to evaluate the GSN in the context of other global networks. A special NSF-mandated external review of the GSN in 2003 resulted in improvements in GSN operations and started a process that has now evolved to network-wide standardization of GSN equipment. Similarly, a special NSF-mandated external review of PASSCAL in 2008 endorsed the excellence of that program and made recommendations for enhancement of PASSCAL. A joint IRIS/NSF review of the E&O program is being carried out in 2009. The pervious management review of IRIS in 2004 endorsed the simplification of IRIS governance and by-laws that resulted in the nine-member Board structure described earlier. These reviews of individual programs and overall IRIS management will be complemented by an NSF Business Systems Review planned for later in 2009.

Collaborations and Partnerships

IRIS has entered into partnerships with both national and international agencies and groups whose scientific goals overlap those of IRIS. These partnerships range from formal documents and MOU's to "a handshake," illustrating the flexibility with which IRIS can act in serving and furthering its scientific programs. In addition to various modes of interaction with Consortium member institutions, some of the principal organizations with which IRIS interacts in the US include: the United States Geological Survey (USGS), the Southern California Earthquake Center (SCEC), the USGS Advanced National Seismic System (and many of the associated regional networks), UNAVCO, Inc, the Network for Earthquake Engineering Simulation (NEES), GEON, Computational Infrastructure for Geodynamics (CIG), Cooperative Institute for Deep Earth Research (CIDER), the UNIDATA program center of the University Consortium for Atmospheric Research (UCAR), the American Association of State Geologists (AASG), NASA/JPL, DOE and its labs, and AFTAC.

Among its US partners, IRIS has formed its strongest ties with the USGS. The USGS presence and stability have proven to be of great importance throughout the IRIS programs. The USGS (through it Albuquerque Seismological Laboratory, ASL) has been a partner with IRIS in the GSN since its inception. The ASL group is responsible for operation of more than 60% of the GSN stations. Under long-standing arrangements, re-confirmed in a 2002 GSN Annex to a Memorandum of Understanding between NSF and USGS, IRIS provides the capital investment for the station instrumentation at joint stations and the USGS funds the operations and maintenance. Data collection and quality control are carried out jointly with all data from the entire GSN available through the IRIS Data Management Center. There has also been close collaboration between IRIS, EarthScope and the USGS

Advanced National Seismic System (ANSS), primarily though the USGS group in Golden, CO, related to development of the ANSS Backbone (which serves as the USArray Reference Network) and data distribution. Numerous experiments involving USGS scientists, often in partnership with university PIs, have made use of PASSCAL instruments in crustal studies in the US and abroad. These have included a number of significant investigations of basin structure in urban areas in the western US related to seismic hazard evaluation. The USGS and the IRIS Education and Outreach Program have also collaborated on the development of a very successful museum display and outreach program.

EarthScope represents a significant example of the benefits of strong partnerships and collaboration in the development of a major facility program. The formation of EarthScope can be traced back to the early 1990's, when independent discussions, related to the need and opportunities for new facilities within the seismic, geodetic and fault-drilling communities, began and merged into a unified approach to NSF led by community-based organizations represented by IRIS, UNAVCO, SCEC and the San Andreas drilling team. The long road to funding, specification and implementation of EarthScope involved collaborative planning efforts between these organizations and with NSF and USGS. As with USArray and IRIS, much of the design of the Plate Boundary component of EarthScope grew from experience at UNAVCO with GPS instrumentation. The management of EarthScope construction, under the EarthScope Facility Executive Committee (EFEC), required close collaboration and sharing of technical and organizational experience between UNAVCO and IRIS and the development of the management structure of USArray was closely monitored by the IRIS Board of Directors.

In the international sphere, collaborations with many organizations have been essential to the health of the GSN as a global observing program. The map of GSN stations and the list of GSN partners in the following section indicates the scope these collaborations, many of them established through the international Federation of Digital Seismograph Networks. Each of the more than 100 GSN stations outside the US represents some level of formal international partnership developed by IRIS, USGS and UCSD. These range from large and complex agreements with China, Russia and many of the states of the former Soviet Union, to arrangements with national universities or Geological Surveys, to operating agreements with private organizations and individuals. A significant program with Japan has resulted in joint installation of stations at remote islands in the Pacific, including real-time satellite telemetry. Exchanges with the Central Asian republics of the former Soviet Union have also been fruitful and are currently being re-invigorated. Collaborative projects, many of them initiated by IRIS, have made it possible to install modern seismic stations and gather first-class data from regions of the world that were inaccessible to seismologists twenty five years ago. GSN stations play an important role in the International Monitoring System for the Comprehensive Test Ban Treaty Organization and arrangements for shared satellite communication with that organization are greatly improving the real-time access to some GSN stations. These and other partnerships provide an extremely cost-effective mechanism to operate a global facility like the GSN, and provide an avenue for US researchers to work in regions of the world that would be difficult to access. Many PASSCAL experiments have been able to build on contacts that have emerged though IRIS interactions with foreign institutions. Conversely, many of the IRIS Foreign Affiliates listed in Appendix I have resulted from interest in IRIS and its programs developed though contacts made during GSN installations or PASSCAL-supported experiments.

The IRIS Data Management System has also been a vehicle and stimulant for international collaboration, especially in the area of data exchange. Through the international Federation of Digital Seismograph Networks, many national and regional networks exchange data and contribute to the FDSN archive at the IRIS DMC. A number of national data centers have adopted IRIS-developed formats and procedures for data management, greatly facilitating data exchange. The IRIS DMS has lead an effort to develop the concept of networked data centers that is being used to share resources and data among major centers in the US, Europe, Japan and China. DMS has recently initiated a series of Metadata Workshops, held at international venues, which provide training on data management to encourage the proper documentation of modern digital data, adherence to standards and facilitate data exchange.

While these international and domestic partnerships play a significant role in efficient operation of the IRIS facilities, the stability and strength of these relationships is grounded in the role that IRIS plays as a university-based Consortium encouraging international scientific exchanges and collaboration in Earth science research.

IRIS Programs

Data Management System

The Rainbow Proposal submitted by IRIS to NSF in 1984 sought funding to develop, in parallel with the seismological equipment facilities, "Central Data Management and Distribution Facilities" to provide community access to the data collected, and a "Major Computational Facility" to support analyses of these data. The proposal stressed the development of a central node called the IRIS Data Management Center (DMC). The anticipated requirements were to manage about 500 gigabytes of new data per year and service a few hundred data requests per year. Currently, the DMC, which is located at the University of Washington, is adding over 17 terabytes of wave form data to the archive each year and servicing over 650,000 customized requests annually. Furthermore, entirely new methods of data access have evolved over the past five years as an emphasis on real time data input and distribution to researchers, along with a maturation of client server data distribution techniques that are implemented at the DMC. As new data sources, such as USArray, continue to be added to the data collection at the IRIS DMC, we anticipate increasing amounts of data to be distributed to the research community.

The fundamental goals of the initial DMS were to coordinate the routine aspects of data gathering and organization and shift these tasks to a central facility accessible to all researchers. The DMS would enable seismologists to focus on their research instead of the more mundane aspects of collecting and assembling the required data sets prior to beginning research.

Two initial studies guided the development of the IRIS DMC. "Strategies for the Design of the IRIS Data Management Center" developed for IRIS by the Science Horizons Corporation (Minster and Goff, 1986) and the TASC report (TASC, 1987) identified several guiding principles for a successful DMC.

Initially the concept of a large, self-contained DMC was pursued with the understanding that

- the task before it was formidable
- the budget for such a system would be greater than $10,000,000 per annum
- existing technologies within the reach of the university community could not manage the envisioned amount of data.

Over time, the structure of data management within IRIS has changed from the original centralized system that was envisioned to a hybrid system that takes advantage of both centralized and distributed components. While the IRIS DMC is still the largest component of the DMS, roughly one-third of the financial support of the DMS is provided to facilities and projects other than the DMC. In the case of the permanent data from the Global Seismic Network (GSN), two Data Collection Centers (DCCs) are co-located with the Network Operations facilities in San Diego and in Albuquerque. This allows technical staff familiar with the details of the recording systems and their

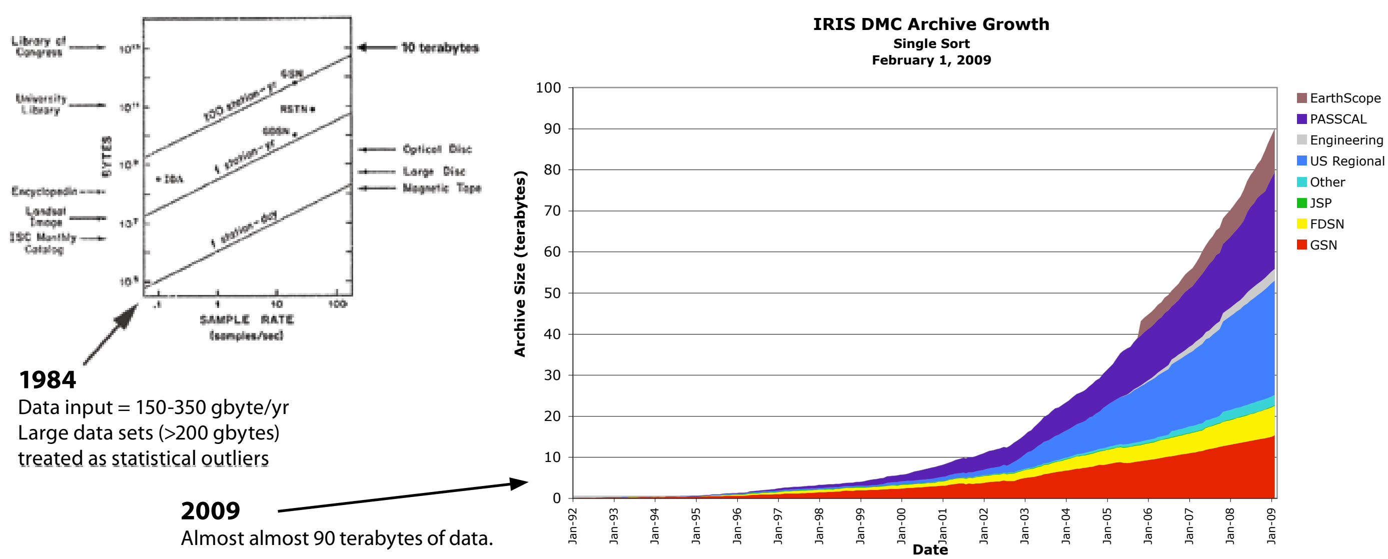


Figure 6. Data Management System—Then and Now. The 1983 report on "Effective Use of Earthquake Data" considered large data sets of more than 200 Gbytes to be "statistical outliers" beyond the capabilities of mass store systems available to the seismological research community. Today the archive at the IRIS Data Management Center contains almost 90 terabytes of data and its mass storage system has the capacity to expand as needed as the data under management grows. To insure the integrity of the data, an Active Backup system also exists providing protection to this valuable scientific resource.

installation to be readily accessible to the technicians dealing with data and metadata issues. These three centers—IRIS DMC, ASL DCC and IDA DCC—form the heart of the DMS. The capabilities of these three centers are augmented via smaller and carefully monitored activities at U.S. universities and in some cases, international data centers. Data quality assurance for data generated by the portable deployments of seismometers of the Program for Array Seismic Studies (PASSCAL) is funded directly by the IRIS PASSCAL program but strong and effective interfaces (people and computers) have been forged between the DMS and the PASSCAL programs.

An International Facility

IRIS is inherently an international organization due to the geographic distribution of seismic sensors it operates. The IRIS DMS has worked with international operators of a variety of networks to develop standardized data formats, data request methods, data distribution techniques and documentation. The IRIS DMS has supported the installation of networked data center systems in seven countries including the Netherlands, France, Italy, Germany, United Kingdom, Canada, and three locations in the United States. IRIS' involvement in the International Federation of Digital Seismographic Networks (FDSN) has resulted in data exchange with roughly 60 organizations in more than 50 countries and FDSN member countries dominate the list of countries contributing data. The DMC is the FDSN Archive for Continuous Data and as such manages data from more than 300 stations operated by FDSN partner organizations. In most instances, these data meet the standards set for data from the IRIS GSN. The DMC presently manages data from 100 permanent networks and more recently has begun receiving data from temporary experiments funded in other countries such as the UK, France, and New Zealand. The IRIS DMS is strengthening its international presence by hosting metadata workshops that assist developing networks in the understanding of modern practices in data management and data sharing. The first three metadata workshops have been hosted in 1) Africa and the Middle East, 2) Central and South America, and 3) Southeastern Asia. We will return to the Africa Middle East region in 2009 with the 4th Metadata Workshop in Cairo, Egypt to be held in November. ORFEUS, the European Data Centre, often co-sponsors these workshops with IRIS.

Many of our international partners consult with IRIS on data management and data distribution methods. Seismological networks around the world are using applications developed by the DMS to archive, distribute and quality control their seismological data. In turn IRIS takes full advantage of developments led by our FDSN partners. In cooperation with U.S. Geological Survey, the DMS has encouraged the exchange of data between other U.S.-supported networks. Most regional networks in thge U.S. now contribute data to the DMC and cooperate with the DMS in the development of new techniques for interactions between data centers.

Data Ingestion and Automated Quality Control

The primary goal of the DMS is to provide users with a complete and continuous archive of quality-controlled information (waveforms and associated metadata) from all IRIS installations (Figure 6) and from all partners contributing data to the DMC. In developing this complete archive, in the past five years the DMC has placed a very high emphasis on receiving data through real time data feeds. This is a totally different approach than the GSN data flow of 10 or even 5 years ago when most data were received after weeks at a GSN DCC, quality controlled and then forwarded to the IRIS DMC. The DMC has developed the capability to receive data in near real time using any of the major protocols in use by equipment manufacturers and seismic network operators.

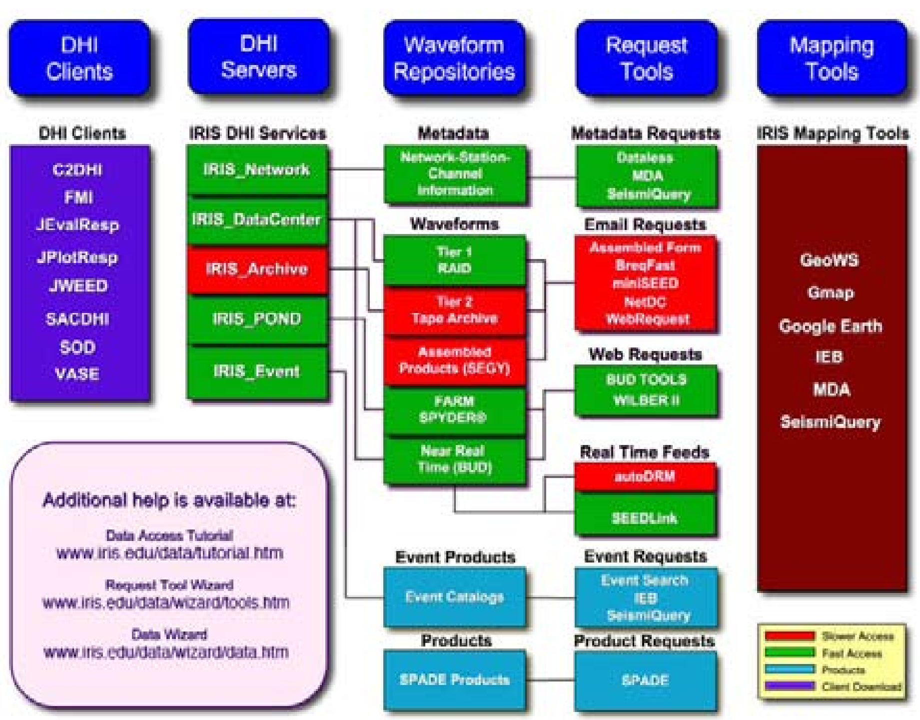


Figure 7. The chart is organized into five categories: DHI Clients, DHI Servers, Waveform Repositories, Request Tools, and Mapping Tools. Below each category are the related data resources and request tools. For example VASE is listed under DHI Clients, and IEB (IRIS Earthquake Browser) is listed under Mapping Tools. In the web version of this figure, you can click on a topic to go to the related information or request form.

With the exception of data from non-telemetered stations from temporary deployments, such as PASSCAL, more than 95% of data received by the DMC is done through the Buffer of Uniform Data (BUD) real time system developed by IRIS. Independent of the protocol used in data reception, once data are in the BUD, they are very uniform in their characteristics. On a typical day, between 1,800 and 2,000 stations are delivering data to the IRIS BUD real time system.

Waveform data entering the DMC are handled using well-established international standards for formats and metadata (SEED and miniSEED). Procedures are in place to exchange metadata information with network operators to update needed information related to station configuration. The waveforms are stored in on-line disk-based RAID systems and the metadata are managed in an Oracle Database Management System. Passive-source PASSCAL data are stored in a manner analogous to the way GSN data are archived. DMC statistics show a high percentage of data shipments that contain data from both permanent stations and temporary deployments and this attests to the effective integration of all broadband data as well as the scientific need to have data from both permanent and temporary stations in many research problems. Data that are acquired from active-source experiments are received and stored in SEGY format and distributed as special volumes of "assembled data sets." Working very closely with the PASSCAL Instrument Center, the DMC is in the early stages of a more flexible method of handling active source data as well. The DMS is working closely with PASSCAL to improve the manner in which data from active source experiments are available and we hope that in the future data requests from both passive and active source data collections can be serviced as the result of a single request. The discovery and access tools have been significantly enhanced in order to ease the task researchers have in gaining access to these valuable data sets.

Since data reaching the DMC in real time have not undergone quality control, the Quality Analysis and Control Kit (QUACK) was developed by DMC staff. QUACK is the most powerful and automated quality analysis system in operation at any seismic data center. One of the key capabilities of QUACK is its ability to generate Probability Density Functions that completely characterize a station in terms of power recorded over a broad range of frequencies. These noise characterizations can help identify station installation or operational difficulties and the PDFs are widely used by many networks. Roughly 12 other metrics are also measured by the QUACK system and a powerful query system is in place to identify problematic seismic channels. All seismic stations that have data received through the BUD real time system have QUACK quality assurance applied to them.

Data Archive

On-line Mass Storage Systems: Most data managed by the IRIS DMC are stored in a primary on-line disk RAID system and are called Tier-1 data. This RAID system was acquired in the past five years and has a capacity that can expand to meet IRIS' future storage requirements. This has allowed the DMC to increase operational efficiencies needed to support an ever-increasing number of data requests and services without adding

A Brief History of Mass Storage at the DMC

In 1988 an Interim DMC was established at the University of Texas, Austin. While at this center, the preliminary techniques for managing the data from the GSN were developed. While in Austin the DMC used the mass storage capabilities at the Center for High Performance Computing. The system developed around SUN Microsystems servers and SUN workstations, and today the DMC still is structured around high-end SUN and UNIX-based systems. In 1991 the DMC acquired its first mass storage system. A Metrum RSS-600 running AMASS software was capable of storing 6 terabytes of information. This system served the DMC very well for nearly five years. Unfortunately it was the primary storage system for six years. The technology required to read the media became nearly impossible to maintain. The DMC learned the importance of insuring that data are routinely transcribed to newer technology storage systems roughly every four years, which is consistent with practice at other major data centers such as NCAR. It is not the life of the media that proved important; it is the ability to support the recording devices that truly controls the viability of an archiving system. In 1997 the IRIS DMC acquired a StorageTek Wolf-creek robot with helical scan Redwood tape drives and capable of storing 50 terabytes of data. In 2001 the DMC upgraded its storage robot to a 6000-slot capable Powderhorn robot with T9940 tape drives. This system was capable of storing 360 terabytes of data. As the technology in tape drives evolved the DMC began transcribing data to higher capacity 9940B tape technology in 2004 and the robot's capacity grew to more than 1.2 petabyte (1×10^{15} bytes). In 2005 the price of disk storage had decreased enough that the DMC purchased an Isilon Storage Cluster that put the entire archive of Tier-1 data (most of the DMC data) on-line. In 2006 the DMC put an Active Backup system into operation at the PASSCAL Instrument Center and data were remotely backed-up onto tape. In 2009, the tape system was replaced with a RAID system. In 2009, the Active Backup system was repositioned to UNAVCO in Boulder, Colorado and this system was also transitioned to a RAID system.

operational staff. Coupled with this on-line primary archive is an Active Backup system that is also RAID based. The system is now operational in Boulder, Colorado, protecting the IRIS data collection from catastrophic failure at a single location. Having on-line access to the waveform data, allows IRIS to develop new highly automated data delivery services.

Near-line Mass Storage Systems: A few data sets managed by the DMC are very voluminous and also infrequently accessed. We call data sets such as these Tier-2 datasets. These datasets do not warrant management in expensive RAID systems and so the DMC has 2 SUN Microsystems SL-500 tape based storage systems, one in Seattle and the other at the Active Backup location to manage Tier-2 data.

Data Holdings: The DMC data holdings in 2008 came primarily from eight different sources. The IRIS GSN data holdings total 14.8 terabytes, the IRIS PASSCAL program holdings total 21.8 terabytes, regional networks within the US total 27.1 terabytes, networks from the FDSN have contributed 7.1 terabytes, EarthScope has contributed 10.1 terabytes and other data sources have contributed roughly 5.5 terabytes to the DMC archive.

As of December 2008 the archive contained roughly 89 terabytes of data. Data are only stored once in each RAID storage system with the redundancy coming from the primary archive in Seattle and the Active Backup system out of Washington State.

Enabling Technologies:

Enhancements to the WILBER System. Many seismological investigations are based on analysis of all available data from specific events (earthquakes or explosions). Once the origin information (location and time) of an event is known, automated tools can be used to extract the time windows of interest for waves arriving at any seismic station and assemble them into waveform products. At the IRIS DMC, these on-line waveform products have been called FARM (Fast Archive Recovery Method), for quality-controlled data from the archive and SPYDER® (for access to events whose data are in the near-real-time BUD system, before quality control). WILBER was a web-based tool that allowed access to event data in the FARM and SPYDER® product repositories. During the past several years, the DMC has moved the FARM and SPYDER® systems from systems that just delivered data from GSN stations to one that includes data for all seismic networks that have data managed at the DMC. The WILBER II system was enhanced to enable access to event windowed data from all networks managed at the DMC. The WILBER II system has been installed and is in operation at data centers in Europe and in China where it is the primary system used for providing access to event products. Within hours of an event, WILBER II routinely provides access to data from more than 1,000 stations. WILBER II also provides access to Seismic Record Sections, products that are routinely used by seismologists.

Enhancements in Data Distribution. During the past 5 years the DMC has improved data distribution methods in several ways;

- For traditional requests, the DMC has moved request processing to a series of inexpensive Intel-based processors. Each system can process tens of simultaneous requests for data. Taken together, the DMC can now process hundreds of traditional requests for data simultaneously.
- A major development at the DMC has been to add the ability to send data to end users in real time. Originally we supported the LISS protocol developed by the USGS/ASL. We added support for the German developed SeedLink protocol within the past five years and recently made SeedLink the only protocol supported by the IRIS DMC for real time feeds. Data can leave the DMC with almost no latency added within the DMC real time systems.
- The Data Handling Interface allows client-server access to waveforms, metadata and event catalogs. For the power user, client side tools such as SOD, jWeed, and Vase allow access to globally distributed data centers and their data collection seamlessly. USArray data users have found the DHI servers and effective way to access USArray data in sophisticated ways. DHI enabled clients can access data centers at multiple locations around the globe.

Client Side Data Applications: During the past five years the DMC has developed or sponsored the development of DHI enabled clients. SOD, jWeed, and VASE are the most frequently used clients and provide powerful and easy to use methods to access large amounts of data from the DMC data repositories.

jWeed and VASE are enabled with Web Mapping Services and presents a map of the world to help select seismic stations and/or events of interest. All interactions take place with the DHI servers operated at the IRIS DMC. SOD is a method that after configuration can continue recovering data with specified constraints into the future. Support for Google Earth displays are also now supported.

Google Maps and Google Earth: IRIS now has many applications, both client applications and web based, that display information on Google maps. In so doing users find it very easy to interact with interface. Network operators can even use these interfaces to quality check metadata validity.

Metadata Aggregator: The Metadata Aggregator or MDA is a powerful tool that allows both network operators and research scientists to dig deeper and deeper into the metadata for a given network, station, and channel. The MDA quickly shows stations that have archived data at the DMC or that have data in the BUD real time system.

SPADE: As a key element of USArray it became clear that the community is interested in the development and management of value-added products in seismology. Funded by EarthScope, the SPADE product management system has been developed and is capable of managing any product that is encapsulated within an XML wrapper. Searchable fields are embedded in the XML and the product is stored in a Product Archive. At the present time a number of products (centroid moment Tensors, ground motion vizualizations, seismic phase readings, hypocenter catalogs, and historical scanned images) are available through SPADE and the user interface continues to be developed.

IEB – IRIS Earthquake Browser: The IEB offers a new way to view earthquakes meeting a variety of user-defined constraints such as earthquake time, location, and magnitude. A Google Map interface provides a familiar user experience and allows the user to easily browse through displays of earthquakes. IEB allows hypocenters to be exported in a variety of ways, including export to the netCDF format where data can be displayed in three dimensions using a variety of tools such as GEON IDV.

WebServices, Portals and Workflows: The IRIS DMC is continually evolving the technology it supports to bring enabling technologies to the research community. The DHI provides powerful client server interactions. Coupled with tools such as SOD, jWeed and Vase, powerful interactions between users and the DMC are possible. However DHI is built upon CORBA, a technology that has fallen out of favor. The DMC is actively developing REST and SOAP/WSDL web services that promise far more flexibility and are the dominant technology used to provide services over the Internet. The IRIS DMC teamed with partners at Lamont Doherty Earth Observatory and UNAVCO to develop web-mapping services as part of the GeoWS collaboration. The DMC is teaming with Microsoft External Research to bring scientific workflow engines to our scientific discipline. Web Services are operational at the DMC and drive much of the time series information that feeds the EarthScope Data Portal. (www.earthscope.org/data) While only a few of these new services are in operation at the present time, IRIS is well positioned to extend these technologies to the research community in the next few years.

Staffing

At the beginning of 2009, the staff of the IRIS DMC numbers 23, the ASL DCC has 5 staff and the IDA DCC has 3.2 staff. Staff at the IRIS DMC and IDA DCC is fully funded from annual support from the NSF (I&F and EarthScope) to IRIS. Financial resources from the U.S. Geological Survey (USGS) are used to pay for the staff at the ASL DCC but most major equipment used in the data collection activities at the ASL DCC are funded through IRIS.

DMC staff is divided into three primary groups. The operations group consists of 11 people who are responsible for archiving data, servicing requests for data from the user community, two UNIX systems administrators and for USArray seismic analysts that review USArray data for quality. The software engineering group consists of eight people whose responsibilities include the development and maintenance of all software used within the routine operations of the DMC, development of new user access tools, and development of new methods of serving data to the research community. The software group possesses strong computing skills that include relational database management systems, object-oriented software development, and web services distributed computing techniques. The final group of four people includes the DMS Program Manager, the DMS Director of Projects, the Web-master, and the DMC Office Manager.

The IRIS DMC is considered to be the place most researchers go to obtain the data necessary to perform their seismological research. Twenty years after the formation of IRIS, most of the original goals of data management within IRIS have been met or exceeded. Data volumes exceed the earlier projections by more than an order of magnitude (Figure 6), use of the system as measured by individual requests for data exceed expectations by more than two orders of magnitude (Figure 8), and data from hundreds of recording systems are available in seconds to a few tens of minutes after real time. This was accomplished for a variety of reasons, not least among them that the seismological community retained tight control of the overall direction of the DMS and yet allowed a professional staff to take advantage of technological advances, achieving greater efficiencies than were imagined.

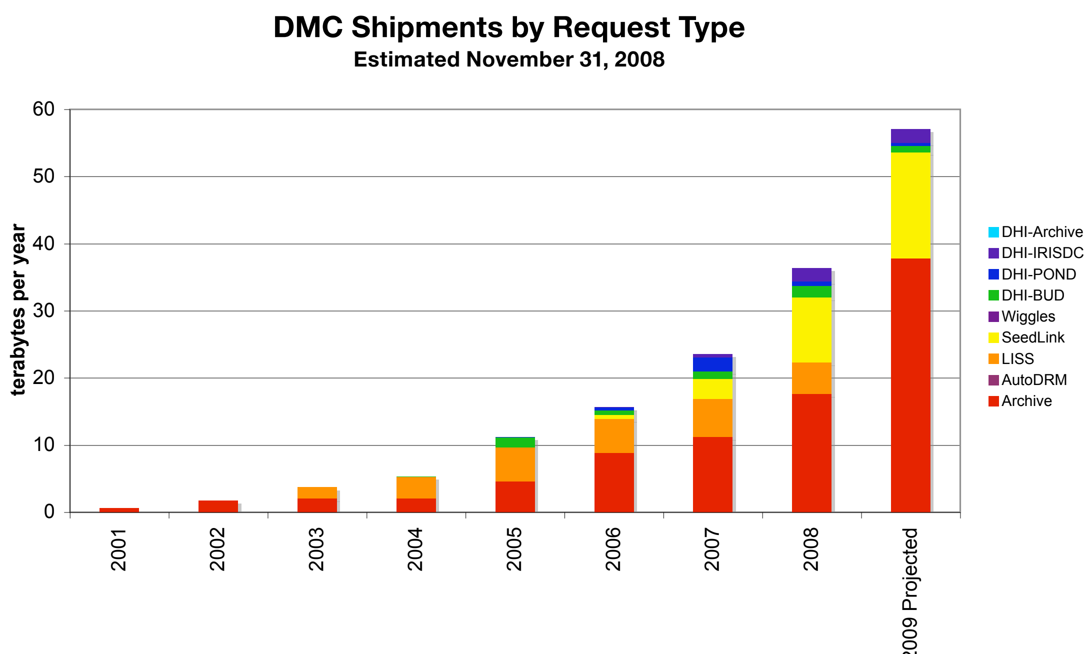


Figure 8. The best measure of data flow from the DMC to the scientific community is captured by the amount of data shipped in gigabytes. In 2009 we project that almost 60 terabytes of data will be shipped to the research community. More than half of the data shipped results from traditional request methods (red) such as Breqfast or NetDC. Approximately 1/3 of the data will be delivered by real time delivery mechanisms (orange and yellow) and DHI methods (green, blue, and purple) account for about 1/8th of the shipment volume. Roughly twice as much data leaves the DMC presently than new data reaches the DMC.

Global Seismographic Network

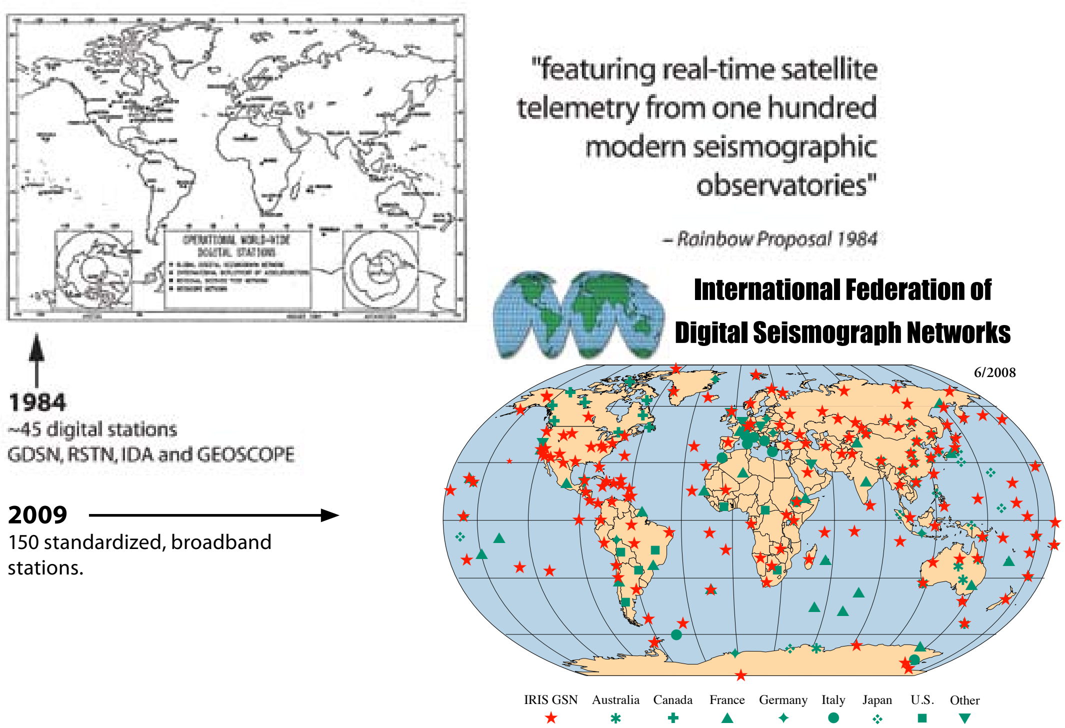
The Global Seismographic Network (GSN) is a cooperative partnership of U.S. universities and government agencies, coordinated with the international community, to install and operate a global, multi-use scientific facility as a resource for environmental monitoring, research, and education. The GSN is also a state-of-the-art digital network of scientific instrumentation and is part of a century-long tradition in seismology of global cooperation in the study of Earth. GSN instrumentation is capable of measuring and recording with high fidelity all of Earth's vibrations from high-frequency, strong ground motions near an earthquake to its slowest free oscillations. Sensors are accurately calibrated, timing is based on satellite clocks and most data are collected in real-time. The primary focus in creating the GSN has been seismology, but the infrastructure is inherently multi-use, and can be extended to other disciplines of Earth science.

The seeds of the GSN were planted in the late 1970s when modern seismometers with feedback electronics became available with very-broad bandwidth (from ~12-hour tidal periods to frequencies of tens of Hz), high-dynamic range, and linearity for recording the largest earthquake signals, and instrumental noise below the lowest natural seismic background noise. Computer costs were declining while processing speeds and recording capacities were increasing exponentially. Global telecommunications were being put in place. This strong technological foundation came at a time when the science of seismology had advanced theoretically beyond its observational capacity. The questions being posed by the science could not be answered with the limited data available. Furthermore, existing seismic stations were unevenly distributed about the planet and strongly biased in coverage—enormous areas of the oceans and large sections of continents were not instrumented at all. The southern hemisphere was particularly poorly monitored. At the same time, scientists' view of Earth as a system was coming into focus. Seismology with its unique vantage into the planet was called to image Earth's interior and provide fundamental physical data for other branches of the geosciences. Finally, the deaths of several hundred thousand people in a single earthquake in Tangshan, China in 1976 and the billions of dollars lost world wide in earthquake damage accentuated the need to understand better the dynamics of earthquakes in order to mitigate their hazards.

With the seismology community's scientific needs, and concurrent rapidly developing technologies, as a backdrop, the IRIS Consortium initiated the GSN in 1986 with funding from the National Science Foundation, and in cooperation with the U.S. Geological Survey. The GSN built upon the foundation infrastructure of the USGS's analog World Wide Standard Seismograph Network (WWSSN) and the digital Seismic Research Observatories (SRO) stations and the UCSD International Deployment of Accelerometers (IDA) stations, and extended them to create new and more uniform coverage of Earth. The GSN evolved with technological advances, and added telephone, Internet, and satellite communications with its stations toward its design goal of global real-time telemetry.

Growing slowly at first, then accelerating with funding from the nuclear verification community in anticipation of the Comprehensive Nuclear Test Ban Treaty (CTBT), the GSN is now a state-of-the-art digital network with terabytes of multi-use data from its 152 stations. In building the GSN, IRIS has extended seismology's reach into extreme environments, establishing in 2001 the QSPA station in the Quiet Sector at the South Pole, and

Figure 9. The growth of global seismic networks 1984–2008. Data from less than 40 digital stations were openly available when IRIS was formed and the global distribution was uneven. Today more than 150 standardized, broadband stations form the core of the IRIS/USGS Global Seismographic Network and its Affilates. Over 95% of the GSN is available in near-real-time. Additionally, there are many more regional and national stations available through the International Federation of Digital Seismograph Networks.



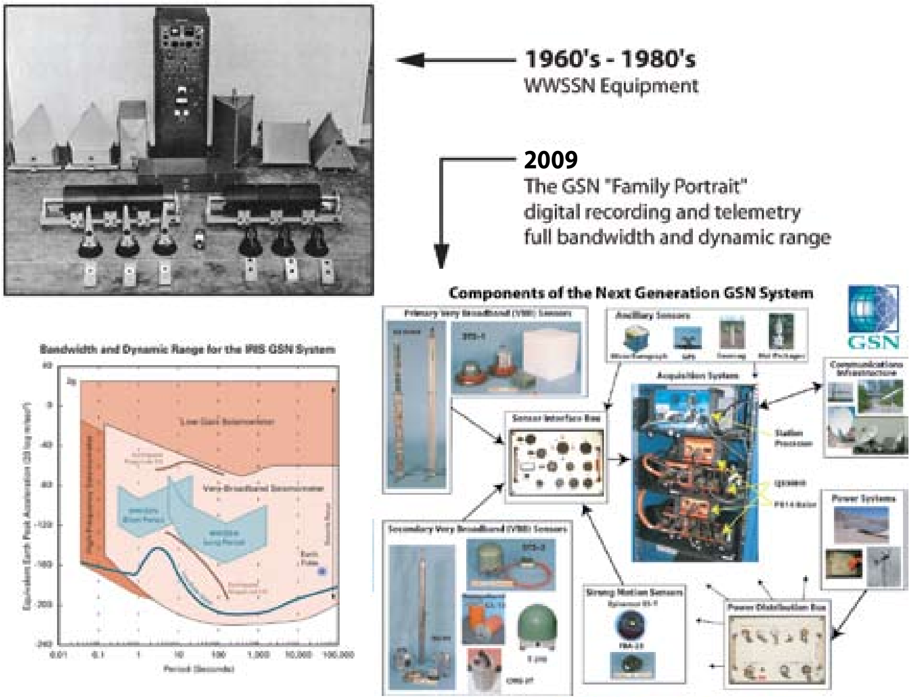


Figure 10. The evolution of seismic instrumentation from the 1960s to today. The narrow band seismometers and photographic recorders of the World Wide Standardized Seismographic Network (WWSSN) had limited dynamic range and bandwidth. Today's GSN instrumentation covers the entire range of amplitudes and frequencies required to study regional and teleseismic earthquakes.

developing and deploying between 1999–2003 the first real-time seafloor station, the Hawaii–2 Observatory, H2O.

The Great Sumatra Earthquake (Mw~9.2) in December 2004 and concomitant Indian Ocean tsunami disaster raised the prominence of the GSN. With over 88% of the network operational at the time of the event (70% in real-time), the GSN had an immediate and recognized impact not only on the science, but on global tsunami warning systems. In testimony before the U.S. Senate, February 2, 2005, on the Indian Ocean Tsunami of 2004, Arden L. Bement, Jr., Director of the National Science Foundation (NSF) said:

> *"This disaster has raised awareness of and attention to the phenomena of earthquakes and tsunamis, and their predictability. NSF has long funded scientific and engineering research infrastructure aimed at detecting and understanding the impacts of these phenomena. Prominent examples include the real-time Global Seismographic Network (GSN), the data from which forged the critical core of the early warning of the December 26, 2004, earthquake. This Network, operated by the Incorporated Research Institutions for Seismology, is funded in partnership by NSF and the United States Geological Survey, and is the primary international source of data for earthquake location and tsunami warning."*

Recording the earthquake—the largest in 40 years—on-scale with full-fidelity, the GSN created a wealth of scientific observations still being actively published today, and brought worldwide recognition of the crucial role that very-broadband instrumentation employed by GSN has for earthquake and tsunami monitoring. Furthermore, the openness of GSN real-time data has influenced international opinion on the importance of open data systems for societal benefit, which has led to a substantial increase in available international open seismic data. The GSN has served as a model in the development of national and international networks for tsunami warning since 2004, and still serves as the core global network for tsunami warning.

Over 95% of the GSN now has available real-time communication either through satellite links or the Internet. Of the satellite links, the GSN is directly responsible for twenty VSATs globally, including one VSAT in Africa and four in South America under our Houston Hub, and ten VSATs in the Pacific under our Oahu Hub in cooperation with the Pacific Tsunami Warning Center and the National Weather Service. The GSN coordinates its satellite infrastructure with ANSS at eight sites in the United States and nine in the Caribbean, and at ten sites in China with the NCDSN. The GSN has successfully developed the sharing concept with the CTBTO Global Communications Infrastructure, and coordinates with GCI in telemetry sharing at twenty-four GSN stations for primary or back-up communications. Established for seismology, the GSN infrastructure now serves as host for the world's largest microbarograph infrasound network, one of the largest global GPS networks, as well as for geomagnetic and weather sensors.

Through IRIS, the GSN is a founding member of the International Federation of Broadband Digital Seismographic Networks (FDSN), which has served to help coordinate siting of global stations among member networks and to establish an international data exchange format for seismic data (SEED). The GSN cooperates internationally through its individual relationships with 112 organizations that host GSN stations in 69 nations around the world. These cooperative efforts result in the contribution of seismic equipment, telemetry, and other in-kind support that has enhanced GSN stations above and beyond the funding from the United States.

As the GSN approached its design goal for 128 uniformly distributed stations globally, the emphasis has shifted from growth to long-term sustainability. Through increased coordination with other national and international networks, the GSN has partnered with Affiliate stations—whose data meet GSN standards and are distributed as part of the GSN, but which are funded elsewhere. This approach has created opportunities for regional expansion, such as in the Caribbean with the USGS Tsunami Warning initiative, collaboration with the Air Force in opening its US and Antarctic stations and arrays, and adding key global locations with international partners. Through growth with Affiliates, the GSN stands at 152 stations. A the same time, through its 10-station partnership with the China Digital Seismic Network, the GSN has served as a model for the growth of the 200-station Chinese National Seismic, and is engaged with China in opening these data for international sharing. In collaboration with the Geophysical Survey of the Russian Academy of Sciences, where 12 GSN stations are jointly operated with their National Network, the GSN is working to secure Russian funding for upgrading sites to new GSN standards, and in expanding Russian national coverage and open data exchange with GSN. At home in the United States, the GSN has worked both closely with the USGS Advanced National Seismic System (ANSS) and through its leadership in the Earthscope/USArray Reference Array to advance the ANSS Backbone Network, in which GSN participates with 14 stations in the conterminous US. Utilizing standard data acquisition systems and sensors with ANSS, GSN is able to achieve efficiencies in its USGS network operations.

Instrumentation

The basic GSN instrumentation design goal is to record with full fidelity all seismic signals above Earth's background noise. This has been accomplished using a combination of high-quality seismometers and data acquisition systems deployed in ways to minimize background noise. The bandwidth of the GSN system meets the diverse requirements of the scientific community, national/regional/local earthquake monitoring, tsunami warning networks, strong-ground-motion engineering community, and the International Monitoring System for the Comprehensive Nuclear Test Ban Treaty.

To achieve this full coverage, several state-of-the-art, very broadband seismometers are used in combination. Data acquisition systems (DAS) are computers with state-of-the-art analog-to-digital encoders and accurate clocks. The computer systems time-stamp the data from a GPS reference standard, provide an interface for operator functions, format data, manage the communications interface, and store all data to a local recording medium. Following a review in 2004, the GSN embarked upon a major upgrade of its data acquisition system, replacing its original DASs deployed in the 1990s with a standardized, low-power next-generation system, which meets or exceeds all scientific and seismic monitoring requirements. With guidance from the IRIS Board to standardize on a single DAS for the GSN, and with input from the IRIS Instrumentation Committee on testing and acceptance new DAS, the GSN selected the Quanterra Q330 HR data acquisition system. Through enhanced collaboration working together with IRIS management, The network operators have successfully completed the system integration of the next generation GSN field system, developing the necessary hardware (including a sensor interface box and power distribution box) and

GSN management includes a far-reaching international component of direct relationships with:

- Geophysical Survey of the Russian Academy of Sciences
- Chinese Seismological Bureau
- Geoscience Australia
- Natural Resources Canada
- University of Brazil
- Germany's GeoForschungsZentrum and Geological Survey
- Mexican National Seismic Network
- British Geological and Antarctic Surveys
- Japan Marine Science and Technology Center (JAMSTEC)
- National Research Institute for Earth Science and Disaster Prevention of Japan
- University of Tokyo Earthquake Research Institute
- France's Institut de Physique du Globe de Paris
- Dipartement Analyse et Surveillance de Environnement
- New Zealand Geological and Nuclear Sciences
- Comprehensive Test Ban Treaty Organization International Monitoring System
- Global Earth Observing System of Systems (GEOSS)
- International Federation Digital Seismographic Networks (FDSN)

National partnerships include:

- National Science Foundation (Earth, Oceans Atmospheres and Polar Programs)
- USGS (Albuquerque, Reston, Golden and Menlo Park)
- National Weather Service/NOAA
- Pacific Tsunami Warning Center
- NASA/JPL
- AFTAC
- US State Department Verication Monitoring Task Force
- UNAVCO
- Various University Partners

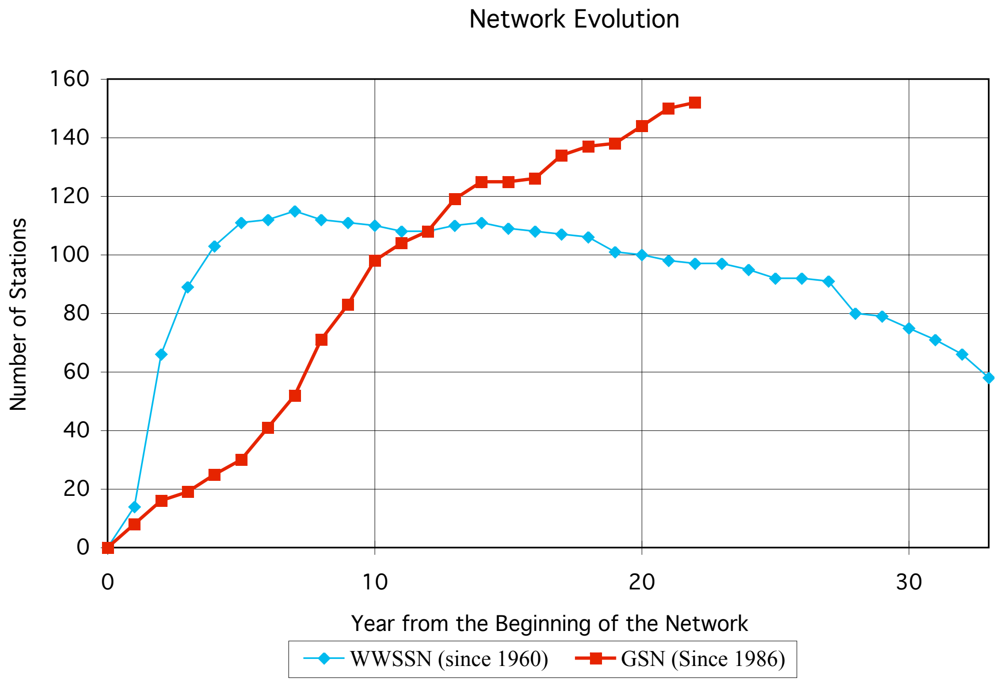


Figure 11. The growth of the GSN is compared with a predecessor network from the 1960's, World Wide Standardized Seismographic Network (WWSSN). Whereas the WWSSN faced almost immediate decline after installation, the GSN has continued to remain vital through efficient operations and maintenance practices, and by expanding collaborations with many national and international partners, including GSN Affiliates.

software (telemetry) interfaces. Real-time telemetry to a Data Collection Center is the principal mode of data transmission, backed-up with local storage for data re-request or retrieval of the physical media. These new GSN field systems are now being actively deployed throughout the network (15 sites in 2008).

GSN stations are deployed to provide uniform Earth coverage. Local noise conditions vary dramatically. Sites are chosen to achieve the best possible low-noise noise conditions, while balancing cost and logistical considerations. Many GSN stations are deployed in a split configuration where a local radio link exists between a remote seismometer/digitizer, deployed for low noise conditions, and the computer system located at a local host organization where local personnel are directly involved in the operation and maintenance of the system.

The GSN Network Operators—USGS Albuquerque Seismological Laboratory (ASL) and the UCSD Scripps Institution of Oceanography (IGPP) IRIS/IDA group—have coordinated and conducted a variety of tests in many environments to determine the best siting modes. In general, underground siting is best—getting away from wind-generated and diurnal temperature influence—if one can avoid groundwater and noisy pumps. Hard rock provides for the best coupling of the sensor to the Earth. Sediment sites tend to trap high noise into the layer, and also have spurious local resonances. Boreholes work effectively to reduce long-period (>20 sec) horizontal noise on both the continents and larger islands, and also reduce high-frequency noise (>3 Hz) though not as dramatically. However, ocean-loading effects on very small islands and atolls produces additional long-period noise that is not mitigated by a borehole deployment. Noise level in the "microseism" band from about 2 Hz to 20 sec is generated by the oceans and is not mitigated by installation depth. Here the distance from the sea is the determining factor, with the best sites being within the continental interiors.

As emphasis has shifted from installation to operations and maintenance of the GSN, increasing attention is being given to data quality. Furthermore, whereas the GSN performed exceedingly well during the Great Sumatra M9.2 Earthquake of 2004, some sensors (the borehole CMG-3TB) did not meet manufacturer stated specifications, which has refocused GSN quality assurance. Real-time data, which forms more than 95% of the GSN, undergo a detailed regime of quality-control procedures at the IRIS Data Management System, augmented by the routine, rigorous procedures by GSN Data Collection Center staff. The Waveform Quality Center at Lamont performs valuable monitoring of station calibration in its routine scientific monitoring of earthquake mechanisms and independently estimates sensor orientations. GSN operators maintain station metadata, calibrate stations and correct a variance from calibration, and work closely with data centers in assuring GSN data quality, which is internationally recognized as among the best in the world.

Geophysical Observatories

The GSN has pursued a steady course toward expanding the use of its infrastructure for broader scientific observatory measurements. Some additional sensors are specifically useful in a seismological context. The GSN operates LaCoste-Romberg gravimeters at some of its locations. Microbarographs are in the process of being deployed throughout the network to augment seismic data with acoustic wavefield data. Such pressure data are useful for monitoring atmospheric events, such as volcanic explosions, and for understanding pressure-related noise processes at the seismic station. With 55 microbarographs now deployed, the GSN is the largest global network of this kind.

With initial funding from the National Imaging and Mapping

Agency (NIMA), the GSN has served as a vehicle for establishing GPS sites co-located at twelve GSN stations in Russia. The GSN is also collaborated with JPL/UNAVCO to establish GPS at GSN stations in Gabon, Uganda, the Galapagos, the Seychelles, Madagascar, and Easter Island. Some basic surface meteorological measurements (pressure, temperature, and humidity) greatly increase GPS data's scientific usefulness. The GSN has installed meteorological sensor packages at ten Russian GPS sites and in Africa in coordination with its JPL/UNAVCO installations. These GPS+Met sites have been registered with SuomiNet, a national real-time GPS network for atmospheric research in the United States (see http://www.unidata.ucar.edu/suominet/).

Since 2004 GSN has participated as a US Observing System within the Global Earth Observing System of Systems (GEOSS), and works closely with the International Federations of Digital Seismograph Network (FDSN) in coordinating with the Group on Earth Observations (GEO), which oversees GEOSS. One of the Tasks associated with GSN/FDSN participation in GEOSS has been to "Advocate and coordinate use of GSN/FDSN as a logical framework for other GEOSS in-situ measurements." This has now been reflected in the GEO 2009-11 Workplan to "Broaden the scope of this activity to identify and build upon synergies across in-situ observing network types (e.g. seismological, GNSS, hydrological). Synergies could range from the use of the same best practices and operational approach, to the use of a common part of the infrastructure for collection and dissemination, and co-location of in-situ instruments." Working with FDSN, GSN will continue to engage GEOSS. However, the ponderous development of the GEOSS framework, which to date has largely been comprised of satellite-based systems, may still hold some promise as a means for better collaboration among in-situ oberving system.

Operations and Maintenance

The GSN's single most important task is network Operations and Maintenance (O&M). O&M is the annual investment that the seismological community must make to insure a healthy return of high-quality data from the installed base of state-of-the-art GSN stations. O&M requires people, equipment, supplies, travel and cooperation with our station hosts. Average station uptime in 2008 was 85% for the network. As the GSN has evolved from its installation phase into operations and maintenance, there is increased emphasis on standardization of equipment, improvements in data quality, and real-time data availability. GSN goals for data availability are 90% for critical real-time streams for tsunami and earthquake hazard monitoring, and 75% for all archival data for scientific research within 2 months of real-time.

O&M includes not only activities in support of the network stations, but also the flow and quality assurance of the data from the stations. The GSN has two primary Network Operators. The USGS Albuquerque Seismological Laboratory (ASL) operates 80 IRIS/USGS stations, and the University of California San Diego operates 40 IRIS/IDA stations. Additionally, 32 GSN stations are operated as part of individual University Networks or as GSN Affiliates. NSF provides O&M support for the IRIS/IDA element of the GSN, for the renovation of all GSN equipment, and for part of the recurring telemetry costs to bring GSN data to the US in real-time. The basic O&M support of the IRIS/IDA element of the GSN also includes personnel, O&M travel, station supplies, stipends, repairs and overhead.

Funding for routine O&M support of the IRIS/USGS component of the GSN by ASL is provided separately by the USGS. IRIS, NSF and USGS coordinate and cooperate in their roles and responsibilities for the GSN under the NSF-USGS Memorandum of Understanding Annex on the Global Seismographic Network (2002).

As an international enterprise, the GSN seeks international collaborations in sustaining the network. GSN has successfully engaged the Comprehensive Nuclear Test Ban Treaty Organization International Monitoring System (CTBTO/IMS) in linking designated GSN stations to the CTBTO International Data Center, receiving ancillary equipment, site infrastructure and deployment funds for sites, collaborative training exercises for GSN station operators, and access to the CTBTO global communications infrastructure for GSN telemetry. China has taken an active role in operating and maintaining its 10 joint sites with GSN within China. Russia is now engaged in providing new generation GSN equipment for the 12 joint sites with the Russian National Network. Australia is now engaged in offering for some operations and maintenance support with GSN sites in the western Pacific which are crucial to their Tsunami Warning program.

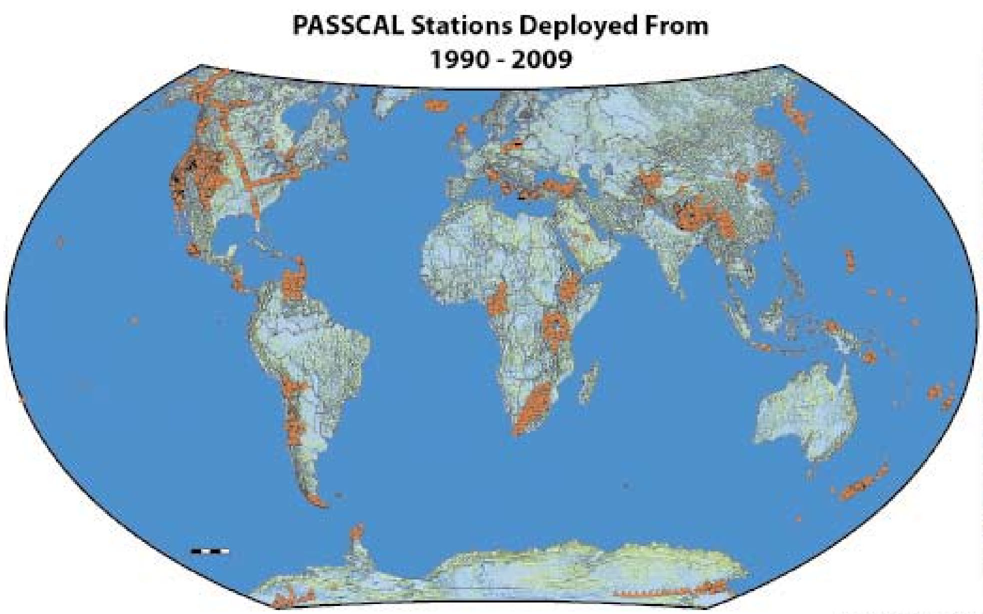
PASSCAL

Background

IRIS launched the Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL) in the mid-1980s to develop, acquire, and maintain a new generation of portable instruments for seismic studies of the crust and lithosphere. PASSCAL formed the flexible complement (the "Mobile Array" in the original Rainbow Proposal) to the permanent observatories of the Global Seismographic Network. During the first cooperative agreement between IRIS and NSF (1985-1990) the primary emphasis was on the careful specification of design goals and the development and testing of what became the initial 6-channel PASSCAL instruments. While not the direct result of PASSCAL efforts, three other technological breakthroughs in the 1985-1990 time period were critical for the success of portable array seismology: the development of a low-power portable broadband force-feedback sensor; the availability of a highly accurate GPS absolute time base; and the advent of compact high-capacity hard disks. An initial 35 seismic systems incorporating these advances were delivered in 1989 and maintained through the first PASSCAL Instrument Center at Lamont-Doherty Earth Observatory of Columbia University. During the second cooperative agreement (1990-1995), the Lamont facility, which focused on the use of broadband sensors used primarily in support of passive source experiments, grew to more than 100 instruments. Starting in 1991, a second Instrument Center was established at Stanford University to concentrate on support of a newer, 3-channel instrument designed for use in active source and rapid deployment

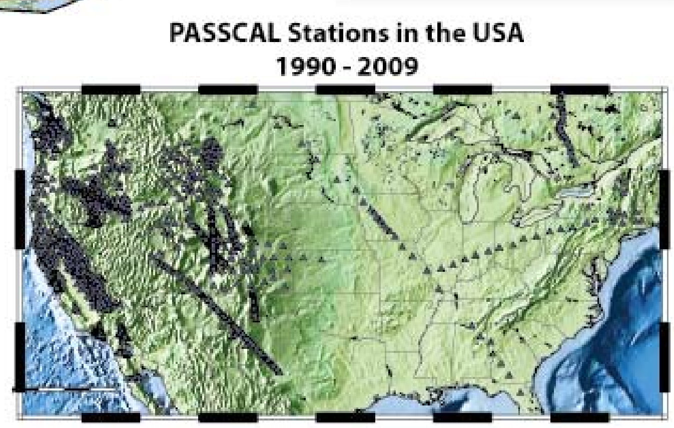
Figure 12: PASSCAL instruments have been used to support more than 800 experiments since 1989. The world map shows locations of deployments of broad-band experiments. The US map shows both broad-band deployments for passive investigations and short-period profiles for active source experiments.

> "A Mobile Array comprised of one thousand portable digital seismographs to be used for studies of the continental lithosphere"
>
> – *Rainbow Proposal 1984*



2009 PASSCAL Inventory

Broadband Sensors	450	
Intermediate Period Sensors	160	
High Frequency Sensors	630	
Active Source Recorders "Texans"	540	IRIS
	440	UTEP
Multi-channel Recording Systems	12	



earthquake aftershock experiments. By 1995, almost 300 of these instruments were available.

The core facility for support and maintenance of the PASSCAL instruments has now been established at a combined PASSCAL Instrument Center (PIC) located at New Mexico Tech in Socorro, NM. This facility, established in 1998 following proposal solicitations and exhaustive review, served to consolidate experiment-support efforts, improve efficiency, and lower the operational costs associated with previously maintaining two instrument centers. The Center is housed in a new building with 7500 sq. ft. of lab space and 15000 sq. ft. of warehouse space. The building was designed by the PASSCAL technical staff to optimize Center operations. The centralization of the facility has allowed us to provide improved services while maintaining the same number of outstanding employees even as the number of instruments and experiments grows.

The Instrument Center, which is operated under subaward from IRIS to New Mexico Tech, has a staff of 13 to support the core PASSCAL program including the Center Director, four Software Engineers, six Hardware Engineers, an Office Manager and Administrative Assistant. The IRIS PASSCAL Program Manager and Deputy Program Manager are also stationed in Socorro.

Currently, PASSCAL has a stable of more than 1422 portable, digital seismic recording systems, comprised of approximately 860 3-channel recorders, 550 small, light-weight, single-channel "Texan" instruments, eight 24 channel systems and four 60-channel reflection/refraction systems. In addition to the instruments owned by IRIS, PASSCAL provides maintenance support for 440 "Texan" instruments owned by the University of Texas-El Paso.

While one basic metric used to measure PASSCAL's progress has been the number and capability of instruments available for use in experiments, the scope of the facility extends well beyond hardware alone. Underlying the hardware pool, PASSCAL maintains an extensive support structure for instrument design, maintenance, and testing; field support; software development and documentation; and user training. PASSCAL operates as a resource for the research community, in effect serving as a "lending library" for specialized seismological equipment, but also providing technical support and user training.

Scientific Impact

Images of the Earth's interior provided by both active- and passive-source seismic experiments are of fundamental importance in the study of the structure and evolution of the solid Earth and the dynamic processes that shape it. Since the first active- and passive-source PASSCAL experiments in 1986 and 1988, respectively, the breadth of new information about Earth structure and dynamics developed through PI-driven PASSCAL experiments is astounding. In just the past 10 years, over 800 large- and small-scale PASSCAL arrays have been deployed to image many of the planet's major plate boundaries, cratons, orogenic systems, rifts, faults, and magmatic systems. Key tectonic provinces worldwide serve as natural laboratories to study a wide range of structures and processes (e.g., Himalyan collisional belt and Tibetan Plateau, Rocky Mountain Front, Andean and Cascadia subduction zones, Yellowstone, Iceland and Hawaiian hotspots, the Rio Grande, Baikal and East-African Rifts, Basin and Range Province, Canadian Cordillera, Abitibi Greenstone Belt, Tanzanian, Kaapvaal and Zimbabwe Cratons, southern Sierra Nevada, Tien Shan, Antarctic Mountains, Archean-Proterozoic Cheyenne Belt suture, etc.).

The advances made possible by PASSCAL are driven by the creativity of scientists using the PASSCAL facilities, by the technology that PASSCAL makes available, and by the flexibility of the instrument pool to foster innovative research. While we sometimes measure the success of the PASSCAL's program by the number of instruments available and the number of experiments conducted, the real measure of success of the program lies in the diversity of important science that has been accomplished. In addition to the types of studies typical of PASSCAL-supported experiments over the past decade, new opportunities exist for forging broad partnerships and interdisciplinary research collaborations.

Instrumentation

In the original 1984 Rainbow Proposal, it was estimated that about 1000 instruments with 6000 recording channels would be needed to support the experimental requirement for field programs in seismology. The size and composition of the PASSCAL inventory has evolved through a continuing reassessment of the balance between technical and scientific pressures. While standardization of equipment, data formats and operational procedures is an essential ingredient in the success of all IRIS programs, PASSCAL must handle special challenges in the trade-offs between standardization, specialization and optimization. The wide variety of experimental configurations supported by PASSCAL, and the need for performance optimization under extreme field conditions, have led to the development of a number of "standardized" field systems. On the technical side, desires to keep the equipment "state-of-the-art" are balanced by issues of reliability, portability, simplicity and cost. In a facility that provides equipment for use by operators with a wide range of technical skills and training, there are advantages in minimizing the number of different types of instruments. Nevertheless, the wide range of field conditions and scientific problems to be addressed requires an appropriate variety of instrument characteristics. On the scientific side, the PASSCAL Standing Committee, with input and oversight from other IRIS committees and staff, continually addresses the balance of resources provided to support the special needs of different sectors of the research community. The facility now encompasses a full spectrum of instruments: telemetered broadband arrays; high-resolution, multi-channel instruments; single-channel reflection/refraction instruments; and advanced short-period and broadband instruments for portable array seismology to address the range of research needs. PASSCAL systems have become de-facto standards for portable seismic instrumentation worldwide.

Multi-Channel Instruments: PASSCAL maintains twelve multi-channel recording systems. The equipment, each of which records multiple (24 to 60) channels on a single recorder, has been used very effectively for crustal imaging and a number of shallow studies of fault zones, aquifers, and hazardous-waste sites, as well as training and education in undergraduate classrooms and field labs. The number of experiments supported by this pool of instruments is now on the order of 25 per year, with many experiments utilizing multiple systems. The multi-channel equipment is intended to supplement similar systems already in the research community. In most of the major experiments, the PASSCAL equipment is augmented with similar equipment owned by the PI or the USGS.

Active-Source Experiments ("Texans"): These experiments are designed to observe artificial sources such as explosions, air guns and vibrators. The primary data requirements are for high frequency recording at high sample rates, and precision timing. The typical experimental mode is to record specific timed segments, synchronized with the timing of the artificial sources. The instruments are moved often to occupy many sites. PASSCAL's single-channel "Texan" is currently used for most active-source experiments as it is small, lightweight and easy to use. PASSCAL currently has 550 Texan instruments and supports another 440 Texan instruments in the PASSCAL instrument center through a cooperative agreement with the University of Texas, El Paso (UTEP). The UTEP-owned systems are used for PASSCAL experiments effectively in the same fashion as the IRIS instruments.

Long-Term Passive Deployments (Broadband): Much of PASSCAL's effort centers around the fielding of long-term deployments of arrays of up to 100 or more broadband stations focused on dense spatial sampling of the teleseismic, regional, and local seismic wavefield. These large, densely sampled experiments are designed by individual NSF funded investigators to target deep structure of the Earth from lithosphere to the inner core. In addition, they have been used to study earthquake-aftershocks, fault-zone-properties, and active volcanoes. The PASSCAL instruments used for passive experiments 3-channel data acquisition systems, typically coupled with intermediate-period sensors whose long-period response extends to below 30 seconds. With at least 400 broadband instruments in the field at all times, many in long-term deployments, PASSCAL is supporting a combined array approximately twice the size of the GSN. The PASSCAL data policy requires that all data be archived at the DMC (usually within months of their field collection) and made publicly available within two years of the end of the field deployment. The broadband data are archived at the DMC in a manner identical to the GSN data, so that users can make requests combining data from multiple experiments. While each deployment of the portable PASSCAL networks is targeted at a specific research experiment, the combined effect of multiple experiments around the world is to effectively provide temporary, high-resolution augmentation to the permanent coverage provided by the GSN.

RAMP (Rapid Array Mobilization Program): PASSCAL reserves ten instruments for the RAMP instrument pool to enable very rapid response for aftershock-recording following significant earthquakes. PASSCAL instruments were first used in an aftershock study at Loma Prieta, less than one month after the first instruments were delivered in 1989. The pool continues to be used for aftershock studies, but also for special short-term projects that otherwise could not get access to instruments. In the event of a significant earthquake requiring an aftershock response, all RAMP instruments are available for shipping within 24 hours.

PASSCAL Review – 2008

In 2008, an NSF-mandated review of PASSCAL assessed the impact and current state of the program. A report prepared by PASSCAL for the review (http://www.iris.edu/hq/files/publications/passcal_review.pdf)provides extensive detail on the instrumentation and services provided by the program. In its overall findings, the Review Panel stated, in part:

PASSCAL has become a model program for how to structure facilities in other areas of the geosciences for good reason. We were pleased to find that the community of Principal Investigators served by PASSCAL are productive and doing cutting-edge science despite either flat or declining budgets across the Geoscience directorate.

The application of PASSCAL equipment has expanded from its origins in imaging deep crust and lithosphere to embrace questions in climate change, environmental sciences, national security, and other important areas of societal relevance. The program has successfully achieved the goal of equal access for seismologists for mounting ambitious field programs requiring large capital investment and well-maintained field gear regardless of size of department or institution.

Early on, the program's policy of requiring that data be deposited in a central data bank where it could be publicly accessed set an example in both the national and the international community. This policy has taken the PASSCAL program far beyond "a warehouse for instruments," in that researchers with no interest in proposing field programs can benefit from legacy data sets, reprocessing them with newer methods years after their original acquisition.

Education and Outreach

Over time, IRIS members have increasingly recognized the fundamental need to communicate the results of scientific research to the public more effectively, and to attract more students to study science. To address these issues, IRIS formed the E&O Standing Committee in 1997, who then convened a conference of representatives from diverse science and science education disciplines, to develop a broad vision of how IRIS could uniquely contribute to science education and outreach. The discussions and collaborations that developed during the conference formed the basis for a program plan published in 2002 and have guided IRIS' E&O efforts since then. The E&O program began in 1998 with a single staff member, and since 2002 has grown slowly to 4.5 IRIS staff members managing a number of subcontract and consultant awards, with significant contributions from members of the IRIS community.

The mission of the IRIS E&O program is to enable the next generation of Americans to have a greater understanding of Earth science and seismology, while helping to attract the best and brightest to our discipline. The E&O program seeks to maximize the impact of its efforts by defining the bounds of its activities such that they align with the expertise and resources of the IRIS Consortium. This focus on seismology and the use and explanation of seismic data has allowed the IRIS E&O program to develop and disseminate a unique suite of programmatic offerings described below that range from those that impact large numbers of people for brief time periods to those that impact smaller numbers of people through extended interactions.

The IRIS E&O program applies several key strategies to order to effectively implement its activities. First, the program looks inward to the ranks of IRIS member institutions to enfranchise them and draw on their expertise and talents. Next, to continuously improve the products and programs offered, and to ensure the most effective use of both time and financial resources, IRIS E&O activities are evaluated via a combination of both internal and external assessments. Finally, we recognize that while IRIS can make advances in scientific education through the disciplinary depth of its contributions in seismology, an even greater impact is achieved through coordination with other organizations.

Summer Internships

Since its inception in 1998, the IRIS Undergraduate Internship Program has provided 71 undergraduate students with the opportunity to work with 40 different faculty members, and to produce research products worthy of presentation at large professional conferences. The goal of this program is to provide undergraduate students with research opportunities early in their educational careers, thus encouraging more students who represent a more diverse population to choose careers in Earth

Figure 13: IRIS summer interns work with faculty from University of Nevada, Las Vegas to collect reflection during the intern orientation week at New Mexico

science. The success of the program is shown in the 85% of alumni who have attained or are pursuing a graduate degree in a field of geoscience.

Given the distributed nature of the Consortium, the program has developed an approach that blends telecommunications and recent research on distance learning to achieve the spirit of a traditional Research Experience for Undergraduates (REU). Each summer experience begins with a one-week orientation held on the campuses of New Mexico Tech and the PASSCAL Instrument Center. The purpose of the orientation period is to develop a strong sense of community among interns, provide training in distance collaboration, and introduce the interns to some of the most exciting aspects of modern seismology. Following the orientation, interns spend 8 to 10 weeks working on a seismological research project with researchers at an IRIS member institution. Research projects may involve the deployment of seismic instruments in the field (within the US or internationally), and/or analyses of seismic data in a lab setting. Students maintain contact with each other throughout the summer via individual blogs, which also serve as a way for the interns to monitor their own progress. The culmination of each student's internship experience is the opportunity to present the results of their summer research at the Fall American Geophysical Union (AGU) meeting. Not only does attendance at AGU bring closure to the research project, it is an important opportunity for students to gain meaningful exposure to Earth science research as a viable career option.

Figure 14: The IRIS Active Earth Display.

Professional Development

Stimulating an interest in seismology requires access to high quality educational resources designed for specific educational audiences. To enable educators to use these resources, providing accurate and efficient professional development in Earth science and seismology is critical. To serve this need the E&O Program organizes a set of 1-3 day professional development experiences for middle and high school teachers, as well as for college faculty. These workshops are often held in conjunction with state, regional, or national science and science education conferences. Over 975 teachers and college faculty have attended 1-day or longer IRIS workshops and these instructors have the potential to reach over 74,000 students annually.

The E&O program seeks out venues that offer the opportunity to have an impact on minority communities. For example, IRIS E&O staff members have been collaborating with faculty from Penn State to offer professional development workshops on the campus of NC A&T (an Historically Black College or University, or HBCU) since 2006. These workshops serve two purposes: 1) to train faculty in the physics department of NC A&T to facilitate their own workshops and 2) to deliver greatly needed Earth science professional development to teachers of a local, largely African-American community. An evolving focus is to increase the impact of our professional development by reaching an audience of teachers that do not traditionally seek out such opportunities. To do this, IRIS pursues multi-year partnerships with school districts as well as other science education programs to create science professional development that is focused on generating a perceptible change in student knowledge and skill, and seeks to enhance teacher content knowledge. An initial pilot of this integrated model was completed in the spring of 2008 after a three-year partnership with the Yuma Union High School District, a primarily Hispanic-serving district located in Yuma, AZ.

Museum Displays

Museums are an important mechanism for scientific outreach to the general public, and the display of real-time seismic data offers the opportunity to capitalize on visitors' enthusiasm for current information. The IRIS/USGS museum displays have used this interest to present seismology to large numbers of the general public. The focus of the museum programs has evolved, first via a few large displays in major museums and more recently through a smaller, more flexible, and more widely distributed display. The IRIS/USGS museum displays are designed to engage many visitors for a short time and to convey the frequency and global distribution of earthquakes. The large displays have been developed as partnerships with major museums and are based on a successful traveling display originally constructed for the Franklin Institute in 1998. Annually 13 million people visit the 3 museums where we currently have major permanent displays, including the New Mexico Museum of Natural History, American Museum of Natural History, and the Smithsonian Institution National Museum of Natural History.

On the basis of demonstrated audience interest in real-time information, a need from the IRIS community to attract students at their institutions, and the evaluation results from the large displays, IRIS has recently developed a more-versatile, and less-costly Active Earth Display that is aimed at smaller formal and informal learning institutions. Displays have been installed in locations ranging from visitor centers in national parks to small museums, NSF headquarters, departmental lobbies in universities, and the South Pole Station. The content, including both real-time and longer-term information, is delivered via a web browser. This requires less support and maintenance and

Figure 15: Teachers practice setting up and operating an AS1 as part of a 2.5 day seismographs in schools training course.

allows the displays to be individually tailored to provide content and data relevant to each institution. Unlike the large displays, in most cases IRIS provides the software and content but not the hardware for the display. Twenty-four displays were in operation as of January, 2009. Content, particularly a new set of pages focusing on Cascadia, has been developed in collaboration with UNAVCO and the EarthScope National Office.

Seismographs in Schools

One of the best ways to engage students is to give them opportunities to work with real scientific instruments and data and enable them to experience the discovery of scientific information. The Seismographs in Schools program is now doing this for scores of students in physics and Earth science classes around the country. The foundational activity has been the dissemination of over 180 educational seismographs (the AS1) to classroom teachers and the development and distribution of display software written by Alan Jones (AmaSeis). These simple seismographs are capable of recording earthquakes from around the world yet cost only about $600. Their open design allows students and teachers to see the components of the instrument and understand their function. Having their own seismograph in the classroom gives students a way of collecting real-world data and making measurements that provide them with an understanding of the dynamic Earth. To ensure that the seismometers are properly installed, the IRIS E&O program annually offers a 2.5-day Educational Seismograph Operators Workshop that has been attended by a total of 120 teachers. In addition, to enable teachers to maintain the instruments for many years to come, IRIS E&O provides a range of technical support including video clips featuring "how-to's" for common tasks with both AmaSeis and the AS1. These resources along with many other sets of documentation are freely available via the recently redesigned IRIS Seismographs in Schools website. This site has a number of new or enhanced functions to help teachers make use of seismic data and communicate with other educational seismology users.

Web Resources and Interactive Software

The E&O web pages are the primary means of distributing educational and seismic data resources for consumption by both educational and general public audiences. Such resources include both timely information about recent seismological events and longer lasting information such as classroom activities and animations. For example, there were 2,190,000 visitors to the IRIS web site in 2008, with the largest percentage of these viewing the Seismic Monitor. With the growing trends toward digital mechanisms for archiving and conveying scientific information and education, IRIS E&O has continued to increase its development of resources in these areas with products ranging from training videos to seismic wave visualizations, web data viewers and school seismograph software. To handle this increase in materials, the resource area was completely reorganized when the entire IRIS website was redesigned in 2008. Interactive software includes SeisMac, which was developed in collaboration with IRIS, and which allows every Mac laptop to act as a seismograph. Waveform data is available in three mouse clicks via the Rapid Earthquake Viewer (collaboration with Univ. South Carolina and DLESE). A suite of software designed to enable or facilitate learning of core seismology concepts also supplements IRIS's web offerings. This suite was developed by Alan Jones with support from the IRIS core funding, and features three separate programs; AmaSeis, Seismic/Eruption, and Seismic Waves.

IRIS/SSA Lectureship

There is a strong demand at informal learning institutions like science museums to provide local communities with direct contact with distinguished scientists. In 2003, IRIS and the Seismological Society of America (SSA) initiated the IRIS/SSA Distinguished Lecture Series to help meet this need. Two or three speakers are selected each year for the Lectureship from a pool of nominees generated from the E&O committee and the IRIS community as a whole. Selections are based on scientists' ability to convey both the excitement and the complexities of seismology to a general audience in an engaging way. 13 IRIS/SSA Distinguished Lecturers have given over 81 presentations to public audiences of up to 400 people per lecture at major museums and universities throughout the country.

Publications

IRIS produced its first educational poster ("Exploring the Earth Using Seismology") in 1998 and continues to give out thousands of copies of that poster each year. Development of new posters has continued since then, on topics of general interest such as "History of Seismology", or related to current events such as the 2004 Sumatra earthquake and the commemoration of the 1906 San Francisco earthquake (Century of Great Earthquakes). Over 100,000 IRIS educational posters have been distributed to schools, colleges, and universities, including institutions in 22 different countries. In addition, IRIS E&O creates "one-pagers" that provide clear and concise short summaries of fundamental aspects of seismology.

Educational Affiliates

In 2001, IRIS established a new Educational Affiliate membership category for institutions that teach seismology and other Earth sciences but do not necessarily share the professional research interests of the traditional consortium members. The objective of this membership category is to cultivate a base of institutions committed to excellence in geoscience education through the co-development of E&O activities designed to address their needs. By becoming an EA member of IRIS, institutions gain entrance into a community of educators that is closely connected to the excitement and cutting-edge results of the research community. EA members pursue their common interests and goals within the IRIS community, and enjoy benefits such as discounts on seismometers and access and input to special E&O programs. The first Educational Affiliate members were accepted in 2002 and the total has grown to 17. These members are assisting IRIS in developing E&O activities to address their classroom and research needs. One of the successful programs has been the Sabbatical in Seismology where travel funds were provided to an Educational Affiliate faculty member and an undergraduate to conduct research at an IRIS institution.

IRIS E&O and EarthScope

There are two interrelated parts of the IRIS contribution to EarthScope E&O. The first has been more focused on education and is a collaborative effort among IRIS, UNAVCO, and now the EarthScope National Office. Oversight is provided by the EarthScope E&O Steering Committee, and each of the three organizations takes lead responsibility for different aspects of the program. EarthScope and IRIS activities are closely related with the structure and experience of IRIS E&O being leveraged for EarthScope E&O activities. The Active Earth Display is an example of this where the software "engine" was developed primarily via IRIS E&O funding while much of the Cascadia module was funded via EarthScope E&O. The second major E&O contribution to EarthScope is through USArray Siting Outreach, which is designed to support the construction and operation of the USArray facility. The two key elements of this effort have been the engagement of undergraduate and graduate students in the reconnaissance of Transportable Array seismograph sites, and the development and editing of onSite, a quarterly newsletter for landowners (originally shared with UNAVCO and now the responsibility of the EarthScope National Office). So far 72 students from 19 universities have identified over 670 sites in 15 western and Midwestern states.

Earth Science Literacy Initiative

Based on IRIS E&O's standing in the community, NSF asked IRIS to lead the creation of a document outlining the key concepts in Earth science that a literate public should know, building on similar successful projects in the Ocean, Atmospheric and Climate science communities. Active involvement of the research community was considered a key element of the process and Michael Wysession, as chair of the IRIS E&O Standing committee, chaired the initiative. The document outlining the Big Ideas and supporting concepts of Earth science was created via a combination of online and in-person workshops and an open community review period (http://www.earthscienceliteracy.org/).

IRIS and USArray

In 2003, IRIS, along with UNAVCO and Stanford University, was awarded MREFC funds from NSF to build EarthScope's three observatories to explore the structure and evolution of the North American continent. With the completion of the initial MREFC phase of EarthScope in September 2008, IRIS had constructed the USArray component that consists of four major elements: (1) a Reference Network of permanent seismic stations; (2) a Transportable Array (TA) of ~400 seismic stations; (3) a Flexible Array (FA) pool of seismic instruments for use by Principal Investigators; and (4) a Magnetotelluric (MT) observatory with permanent and transportable instruments. USArray also includes comprehensive data management and siting outreach efforts.

USArray, along with existing permanent regional and national networks, extends uniform coverage to the entire country allowing for a thorough and systematic seismological study of the conterminous United States. The core of USArray is the **Transportable Array**, a telemetered array of 400 broadband seismometers designed to provide real-time data from a regular grid with dense and uniform station spacing of ~70 km and an aperture of ~1400 km. The Transportable Array records local, regional, and teleseismic earthquakes providing resolution of crustal and upper mantle structure on the order of tens of kilometers and increasing the resolution of structures in the lower mantle and at the core-mantle boundary. The array is being installed from west to east and advances across the country in a roll-along fashion. After a residence time of 24 months, the station is removed and the equipment is installed at another site. Over a period of 10-12 years, the array will cover the entire continental United States and Alaska providing unprecedented 3-D imaging from ~2000 seismograph stations. While the initial focus of USArray is coverage within the United States, extensions of the array into neighboring countries and onto the continental margins in collaboration with scientists from Canada, Mexico, and the ocean sciences community are natural additions to this project.

To date, more than 700 stations have been commissioned with nearly 300 stations removed as the array moves eastward during the second phase of EarthScope funding. The array is currently covering the states of Montana, Wyoming, Colorado and New Mexico and moving into Texas, Oklahoma, Kansas, and Nebraska as equipment is removed from sites in Idaho, Utah, and Arizona. Station installation and removal rates have reached full operational levels of approximately 18 installations and 18 removals each month. Improvements to the station design have been developed and implemented, making the stations in the array more consistent and reliable. Data availability for the Transportable Array stations exceeds 90% and data quality is considered very good.

A key element in the success of the Transportable Array has been the involvement of regional networks and IRIS members in station siting and permitting, tailored to suit the partners in each region. In states with regional networks, the network operators conduct much of the siting or participate by upgrading and making existing stations available to the Transportable Array. These groups are also organizing regional efforts, such as the Central Plains EarthScope Partnership, to collaborate on EarthScope-related activities and promote public awareness.

Regional networks and IRIS members are showing strong interest in ensuring the continued operation of Transportable Array stations. In late 2007, USArray initiated a program in cooperation with NSF that permits the transfer of Transportable Array stations to regional networks and other entities. For the cost of the equipment, the new operator obtains one or more proven stations to expand an existing network or use as an educational resource. Thus far, 33 stations in Washington, Oregon, Nevada,

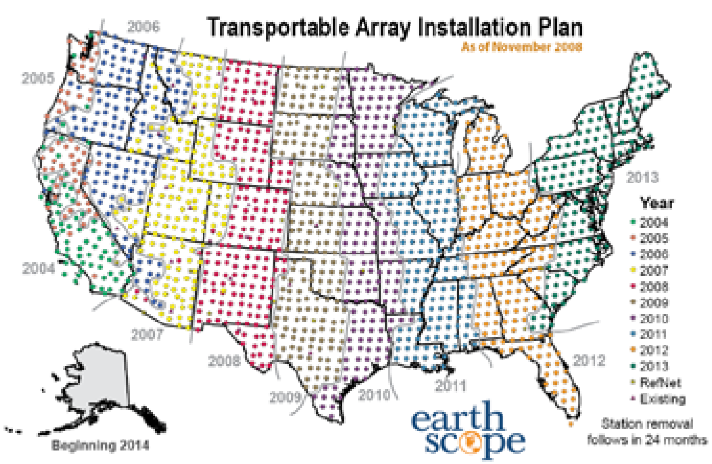


Figure 16. The map displays the current installation plan for the Transportable Array. Approximately 200 new stations are installed on the eastern edge of the array each year and approximately 200 stations on the western edge of the array are removed following a two-year period of operation.

Figure 17. The map shows universities that have provided student teams to identify sites for future Transportable Array stations.

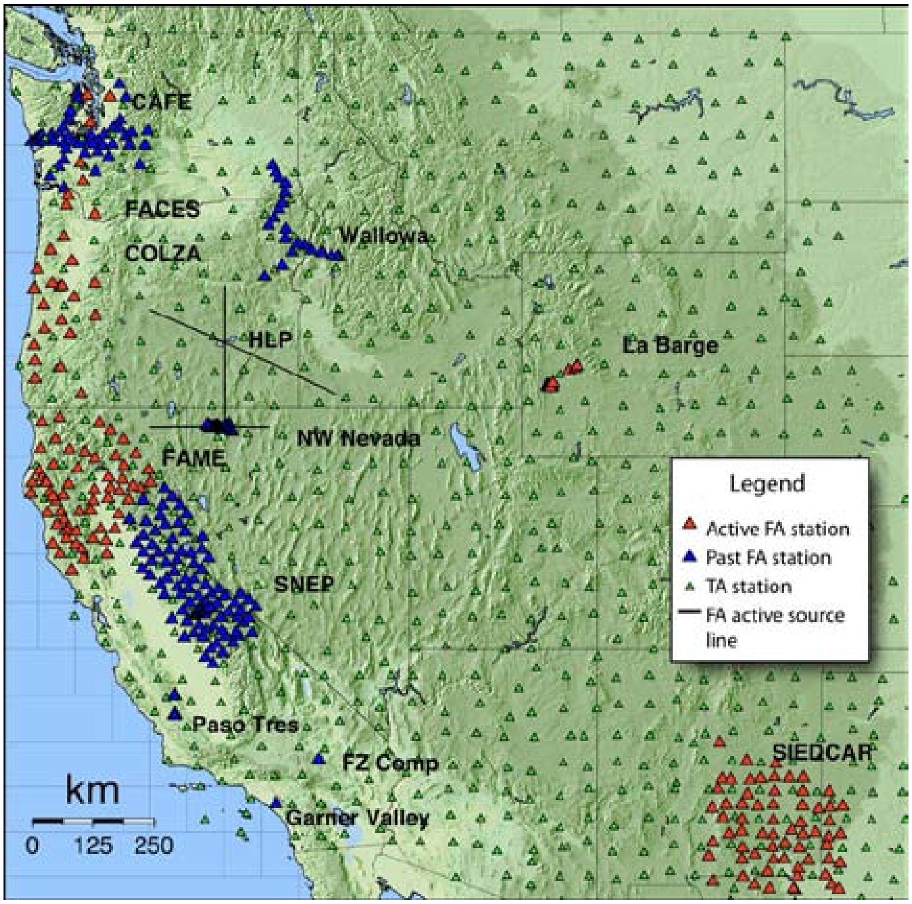


Figure 18. A map of the Flexible Array experiments conducted in the western US, 2003 to 2008. Broadband, short period, and active source instruments are available for these PI-driven experiments.

Idaho and Utah have been 'adopted' and similar efforts in other states are advancing.

USArray has also actively engaged students who will become the next generation of Earth scientists. The station siting process for the Transportable Array provides undergraduate and graduate students an opportunity to participate in EarthScope by identifying candidate sites for future stations. Following a multi-day training workshop that includes a review of criteria for a good seismic station and the use of various electronic equipment and specialized software applications, the two-person student teams spend the next nine weeks finding candidate sites, conducting field investigations, and preparing reports documenting their recommendations. During the summer 2008, 326 sites in North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas were identified by 32 students. Since inception in 2005, nearly 675 Transportable Array sites in 14 states have been identified by approximately 70 students from more than 18 universities.

As a complement to the Transportable Array, USArray's **Flexible Array** includes a pool of 2111 portable instruments. Consisting of a mix of broadband, short period, and high frequency sensors, these instruments can be deployed using flexible source-receiver geometries and permit high-density, shorter-term observations, using both natural and explosive sources. Designed for key geological targets within the footprint of the Transportable Array, the Flexible Array is being deployed to investigate the depth extent of faults, magma chamber dimensions beneath active volcanoes, the relation between crustal tectonic provinces and mantle structure, the shape of terrane boundaries, the deep structure of sedimentary basins and mountain belts, and the structure and magmatic plumbing of continental rifts. Linked with coordinated geological, geochemical, and geodetic studies through the broader EarthScope initiative, this USArray component addresses a wide range of problems in continental geodynamics, tectonics, and earthquake processes. Over the last five years, 18 PI-driven experiments have utilized the Flexible Array and demand for these instruments is increasing.

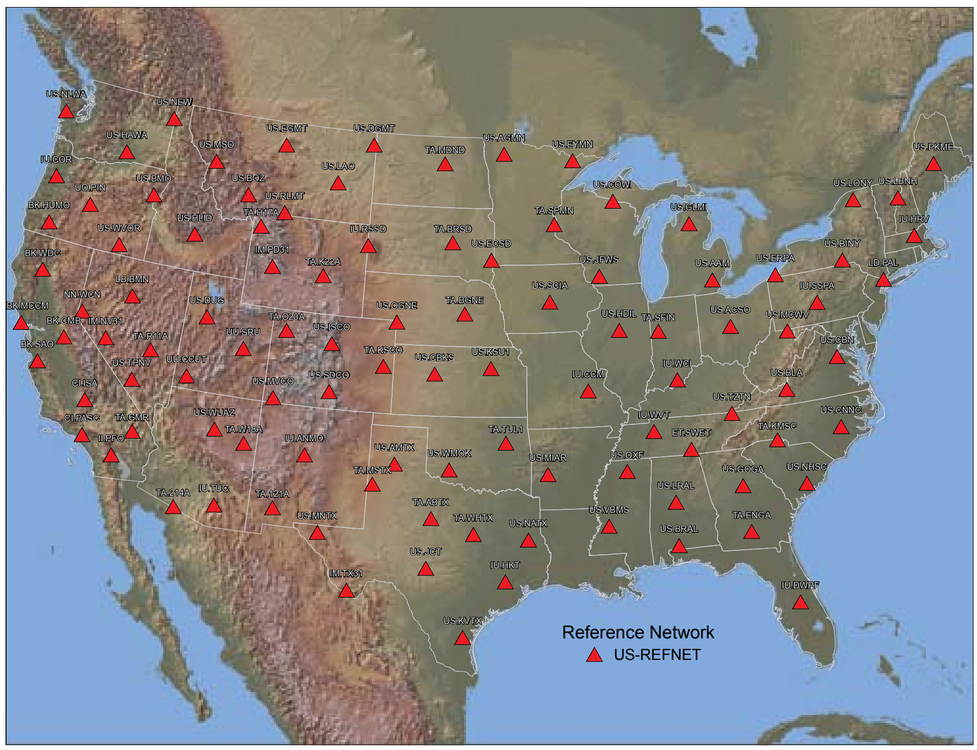
A third element of USArray is the development of a **Reference Network** through augmentation of permanent stations of the USGS Advanced National Seismic System (ANSS) and the IRIS/USGS Global Seismographic Network (GSN) and the establishment of long-term installations at Transportable Array sites in areas of non-uniform coverage. With uniform spacing of 300-350 km, this network is important for tomographic imaging of deep Earth structure, providing a platform for continuous long-term observations, and establishing fixed reference points for calibration of the Transportable Array. These stations, now being operated by the USGS as part of the ANSS Backbone, were completed in 2006. In the last several months, the Transportable Array has installed an additional 20 stations throughout the central and eastern US to complete the Reference Network.

The **Magnetotelluric** facility of USArray consists of both permanent and temporary stations across the contiguous United States. An MT station, whether permanent or portable, consists of two sets of grounded electrical field measurement lines and a ring-core magnetometer. The instruments measure the natural electric and magnetic fields at the Earth's surface that are caused by electromagnetic waves radiated from the sun and from distant electrical storms. MT observations are used to constrain the electrical conductivity of the Earth's lithosphere and asthenosphere, complement the seismic tomography images of the structure beneath North America and, in some cases, provide constraints that are difficult to obtain from seismic data.

The permanent MT network, completed in September 2008, provides a fixed frame of reference and consists of seven stations in selected locations across the US. The MT temporary or transportable array is a set of portable sensors that are deployed each summer over a specific target area. The MT Transportable Array has already occupied 170 sites in the Pacific Northwest (30 sites in 2006, 80 sites in 2007) and in the southern Idaho-northern Utah region (60 sites in 2008) using a grid-like deployment with approximately 70 km spacing.

The successful implementation and execution of USArray is aided greatly by the existence and vitality of the IRIS core programs. The PASSCAL program has a long record of managing and servicing portable instrumentation, and the PASSCAL facility in Socorro and its association with the broadband array program at the University of California, San Diego serves as the key operational base for executing the Transportable and Fexible components of USArray. The USArray contributions to the ANSS Backbone Network were implemented as a natural extension of the collaboration between IRIS and the USGS in operation of the GSN. Equally important, the IRIS DMS program is able to distribute effectively and economically very large amounts of data to the seismological and geophysical community Similarly, the significant educational opportunities presented by USArray are being efficiently capitalized on through the IRIS Education and Outreach program.

Figure 19. The Reference Network for USArray is comprised of stations in the USGS ANSS Backbone, USArray Permanent Array, Advance Deployed Transportable Array Stations, GSN, IMS, and Regional Networks. The network is operated in collaboration with the USGS.



Program Management and Corporate Structure

Management Structure

IRIS management is based on linked operational structures for the five, semi-autonomous programs—the Global Seismographic Network, the PASSCAL program for portable instrumentation, the Data Management System, Education and Outreach, and USArray. The central administrative and business functions are carried out through a Headquarters Office in Washington, DC. As described below and shown in Figure 15, the programs are managed through offices or subawards linked to each of the operational centers for the programs. Overall management is under the direction of a full-time President, appointed by the Board of Directors. Senior staff consists of:

- David Simpson, President
- Ray Willemann, Director of Planning
- Tim Ahern, DMS Program Manager
- Rhett Butler, GSN Program Manager
- Jim Fowler, PASSCAL Program Manager
- John Taber, E&O Program Manager
- Bob Woodward, USArray Director
- Candy Shin, Director of Finance and Administration
- Rob Woolley, Director of Program Support and Special Projects
- Kent Anderson, GSN Operations Manager
- Marcos Alvarez, PASSCAL Deputy Program Manager
- Bob Busby, Transportable Array Manager

Although each of the core programs has a standardized management and oversight structure consisting of a Program Manager and Standing Committee, each program operates through a combination of direct employees, subawards, and partnerships. As indicated in Figure 20 the facilities programs each have their own unique structure, optimized for their particular circumstances.

USArray has a parallel management and oversight structure consisting of a Director and Advisory Committee. USArray has elements that are very similar to those of the core programs. Each of the core programs has been expanded to support its respective element of USArray. The Permanent Array was implemented by GSN, the Flexible Array by PASSCAL, Data Management by the DMS and Siting Outreach by E&O. This is the most efficient and effective way to take advantage of IRIS expertise in implementing USArray. Two unique elements of USArray, the Transportable Array and Magnetotellurics, have their own separate management structure.

Full-time staff devoted to IRIS activities are located at the Data Management Center in Seattle; the PASSCAL Instrument Center in Socorro; the IDA and Array Network Facility groups at UC San Diego and IRIS Headquarters in Washington DC (see Appendix V). There are approximately 122 full-time scientists and technicians involved in the operation of IRIS facilities and IRIS-related programs - 51 full-time employees on IRIS payroll, and an additional 71 supported full time through major IRIS subawards. Partial support is also provided through subawards for important IRIS-related programs at the University of Washington (as host for the DMC) and the University of Texas, El Paso (for support of Texan instruments). IRIS subawards to Harvard and Columbia Universities (for GSN data quality review) and the Moscow Data Center (for communications services and software support in Russia) were recently terminated and support for these activities is covered directly by NSF (for GSN quality review) and the Russian government (for communications and software). The USGS facility in Albuquerque, NM provides significant dedicated support for the GSN, but is separately funded by the USGS.

The **Global Seismographic Network** operates through subawards and partnership agreements. Approximately 30% of the GSN is operated through a subaward with the University of California, San Diego. This subaward provides for equipment acquisition, installation, operation and maintenance and data collection for the IRIS/IDA component of the GSN. The IDA staff includes 8 FTEs for GSN station operations and associated data-collection activities.

Another 65% of the network is operated through a Memorandum of Understanding with the US Geological Survey's Albuquerque Seismological Laboratory in Albuquerque, New

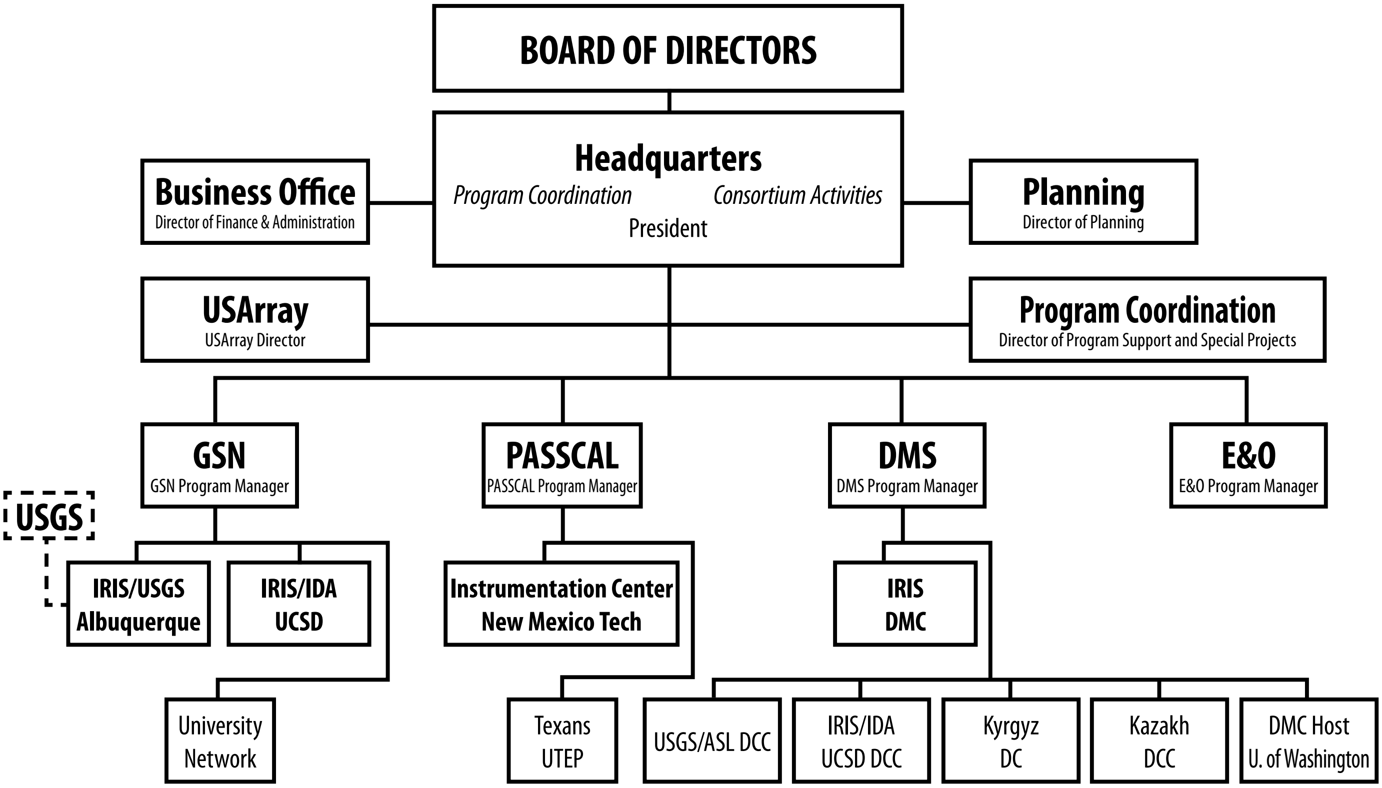


Figure 20: Structure of IRIS operations.

Mexico. The remaining 5% of the network is operated through a suite of partnership agreements with individual universities that host GSN stations and provide operational support for those stations. NSF retains title to all permanent equipment for the GSN; an inventory of over $12M of GSN equipment is maintained by IRIS.

Since 1998, the USGS has provided funding for the operation and maintenance of their component of the GSN through a special line item in the Department of Interior budget for GSN operations. IRIS continues to provide support to the USGS for installation of new equipment. From 1988 to 1996, Congress provided a total of more than $60M to IRIS for support of the GSN, first as part of a Joint Seismic Program with the Soviet Academy of Sciences to install GSN stations and arrays in the Soviet Union, and then as part of a program to further capitalize the GSN for multi-purpose applications including contributions to nuclear monitoring. Funds for these activities were provided by Congress through the Department of Defense budget and transferred via interagency agreement to NSF for inclusion in the IRIS Cooperative Agreement.

The development of the GSN has benefited from other cost-sharing arrangements as well. An agreement with the Japanese government has provided equipment and communication links for remote island stations in the Pacific. The Pacific Tsunami Warning Center through NOAA supports part of the communications costs for key stations in the Pacific. The GSN has developed the concept of sharing telemetry with the International Monitoring System for the Comprehensive Nuclear Test Ban Treaty to support communications from GSN stations that are part of the IMS.

In collaboration with the USGS, 39 stations of the ANSS Backbone were either installed or upgraded as the USArray Permanent Array, completed in September 2006. Due to their similarity to GSN stations, this USArray activity was conducted by ASL. Title to equipment and operational responsibility for these stations has now been transferred to the USGS.

The **PASSCAL** program operates principally through subawards from IRIS to the New Mexico Institute of Mining and Technology (NMT) for core PASSCAL and USArray support. These subawards provide support for a staff of 30 NMT employees to operate the PASSCAL Instrument Center in a special office, lab and warehouse facility provided by NMT and constructed in 1998 with funds from the New Mexico state government. The Instrument Center is responsible for the acquisition, assembly and maintenance of all PASSCAL instruments and for training and experiment support for PASSCAL users. Equipment is allocated to users according to a priority system based on funding source and schedule constraints. Scientists work with the Instrument Center to specify and schedule the equipment needed for each experiment. The Instrument Center prepares equipment for shipment to the experiment site and the PI is then responsible for installation, operation, data archive, and return of the equipment at the end of the experiment. At the request of the PI and availability of PI's, PASSCAL will provide technical assistance in the field for initial set-up of equipment and also help with data collection, quality control and archiving.

All permanent equipment for PASSCAL is purchased directly by IRIS with inventory maintained by IRIS. The PASSCAL program includes an award to the University of Texas, El Paso to support maintenance of a pool of 440 UTEP-owned Texan recorders that are made available for use in PASSCAL experiments.

The USArray Flexible Array expanded the portable instrument pool available for experiments by some 2100 systems. These systems are based on the designs developed by PASSCAL. The PASSCAL Instrument Center (PIC) was expanded by New Mexico Tech to house the Array Operations Facility that supports the Flexible Array and Transportable Array. The Transportable Array component of USArray utilizes some of the resources of Array Operations Facility for instrument acquisition and testing and maintains a separate Transportable Array Coordination Office (TACO) at the PIC for special activities related to permitting and coordination of field programs. The construction and installation activities for the Transportable Array are carried out by separately managed contract awards, under the direction of the Transportable Array Manager.

The PASSCAL program has recently acquired a separate pool of instruments designed for extreme Polar regions. Support for these instruments was made available from the NSF's office of Polar Programs. This is a pool of 40 "cold hardened" stations with specialized electronics, power and communications systems made available to OPP funded experiments.

The **Data Management System** operates through a combined structure of IRIS employees, subawards and partnerships. The Data Management Center, housed in private office space near the University of Washington campus in Seattle, is an IRIS-staffed facility and the primary operational node of the DMS. The mass store system and associated computer facilities are located there, along with a staff of 24 IRIS employees for software development, maintenance of the data archive and user support services. The data-request mechanisms developed by the DMS have emphasized automated procedures to minimize the amount of human intervention required to service data requests. Staff are available, however to provide advice and support to users and assist in producing customized requests. The DMS also provides training to US and international groups on topics related to data management and the use of IRIS-developed database systems. Data collection and quality-control functions for GSN data are preformed under DMS direction through a partnership with the US Geological Survey and through a subaward to the IDA group at the University of California, San Diego. Additional DMS subawards include: the University of Washington as host of the DMC and a data collection center in Kazakhstan.

The DMS grew to accommodate the additional demands of EarthScope. The DMS expanded storage capacity, added new servers, an active offsite backup for all data, and staff to accommodate the added capacity and demands of EarthScope. All USArray data have been incorporated within existing DMS data collection and distribution structures to ensure seamless user access to data. Extensions to the DMS structures have been incorporated into an EarthScope data portal to provide unified access to all EarthScope data.

The **Education & Outreach Program** (E&O) was established in 1998 and is managed out of the IRIS offices in Washington DC. E&O staff includes a Program Manger, Education Specialist, two E&O Specialists, and partial FTE support for a Software Engineer, Web Developer and Media Consultant. E&O activities include the development of print and web-based educational materials; support of the museum program; the Seismographs in Schools Program, organization of teacher training workshops; and the scheduling of the summer intern and lecturer programs. The E&O program has managed a series of small sub-awards to IRIS institutions and consultant agreements for the development of seismogram displays and educational materials and assistance in the Seismographs in Schools program.

EarthScope and USArray have heavily leveraged the IRIS E&O program for providing general outreach and educational materials and for special tasks related to the siting of Transportable Array (TA) stations. A special EarthScope newsletter "OnSite" was initially developed to provide information for private landowners and other hosts for EarthScope sites. A very successful program for identifying potential USArray sites has been developed under which university student teams, trained by E&O and TA staff, select potential sites, meet with landowners to explain the goals of EarthScope and pass on information to professional staff at the Transportable Array Coordinating Office for final permitting. E&O has also been involved with other EarthScope outreach personnel in developing museum displays and other information vehicles for explaining EarthScope science to the public.

Senior Management at **IRIS Headquarters** consists of the President, Director of Planning, USArray Director, Director of Program Support and Special Projects, and Director of Finance and Administration. In addition to direct oversight of the IRIS programs and Consortium activities, the President serves as the primary point of contact between IRIS and NSF and with the IRIS Board of Directors. The Director of Planning works with the Planning Committee to explore new program and funding initiatives and improve the visibility of the IRIS program with the public, member institutions, government agencies, and Congress. The USArray Director manages the implementation of USArray and maximizes the benefit of this facility to the scientific community. The Director of Program Support and Special Projects works with the Program Coordination Committee and Program Managers to strengthen interactions among the programs and develop cross-program initiatives. He is also responsible for coordination of IRIS human resource services, oversees publications and web-based services and undertakes special projects of a short-term nature to assist in program management. Headquarters staff is also responsible for organization of meetings, workshops, publications, human resources, information technology and other Consortium activities.

The **IRIS Business Office** is responsible for accounting and financial reporting, contracts and awards, procurement, inventory, insurance, and general office assistance. The goals of the business office are to implement good business practices in all areas such that:

- Business operations are effective and efficient.
- Activities are in compliance with applicable laws, regulations, award terms and conditions, and internal policies and procedures.
- Program personnel receive the appropriate support for their programs.
- Organizational assets are protected.

The business office staff includes:

- Director of Finance & Administration – plans, organizes and directs the functions of the business office, and reports to the President.
- Business Projects Managers (2) – assist in proposal submissions, oversee award compliance and reporting requirements, prepare and analyze budgets, administer subawards and other agreements.
- Accounting Manager – supervises accounting functions to ensure accurate and reliable data necessary for business operations.
- Staff Accounting (A/P) – processes invoices for payment and maintains invoice files.
- Staff Accounting (Purchasing) – carries out procurement functions and places orders for goods and services.
- Sr. Staff Accountant (A/R) – records accounts receivable, processes billings, and assists human resources.

Funding and Budget Process

The primary source of IRIS funding since its inception has been the National Science Foundation under five-year Cooperative Agreements, which charge IRIS with "establishing, operating, maintaining, and managing the IRIS core programs…," with statements of work that are developed by the NSF Program Officer, in consultation with IRIS, based on the tasks identified in the five-year proposal submissions. The Statement of Work from the current Cooperative Agreement is shown in Appendix VI.

In addition to funding from the NSF Earth Sciences Division, Instrumentation and Facilities Program (EAR/IF), IRIS receives significant awards under NSF's EarthScope Program to build and operate USArray and from NSF GEO/EAR as an REU (Research Experience for Undergraduates) award for support of the E&O Insternship program. NSF allows supplements from other NSF programs, other Federal agencies, or other funds, to be provided through amendments to the Cooperative Agreement, up to a maximum approved by the National Science Board. NSF's Polar Programs has funded IRIS through this mechanism for the past three years. IRIS has also received external funding from a variety of public and private sources, including the Department of Defense, Department of Energy, National Imagery and Mapping Agency, the Comprehensive Nuclear-Test-Ban Treaty Organization, the Keck Foundation, the W. Alton Jones Foundation, and Japanese organizations.

IRIS maintains a separate account of unrestricted funds, built from membership fees, investments and management fees. These monies are used for expenses that are not or cannot be supported by a Federal award. The Board of Directors appoints a three-member Budget & Finance Committee to work with the Director of Finance and Administration and take responsibility for receiving and reviewing monthly budget reports, for oversight of the unrestricted funds, and to initially receive the auditor's reports. The committee identifies and communicates issues in these areas to the Board of Directors for further action when needed.

The funding history for IRIS is shown in Figures 16 and 17. Figure 16 shows the funding source and Figure 17 shows the allocation to individual IRIS programs. The bulk of IRIS core support has come from the Earth Sciences Division, Instrumentation and Facilities Program and, starting in 2003, from EarthScope, but additional funds have been provided under smaller awards through the Cooperative Agreement via interagency transfer from other federal agencies; limited funds have come from private sources. Two significant enhancements to the IRIS programs have come from special Congressional appropriations through the Department of Defense (1988-1996, for support of a joint program with the Soviet Academy of Science and for multi-use application of the GSN including nuclear monitoring) and the Department of Energy (2001-2004, for replacement of PASSCAL data loggers).

Under the Cooperative Agreement with NSF, IRIS is required to submit to NSF an annual Program Plan and Budget, which summarizes the activities over the past year, outlines the program for the year ahead and presents the budget request for the following year. These annual reports are not proposals (which are submitted every five years) but progress reports to the NSF Program Manager and form the basis for annual funding increments. The details of the annual plan and budget are not constrained by the original proposal, but are expected to follow the general plan presented in the proposal and the nominal levels of annual funding increments specified in the Cooperative Agreement.

Typically in January, based on funding targets and guidelines received from NSF, the IRIS Board of Directors meets to set overall policy goals and recommend the balance among programs for the next fiscal year, which begins on July 1. In the early spring, IRIS Standing Committees meet to develop detailed program plans and budgets, review work statements and proposals for subawards, and identify material for the Program Plan and Budget. After the Standing Committee meetings, the IRIS Coordination Committee (CoCom) reviews and reconciles differences between program budgets, develops options for an overall budget plan for presentation to the Board, and prepares an outline for the Program Plan and Budget. In the late spring, the Board meets again to review or modify the overall funding structure, and approves final budgets for the year. IRIS staff then prepares the Program Plan and Budget for submission to NSF based on the guidance from the Board. The new fiscal year for IRIS, and the usual budget year for the core programs, begins July 1. Throughout the year, Program Managers receive monthly budget reports that show variances between budgeted and actual costs. During the early fall, after the accounting books are reviewed and closed and the annual A-1331 audit has been completed, final account balances are reported and programs identify any funds that were not expended as of June 30. These unspent funds are either associated with:

- approved tasks that have not yet been completed;
- tasks that have been dropped; or
- tasks that cost less than budgeted.

The CoCom meets again in the fall and reviews the prior year unspent funds, if any, and makes adjustments to budgets or activities, with recommendations for Board approval.

Overlain upon the IRIS management structure and budget process is the management oversight provided by the National Science Foundation. The Annual Program Plan and Budget, as proposed through the Board of Directors and approved by the NSF Program Officer, forms the basis for each year's program activities. The Cooperative Agreement sets thresholds under which IRIS can make internal changes in budget allocations and provides mechanisms by which requests for more significant changes in the plan can be presented to NSF for approval. The ongoing interaction among the NSF Program Officer, IRIS management and the community representatives on IRIS committees, coupled with the flexible structure of the Cooperative Agreement, has proven to be effective in allowing IRIS to establish and develop its core facilities in response to the evolving needs of the university research community.

The EarthScope annual budget follows a slightly different fiscal year than that for the core programs. Under the Major Research Equipment and Facilities Construction funding that was the major source of EarthScope support through 2008, budgets and annual plans were proscribed by levels and tasks set external to the IRIS governance structure. With the transition to EarthScope O&M funding in 2009, there is more flexibility in the planning and budgeting for USArray and these activities, while still closely monitored by the NSF EarthScope program, are being integrated within the budget process used for the IRIS core programs.

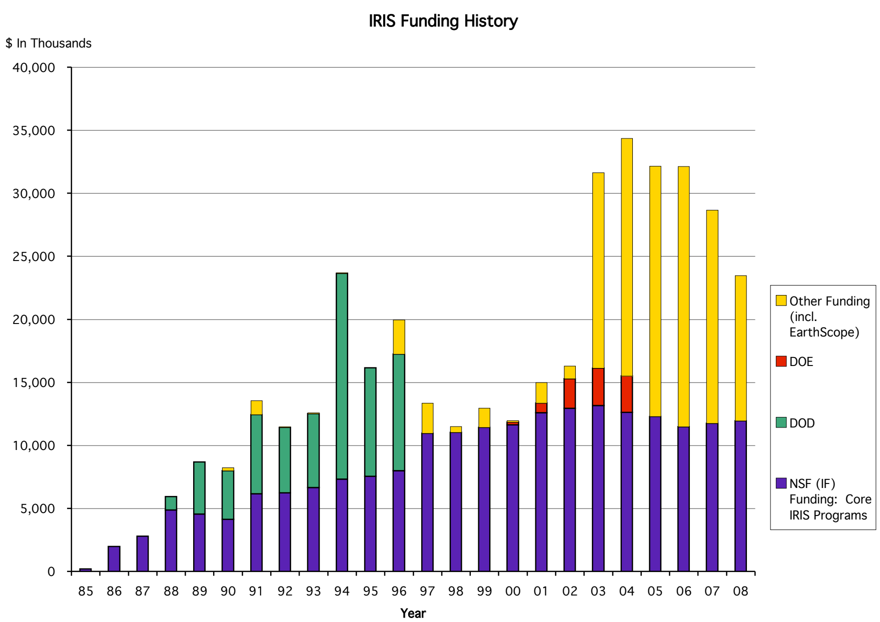


Figure 21. History of support for IRIS showing source of funding. The core support has come from the NSF Earth Science Division, Instrumentation and Facilities Program. Additional support has come from Congressional appropriations to DOD and DOE, transferred to NSF via interagency agreement. Other funding includes the NSF EarthScope (MRE & O&M) awards, as well as non-NSF sources.

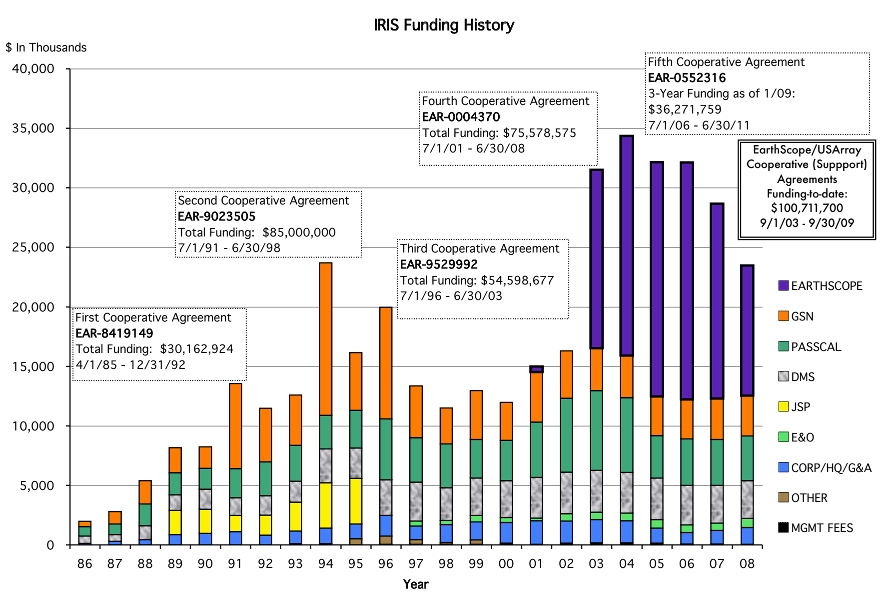
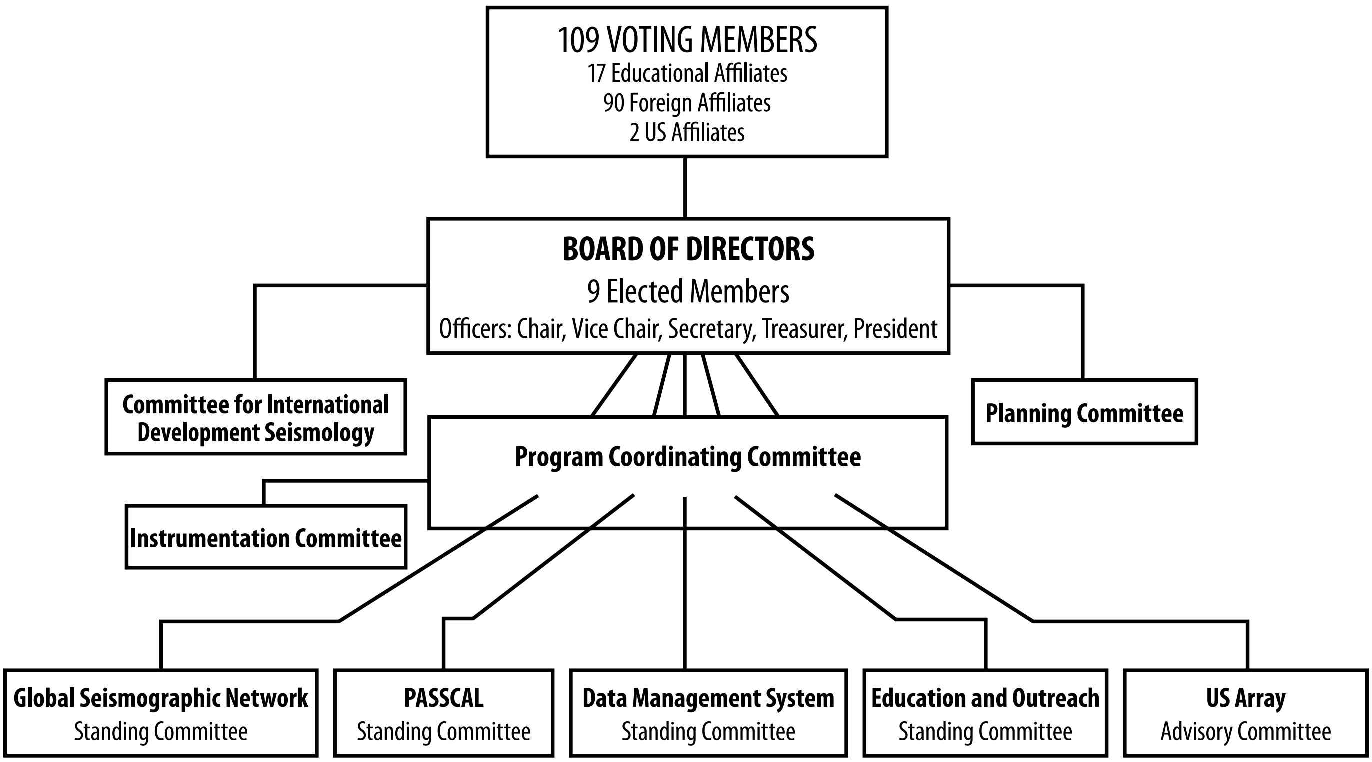


Figure 22. IRIS funding showing annual budgets for each core program. JSP was the Joint Seismic Program with the Soviet Academy of Sciences for support of station installation in Eurasia. Duration and total amounts of funding (NSF plus interagency transfers) during each Cooperative Agreement are shown in the boxes.

Appendix I

IRIS Consortium Membership and Governance Structure



The following pages show the structure, membership and evolution of IRIS Governance.

Consortium Member Institutions, Directors and Alternates

This table gives the names of the 109 member institutions of the Consortium in 2009 and the names of each institution's representative and alternate on the Board of Directors.

IRIS Committee Participants, 1984-2009

This table lists the names and institutions of over 200 individuals who have participated in IRIS governance since 1984, along with the name of the committees on which they have served.

IRIS Standing Committee Charges

IRIS Committee Membership 2009

History of Executive and Standing Committee Membership, 1984-2009

These tables list the membership of each of the Standing Committees from their formation to 2009.

Consortium Member Institutions, Directors and Alternates

Voting Members

University of Alabama
Andrew Goodliffe • Antonio Rodriguez

University of Alaska, Fairbanks
Douglas Christensen • Roger Hansen

University of Arizona
Susan Beck • George Zandt

Arizona State University
Matt Fouch • Ed Garnero

University of Arkansas at Little Rock
Haydar J. Al-Shukri • Hanan Mahdi

Auburn University
Lorraine W. Wolf

Boise State University
Lee Liberty • James Zollweg

Boston College
John Ebel • Alan Kafka

Boston University
Colleen Dalton • Ulrich Faul

Brown University
Karen Fischer • Donald Forsyth

California Institute of Technology
Donald Helmberger • Thomas Heaton

California State University, East Bay
Mitchell Craig • Joshua Kerr

University of California, Berkeley
Barbara Romanowicz • Lane Johnson

University of California, Los Angeles
Paul Davis

University of California, Riverside
Stephen K. Park • David D. Oglesby

University of California, San Diego
Gabi Laske • Jon Berger

University of California, Santa Barbara
Chen Ji • Toshiro Tanimoto

University of California, Santa Cruz
Thorne Lay • Susan Schwartz

Carnegie Institution of Washington
Paul Silver • Selwyn Sacks

University of Colorado, Boulder
Anne Sheehan • Mike Ritzwoller

Colorado School of Mines
Roel Snieder • Thomas M. Boyd

Columbia University
James Gaherty • Felix Waldhauser

University of Connecticut
Vernon F. Cormier • Lanbo Liu

Cornell University
Muawia Barazangi • Larry Brown

University of Delaware
Susan McGeary

Duke University
Eylon Shalev

Florida International University
Dean Whitman

University of Florida
Raymond Russo • Joseph Meert

University of Georgia
Robert Hawman • James Whitney

Georgia Institute of Technology
Zhigang Peng • Andrew Newman

Harvard University
Miaki Ishii • Adam Dziewonski

University of Hawaii at Manoa
Robert Dunn • Milton Garces

University of Houston
Aibing Li

Idaho State University

IGPP/Lawrence Livermore National Laboratory
Bill Walter • Peter Goldstein

IGPP/Los Alamos National Laboratory
Hans Hartse • Leigh House

University of Illinois at Urbana Champaign
Wang-Ping Chen • Xiaodong Song

Indiana University
Gary L. Pavlis • Michael Hamburger

Indiana University/Purdue University at Fort Wayne
Dipak Chowdhury

University of Kansas
Ross A. Black

Kansas State University
Charles Oviatt

University of Kentucky
Edward W. Woollery • Zhenming Wang

Lamar University
Joseph Kruger • James Jordan

Lawrence Berkeley Laboratory
Don W. Vasco • E. L. Majer

Lehigh University
Anne Meltzer • Stéphane Sol

Louisiana State University
Juan Lorenzo • Roy Dokka

Macalester College
John P. Craddock • Karl R. Wirth

Massachusetts Institute of Technology
Robert Dirk van der Hilst • Bradford H. Hager

University of Memphis
Heather DeShon • Beatrice Magnani

Miami University of Ohio
Michael Brudzinski • Brian Currie

University of Miami
Tim Dixon • Falk Amelung

University of Michigan
Jeroen Ritsema • Larry Ruff

Michigan State University
Kazuya Fujita • David W. Hyndman

Michigan Technological University
Wayne D. Pennington • Gregory P. Waite

University of Minnesota
Justin Revenaugh • Val Chandler

University of Missouri
Eric Sandvol • Mian Liu

Missouri University of Science and Technology
Stephen Gao • Kelly H. Liu

Montana Tech of the University of Montana
Michael Stickney • Marvin Speece

University of Nevada, Las Vegas
Jim O'Donnell

University of Nevada, Reno
Glenn Biasi • John Louie

University of New Orleans
Abu K.M. Sarwar

New Mexico Institute of Mining & Technology
Richard C. Aster • Susan Bilek

New Mexico State University
James Ni • Thomas Hearn

North Carolina State University
DelWayne Bohnenstiehl • James Hibbard

State University of New York at Binghamton
Francis T. Wu • Jeff Barker

State University of New York at Stony Brook
William Holt • Daniel Davis

University of North Carolina, Chapel Hill
Jonathan Lees • Jose Rial

Northern Illinois University
Paul Stoddard • Philip Carpenter

Northwestern University
Suzan van der Lee • Seth Stein

The University of Oklahoma
Randy Keller • Roger Young

Oklahoma State University
Surinder Sahai • Ibrahim Cemen

University of Oregon
Eugene Humphreys • Doug Toomey

Oregon State University
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Pennsylvania State University
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Princeton University
Frederik Simons • Robert Phinney

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Christa von Hillebrandt • Eugenio Asencio

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University of Rochester
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Rutgers University
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Saint Louis University
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William Harbert

University of Portland
Rev. Ronald Wasowski

University of Wisconsin, Whitewater
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Marcelo Assumpção

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GEOTOP, Canada
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University of Oulu, Finland
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Roger Clark

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National Taiwan University
Shu-Huei Hung

Academia Sinica, Institute of Earth Sciences, Taiwan
Bor-Shouh Huang

Mahidol University, Thailand
Passakorn Pananont

General Directorate of Disaster Affairs, Turkey
Yildiz Iravul

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Tuncay Taymaz

Kandilli Observatory, Bogazici University, Turkey
Nurcan Özel

Tubitak-Marmara Research Center, Turkey
M. Namik Yalçin

University of the West Indies
Richard Roberts

IRIS Committee Participants, 1984-2009

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Duncan	Agnew	University of California, San Diego	GSN
Ketti	Aki	University of Southern California	PASSCAL
Shelton	Alexander	Pennsylvania State University	Excomm/BOD, DMS
Richard	Allen	University of California, Berkeley	PASSCAL
Marcos	Alvarez	New Mexico Tech	PASSCAL
Charles	Ammon	St. Louis University	GSN, BOD, GSN
Don	Anderson	California Institute of Technology	Excom
Charles	Archambeau	TRAC	JSP
Richard	Aster	New Mexico Tech	PASSCAL, E&O
Shirley	Baher	AFTAC	GSN
Jeffrey	Barker	SUNY, Binghamton	E&O
Chaitan	Baru	University of CA, San Diego	DMS
Bruce	Beaudoin	New Mexico Tech	DMS, PASSCAL
Susan	Beck	University of Arizona	GSN, Excom/BOD, Planning
Harley	Benz	USGS, Golden	DMS, GSN, Instrumentation
Jonathan	Berger	University of California, San Diego	JSP, GSN
Eric	Bergmann	Global Seismological Services	GSN
Gregory	Beroza	Stanford University	GSN, BOD
Susan	Bilek	Mew Mexico Tech	GSN
Gilbert	Bollinger	Virginia Poly Institute and State University	PASSCAL
Harold	Bolton (Obs)	USGS, Albequerque	DMS
Thomas	Boyd	Colorado School of Mines	Excom, E&O
Lawrence	Braile	Purdue University	PASSCAL, Excom, E&O
Thomas	Brocher	USGS, Menlo Park	PASSCAL
Emily	Brodsky	UCLA	DMS
Ray	Buland	USGS, Golden	GSN
Bob	Butler	University of Portland	E&O
Alan	Chave	Woods Hole Oceanographic Institution	PASSCAL, GSN
Ines	Cifuentes	AGU	E&O
Elizabeth	Cochran	University of CA, Riverside	DMS
John	Collins	Woods Hole Oceanographic Institution	PASSCAL
Kenneth	Creager	University of Washington	DMS, GSN, BOD
Robert	Crosson	University of Washington	DMS
Colleen	Dalton	Boston University	GSN
Peter	Davis	University of California, San Diego	DMS, GSN
John	Derr	USGS, Albuquerque	GSN
Robert	Detrich	Woods Hole Oceanographic Institution	DMS, GSN
Douglas	Dodge	Lawrence Livermore National Laboratory	DMS
Diane	Doser	University of Texas, El Paso	PASSCAL
Douglas	Dreger	University of California, Berkeley	GSN
Kenneth	Dueker	University of Colorado	PASSCAL
John	Dwyer	AFTAC	GSN
Adam	Dziewonski	Harvard University	GSN, Excom, Planning
Paul	Earle	NEIC, USGS, Golden	GSN, DMS
Göran	Ekström	Harvard University	GSN, JSP, DMS, Excom, Planning
Kathy	Ellins	University of Texas, Austin	E&O
William	Ellsworth	USGS, Menlo Park	PASSCAL
Robert	Engdahl	USGS	DMS
Susan	Eriksson	UNAVCO	E&O
John	Filson	USGS, Reston	JSP, GSN
Karen	Fischer	Brown University	GSN, BOD
Megan	Flannigan	Lawrence Livermore Natl Labs	DMS
Frederick	Followill	Lawrence Livermore National Laboratory	PASSCAL

Donald	Forsyth	Brown University	GSN, BOD
Matthew	Fouch	Arizona State University	PASSCAL
Clifford	Frohlich	University of Texas, Austin	DMS
Kazuya	Fujita	Michigan State University	GSN
Kevin	Furlong	Pennsylvania State University	E&O
James	Gaherty	Georgia Institute of Technology	GSN, BOD
Edward	Garnero	Arizona State University	DMS, BOD, GSN
Lind	Gee	University of California, Berkeley	Excom, E&O, GSN
Holly	Given	University of California, San Diego	GSN
Peter	Goldstein	Lawrence Livermore National Laboratory	DMS
Joan	Gomberg	USGS, Memphis	PASSCAL
Stephen	Grand	University of Texas, Austin	GSN, BOD
David	Green	NOAA/Maryland	GSN
Michelle	Hall-Wallace	University of Arizona	E&O
Michael	Hamburger	Indiana University	E&O
Steven	Harder	University of Texas, El Paso	PASSCAL
Daniel	Harvey	University of Colorado	JSP
Egill	Hauksson	California Institute of Technology	PASSCAL
Gavin	Hayes	USGS NEIC	GSN
Thomas	Heaton	California Institute of Technology	GSN
Donald	Helmberger	California Institute of Technology	GSN
Thomas	Henyey	University of Southern California	PASSCAL
David	Herring	NASA	E&O
John	Hildebrand	University of California, San Diego	GSN
John	Hole	Virginia Polytechnic Institute	PASSCAL, DMS
William	Holt	SUNY, Stony Brook	DMS
Sue	Hough	USGS, Pasadena	E&O
Heidi	Houston	University of California, Los Angeles	GSN
Eugene	Humphreys	University of Oregon	PASSCAL, Excom
Charles	Hutt	USGS, Albuquerque	DMS, E&O, GSN
Shane	Ingate	University of California, San Diego	DMS
Miaki	Ishii	Harvard University	GSN
David	James	Carnegie Institution of Washington	PASSCAL
Roy	Johnson	University of Arizona	DMS, GSN, PASSCAL
Arch	Johnston	University of Memphis	JSP, Excom
Thomas	Jordan	University of Southern California	Excom, Planning
Alan	Kafka	Boston College	E&O
Hiroo	Kanamori	California Institute of Technology	GSN, Excom
Randy	Keller	University of Texas, El Paso	Excom, Planning
Camilia	Knapp	University of South Carolina	E&O, PASSCAL
Monica	Kohler	University of California, Los Angeles	DMS
Laura	Kong	UNESCO	GSN
Keith	Koper	St Louis University	DMS
Glenn	Kroeger	Trinity University	E&O
John	Lahr	USGS, Denver	E&O
Charles	Langston	Pennsylvania State University	JSP, GSN
Kenneth	Larner	Colorado School of Mines	PASSCAL
Gabi	Laske	University of California, San Diego	GSN
Jesse	Lawrence	Stanford University	PASSCAL
Thorne	Lay	University of California, Santa Cruz	Excom/BOD, GSN, Planning
Alena	Leeds	ANSS	GSN
Jonathan	Lees	University of North Carolina	DMS
William	Leith	USGS	GSN
Arthur	Lerner-Lam	Columbia University	GSN, JSP, PASSCAL, Planning, Excom/BOD
Alan	Levander	Rice University	Excom, DMS, Planning, PASSCAL
Aibing	Li	University of Houston	PASSCAL
Bob	Lillie	Oregon State University	E&O

John	Louis	University of Nevada, Reno	PASSCAL
Peter	Malin	Duke University	DMS
Stephen	Malone	University of Washington	DMS, Excom
Kurt	Marfurt	University of Houston	PASSCAL
Robert	Massé	USGS, Golden	GSN
Guy	Masters	University of California, San Diego	Excom, DMS
Doug	MacAyeal	University of Chicago	PASSCAL
David	McCormack	Natural Resources Canada	GSN
Thomas	McEvilly	University of California, Berkeley	GSN, Excom
Susan	McGeary	University of Delaware	Excom
Jeff	McGuire	Woods Hole Oceanographic Institute	GSN
George	McMechan	University of Texas, Dallas	PASSCAL
Daniel	McNamara	USGS, Golden	DMS
Beatrice	Magnani	University of Memphis	PASSCAL
Robert	Mellors	San Diego State University	E&O
Anne	Meltzer	Lehigh University	PASSCAL, Excom, Planning
William	Menke	Columbia University	DMS, PASSCAL
Kate	Miller	University of Texas, El Paso	PASSCAL, Excom/BOD, Planning
Bernard	Minster	University of California, San Diego	DMS
Brian	Mitchell	St Louis University	GSN
Walter	Mooney	USGS, Menlo Park	PASSCAL
John	Nabelek	Oregon State University	DMS, PASSCAL
Keith	Nakanishi	Lawrence Livermore National Laboratory	DMS
Meredith	Nettles	Lamont Doherty Observatory, Columbia	DMS
Guust	Nolet	Princeton University	Excom, E&O, DMS
Robert	North	Center for Monitoring Research	GSN
Fenglin	Nui	Rice University	GSN
Andrew	Nyblade	Pennsylvania State University	Excom/BOD, Planning
Emile	Okal	Northwestern University	GSN
David	Okaya	University of Southern California	PASSCAL, DMS,BOD
John	Orcutt	University of California, San Diego	DMS, Excom, GSN, Planning
Thomas	Owens	University of South Carolina	DMS, PASSCAL, Excom/BOD
Jeffrey	Park	Yale University	Excom, JSP, GSN
Gary	Pavlis	Indiana University	JSP, PASSCAL, DMS, Excom, E&O
Wayne	Pennington	Michigan Technological University	E&O
Robert	Phinney	Princeton University	PASSCAL, Excom, President
Thomas	Pratt	USGS	PASSCAL
Paul	Richards	Columbia University	Excom, JSP, DMS
Jeroen	Ritsema	University of Michigan	GSN
Michael	Ritzwoller	University of Colorado	JSP, GSN, DMS
Arthur	Rodgers	Lawrence Livermore Natl Lab	PASSCAL
Stephane	Rondenay	Massachusetts Institite of Technology	PASSCAL
Steven	Roecker	Rensselaer Polytechnic Institute	PASSCAL, BOD
Barbara	Romanowicz	University of California, Berkeley	GSN, Planning
Lawrence	Ruff	University of Michigan	DMS
Ray	Russo	University of Florida	PASSCAL
Martha	Savage	Victoria University	DMS
Susan	Schwartz	University of California, Santa Cruz	DMS, E&O
Steven	Semken	Arizona State University	E&O
Laura	Serpa	University of Texas, El Paso	E&O
Peter	Shearer	University of California, San Diego	Excom
Anne	Sheehan	University of Colorado	GSN, PASSCAL, BOD
Paul	Silver	Carnegie Institution of Washington	Excom, JSP, PASSCAL
David	Simpson	Columbia University	JSP, PASSCAL, Planning, President
Stuart	Sipkin	USGS, Denver	GSN, DMS
Kenneth	Smith	University of Nevada, Reno	DMS
Robert	Smith	University of Utah	Excom, PASSCAL, Planning

Stewart	Smith	University of Washington	JSP, President
Catherine	Snelson	New Mexico Tech	DMS, E&O
Sean	Solomon	Carnegie Institution of Washington	GSN
Xiadong	Song	University of Illinois, Urbana Champaign	GSN
Seth	Stein	Northwestern University	Excom, E&O
William	Stevenson	USGS, Denver	PASSCAL
Brian	Stump	Southern Methodist University	JSP, PASSCAL, BOD, Planning
Fumiko	Tajima	University of California, Berkeley	DMS
Toshiro	Tanimoto	California Institute of Technology	DMS
Steven	Taylor	Los Alamos National Laboratory	DMS
Ta-liang	Teng	University of Southern California	Excom, GSN
George	Thompson	Stanford University	Excom
Clifford	Thurber	University of Wisconsin, Madison	PASSCAL, Excom
Doug	Toomey	University of Oregon	DMS
Anne	Trehu	Oregon State University	PASSCAL, Excom/BOD, DMS
Jeroen	Tromp	California Institute of Technology	GSN, DMS
Robert	van der Hilst	Massachusetts Institute of Technology	DMS, Excom
Suzan	van der Lee	Northwestern University	E&O, BOD, DMS
Bruce	Varnum	AFTAC	GSN
Aaron	Velasco	University of Texas, El Paso	E&O
Frank	Vernon	University of California, San Diego	JSP, PASSCAL
John	Vidale	University of California, Los Angeles	Excom, Planning
Christa	von Hillebrandt	University of Puerto Rico	E&O
Lara	Wagner	University of North Carolina, Chapel Hill	PASSCAL
Lisa	Wald	USGS, Golden	E&O
Terry	Wallace	University of Arizona	JSP, GSN, DMS, Excom, Planning
William	Walter	Lawrence Livermore National Laboratory	PASSCAL, DMS
Lianxing	Wen	State University of New York, Stony Brook	GSN
Laura	Wetzel	Eckerd College	E&O
Douglas	Wiens	Washington University, St Louis	DMS, Excom
Ray	Willemann	IRIS	Planning
Richard	Williams	University of Tennessee	PASSCAL
Christian	Winther	University of California, San Diego	GSN
Cecily	Wolfe	University of Hawaii	GSN
John	Woodhouse	University of Oxford	DMS
Robert	Woodward	USGS, Albuquerque	DMS, E&O
Francis	Wu	SUNY, Binghamton	DMS
Michael	Wysessiion	Washington University, St Louis	Excom, Planning, E&O
George	Zandt	University of Arizona	PASSCAL
Colin	Zelt	Rice University	PASSCAL

IRIS Standing Committee Charges

Program for Array Seismic Studies of the Continental Lithosphere

The PASSCAL Standing Committee oversees the evolving policies of the portable instrumentation program, addressing issues in hardware development, usage, and the dissemination of data collected by individual field projects.

1) Set standards of instrumentation and software development for PASSCAL, working in concert with the PASSCAL Program Manager to exploit new technology.
2) Set guidelines for the use of the PASSCAL facility. This includes the use of the PASSCAL data acquisition system (DAS), sensors, field computers and instrument center personnel.
3) Set guidelines for archiving data collected in PASSCAL experiments.
4) Aid in scheduling instrument use.
5) Develop and evaluate strategies for the successful procurement of PASSCAL instrumentation (6000 channels) so as to complete the PASSCAL facility by 1996.
6) Develop new initiatives to enhance the effectiveness of the PASSCAL program
7) Advise the Program Manager and the IRIS President on program planning and yearly budgets.

Global Seismographic Network

The GSN Standing Committee develops policies to facilitate a timely and successful installation of the Global Seismic Network, and the rapid dissemination of the data collected by the GSN.

1) Set standards for GSN instrumentation and data collection
2) Develop and maintain a siting plan that ensures the timely deployment of GSN instruments, and accounts for the contributions of other 'equivalent' networks in maximizing the global coverage afforded by the GSN.
3) Set standards/policies to ensure the timely flow of data from the GSN stations to the DCC's
4) Develop and evaluate strategies for the successful procurement and installation of GSN equipment so as to complete the global seismographic network by 1996 (128 'goal' stations).
5) Cooperate with the USGS, the Federation of Digital Broad Band Seismograph Networks (FDSN), and other groups interested in establishing digital stations for global studies, to establish a well-distributed network in an expeditious manner.
6) Develop plans for the long-term maintenance of the GSN.
7) Coordinate with the OSN Steering Committee to facilitate the deployment of ocean bottom stations, so as to reach the GSN goal of uniform global coverage.
8) Develop new initiatives to enhance the effectiveness of the GSN.
9) Advise the Program Manager and the IRIS President on program planning and yearly budgets.

Data Management System

The DMS Standing Committee operates in an oversight capacity to ensure that the IRIS Data Management System (DMS) is effective in archiving and making available data from the GSN and PASSCAL programs, as well as other data.

1) Develop and maintain policies that ensure that data flow into the DMC in a timely fashion from the DCC's (in the case of GSN data) and from individual investigators (in the case of PASSCAL data). These duties will be closely coordinated with the GSN SC and PASSCAL SC respectively.
2) Ensure completeness of the data archive. Develop policies for the archival of non-IRIS data, particularly FDSN data needed to ensure the global recording of teleseismic events by broadband seismometers.
3) Develop, set and maintain data quality standards for GSN, PASSCAL, as well as other data stored by the DMC.
4) Ensure that users have easy and rapid access to the data archive.
5) Advise in the development of software tools for the display and processing of seismic data by users.
6) Provide oversight for the operation of the IRIS DMC, the IRIS/IDA DCC, the IRIS/USGS DCC, and other DMS components as needed.
7) Develop new initiatives to enhance the effectiveness of the DMS.
8) Advise the Program Manager and the IRIS President on program planning and the yearly budgets.

Education and Outreach

The Committee on Education and Outreach will develop recommendations to the IRIS Executive Committee for programs that will foster within the next generation of research scholars, educators, policy-makers, business leaders, and benefactors an appreciation for and an understanding of seismology and related study of the Earth. The E&O Committee , working with the seismological and educational communities, will develop and implement IRIS programs designed to enhance seismology and

Earth Science education in K-12 schools, colleges and universities, and in adult education. Implementation of such an ambitious program will require seeking additional funding from appropriate agencies such as NSF/EHR. A major objective will therefore be to make seismology accessible to the broadest possible audience, demonstrating that seismology is intellectually fascinating, and that a background in geoscience is valuable and relevant for a broad range of careers. In keeping with NSF's goal of integrating education with research, the educational committee will also give high priority to identifying mechanisms for IRIS research programs and activities to enhance the educational process at all levels.

Planning Committee

The Planning Committee is charged with thee task of studying strategic problems and opportunities related to the vitality of IRIS and the research community in order to advise the Executive Committee in considering priorities and policies. As part of the process, the Planning Committee should review developments in national program which are expected to have a significant impact on IRIS and the IRIS community and explore prospective new scientific directions, instrumentation, or initiatives. The Planning Committee will develop recommendations for review and action by the Executive Committee.

Program Coordination Committee

The Program Coordination Committee is charged with the task of developing an integrated IRIS budget for review and action by the Executive Committee. As part of this process, the Program Coordination Committee should identify ways to enhance scientific effectiveness, coordination among the core programs, and economies of scale. It is expected that the activities of the Program Coordination Committee will result in improved coordination and cooperation of the core programs and optimized development and use of IRIS resources.

Instrumentation Committee

The Instrumentation Committee should be pan-IRIS Consortium, spanning all four programs. As technology evolves, the Instrumentation Committee should be cognizant of cross-programmatic system requirements, and pursue goals of system design that will satisfy these cross-programmatic needs. The Instrumentation Committee should be proactive, encouraging research and development as appropriate, and seeking new products that could meet current, future, and unexpected needs for sensors, data acquisition systems, communications and data distribution hardware. The Instrumentation Committee should be responsive to specific needs for technical advice, by providing reports and recommendations to the IRIS Coordination Committee and Standing Committees when requested. The Instrumentation Committee should also serve as IRIS liaison to similar bodies for other programs such as ANSS.

IRIS Committee Membership 2009

Board of Directors

Susan Beck (Chair)	University of Arizona
Jim Gaherty (Vice Chair)	Columbia University
Kenneth Creager	University of Washington
Don Forsyth	Brown University
Ed Garnero	Arizona State University
Steven Roecker	Rensselaer Polytechnic Institute
Steve Grand	University of Texas, Austin
David Okaya	University of Southern California
Suzan van der Lee	Northwestern University

Planning Committee

Brian Stump (Chair)	Southern Methodist University
Susan Beck	University of Arizona
Randy Keller	Oklahoma University
Thorne Lay	University of California, Santa Cruz
Kate Miller	University of Texas, El Paso
Andrew Nyblade	Pennsylvania State University
John Vidale	University of Washington
David Simpson	IRIS
Ray Willemann	IRIS

USArray Advisory Committee

Matt Fouch (Chair)	Arizona State University
Larry Brown	Cornell University
Charles Langston	The University of Memphis
Maureen Long	Yale University
Guy Masters	University of California, San Diego
David Snyder	Geological Survey of Canada
Joann Stock	Caltech
Rob van der Hilst	Massachusettes Institute of Technology
J. Douglas Walker	University of Kansas

GSN Standing Committee

Xiaodong Song (Chair)	University of Illinois, Urbana Champaign
Susan Bilek	Mew Mexico Tech
Colleen Dalton	Boston University
Adam Dziewonski	Harvard University
Gavin Hayes	USGS NEIC
David McCormack	Natural Resources Canada
Jeff McGuire	Woods Hole Oceanographic Institute
Emile Okal	Northern University
Jeroen Ritsema	University of Michigan
William Leith (ex officio)	USGS
Shirley Baher (obs)	AFTAC
Harley Benz (obs)	USGS NEIC
Jon Berger (obs)	Univ. of CA, San Diego
Pete Davis (obs)	Univ. of CA, San Diego
John Derr (obs)	USGS, Albuquerque
Lind Gee (obs)	USGS, Albuquerque
Alena Leeds (obs)	ANSS

PASSCAL Standing Committee

Richard Allen (Chair)	University of California, Berkeley
Paul Davis	University of California, Los Angeles
Matt Fouch	Arizona State University
Jesse Lawrence	Stanford University
Aibing Li	University of Houston
Doug MacAyeal	University of Chicago
Beatrice Magnani	University of Memphis
Tom Pratt	University of Washington
Arthur Rodgers	Lawrence Livermore Natl Lab
Lara Wagner	University of North Carolina, Chapel Hill
Rick Aster (obs)	New Mexico Tech
Frank Vernon (obs)	University of California, San Diego
Bruce Beaudoin (obs)	PASSCAL NMT
Marcos Alvarez (obs)	IRIS
Steve Harder (obs)	UTEP

Data Management System (DMS) Standing Committee

Keith Koper (Chair)	Saint Louis University
Harley Benz	USGS , Denver, CO
Elizabeth Cochran	University of CA, Riverside
Meredith Nettles	Lamont Doherty Obsv.Columbia
Mike Ritzwoller	University of Colorado, Boulder
Catherine Snelson	New Mexico Tech
Doug Toomey	University of Oregon
Bill Walter	Lawrence Livermore Natl Labs
Bruce Beaudoin (obs)	New Mexico Tech
Harold Bolton (obs)	USGS, Denver, Colorado
Peter Davis (obs)	University of California, San Diego

Education and Outreach (E&O) Standing Committee

Michael Wysession (Chair)	Washington University, St Louis
Bob Butler	University of Portland
Ines Cifuentes	AGU
Glenn Kroeger	Trinity University
Gary Pavlis	Indiana University
Wayne Pennington	Michigan Technological University
Laura Serpa	University of Texas, El Paso
Christa von Hillebrandt	University of Puerto Rico
Susan Eriksson (ex officio)	UNAVCO
Bob Lillie (ex off)	Oregon State University, EarthScope National Office

TA Working Group

Matt Fouch (Chair)	Arizona State University
Caroline Beghein	University of California, Los Angeles
John Collins	Woods Hole Oceanographic Inst.
Stephen Gao	Missouri University of Science & Technology
Ed Garnero	Arizona State University
Hersh Gilbert	Purdue University
Egill Hauksson	California Institute of Technology
Meghan Miller	University of Southern California
Vera Schulte-Pelkum	University of Colorado
Yingjie Yang	University of Colorado
Bob Busby	IRIS-Transportable Array Manager
John Taber (obs)	IRIS-E&O
Frank Vernon (obs)	Array Network Facility
Bob Woodward	IRIS-USArray Project Director

MT Working Group

Phil Wannamaker (Chair)	University of Utah
Gary Egbert	Oregon State University
Rob Evans	Woods Hole Oceanographic
Institution	
Dean Livelybrooks	University of Oregon
Kevin Mickus	Missouri State University
Stephen Park	University of California, Riverside
Adam Schultz	Oregon State University
Martyn Unsworth	University of Alberta
Bob Woodward	USArray Director

Budget and Finance Subcommittee

Ken Creager (Chair)	University of Washington
Don Forsyth	Brown University
Steve Grand	UT Austin
Candy Shin	IRIS
Ray Willemann	IRIS

Program Coordinating Committee (CoCOM)

Charles Ammon (Chair)	Pennsylvania State University
Tim Ahern	IRIS
Robert Busby	IRIS
Rhett Butler	IRIS
Jim Fowler	IRIS
James Gaherty	Columbia University
Alan Lavender	Rice University
Candy Shin	IRIS
David Simpson	IRIS
Xiaodong Song	University of Illinois Urbana, Champaign
John Taber	IRIS
Douglas Wiens	Washington University, St. Louis
Bob Woodward	IRIS
Robert Woolley	IRIS
Michael Wysession	Washington University, St. Louis

History of Executive and Standing Committee Membership 1984-2009

Executive Committee/Board of Directors

NAME	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09
Shelton Alexander	VC	VC	VC																					
Don Anderson	●	●																						
Adam Dziewonski	●											C	C											
Thomas McEvilly	C	●	●								●	●	●	●										
Robert Phinney	●	C	C	●																				
Robert Smith	●																							
Ta-Liang Teng	●	●																						
Clifford Thurber	S	S	S	●	●										●	●	●							
Larry Braile		●	●	●	●																			
Seth Stein		●	●																					
John Orcutt			●	C	C	●																		
Paul Richards			●	●	VC																			
Thorne Lay				●	●															C	C	C		
Jeffrey Park				S	S	VC	VC	C	C															
Paul Silver				●	●	C	C																	
Gary Pavlis					●	●									●	●	●	●						
Susan McGeary						S	S	●	●															
George Thompson						●	●																	
Terry Wallace						●	●			C	C													
Douglas Wiens						●				●	●	●	●											
Arch Johnston							●	●																
Guy Masters							●	●																
Thomas Owens							●	●									VC	VC	VC	VC	VC	VC		
Thomas Boyd								S	S															
Alan Levander								VC	VC	VC	VC													
Guust Nolet								●	●	●	●													
Göran Ekström									●	●				VC	VC	VC	C	C	C					
Hiroo Kanamori									●	●														
Anne Trehu									●	●											●	●		
Lind Gee										S	S	S	S											
Karen Fischer											●	●								●	●	●		
Randy Keller											●	VC	VC											
Eugene Humphreys												●	●	●										
Peter Shearer												●	●	●	●									
John Vidale													●	●										
Thomas Jordan														●	●	●								
Anne Meltzer														C	C	C								
Michael Wysessiion														S	S	S								
Stephen Malone															●	●	●							
Robert van der Hilst																●	●	●						
Susan Beck																	●	●	●				C	C
Andrew Nyblade																	S	S	S	S				
Arthur Lerner-Lam																		●	●	●				
Kate Miller																		●	●	●				
Gregory Beroza																			●	●	●		●	
Brian Stump																			●	●	●			
David Okaya																				●	●			●
Charles Ammon																					●	●	VC	
Anne Sheehan																					●	●	●	
Ken Creager																						●	●	●
Jim Gaherty																						●	●	VC
Suzan van der Lee																						●	●	●
Don Forsyth																							●	●
Stephen Roecker																							●	●
Ed Garnero																								●
Steve Grand																								●

Data Management System Committee

NAME	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09
Shelton Alexander	C	●	●	●	●	●	●																	
Robert Engdahl	●	●	●	●	C	C	C	●																
Lane Johnson	●	C	C	C																				
John Orcutt	●	●																						
Gary Pavlis	●	●	●	●																				
Lawrence Ruff	●	●							●	●	●													
Fumiko Tajima	●	●	●																					
John Woodhouse	●																							
Robert Crosson		●	●	●									C											
Alan Levander			●	●										C	C	C								
Keith Nakanishi			●	●	●																			
William Menke				●	●																			
Bernard Minster				●	●																			
Clifford Frohlich					●	●	●																	
Stephen Malone					●	●	●																	
John Nabelek					●	●	●																	
Toshiro Tanimoto					●		●																	
Göran Ekström						●	●	●																
Peter Malin						●	●	●																
Francis Wu						●	●	C	C	C														
Geoffrey Abers								●	●	●														
Harley Benz								●	●	●	●	●	●											●
Karen Fischer								●	●	●														
Martha Savage								●	●															
Susan Schwartz									●	●	C	C												
David Okaya										●	●	●					●	●	●					
Thomas Owens										●	●	●												
Kenneth Creager											●	●												
Paul Richards											●	●	●											
Steven Taylor											●	●	●											
Terry Wallace												●	●	●										
Jonathan Lees													●	●	●									
Robert van der Hilst													●	●	●									
Peter Goldstein														●	●	●								
William Holt														●	●	●								
Monica Kohler														●	●	●	C							
Stuart Sipkin														●	●	●	●							
Guy Masters															●	●	●							
Robert Detrich																●	●	●						
Kenneth Smith																●	●	●						
Douglas Dodge																	●	●	●					
Edward Garnero																	●	●	●					
Daniel McNamara																		●	●	●				
Guust Nolet																		C	C	C				
Douglas Wiens																		●	●	●	C	C	C	
Anne Trehu																			●	●				
Suzan van der Lee																			●	●	●			
Emily Brodsky																				●	●	●		
Megan Flannigan																				●	●	●		
Keith Koper																				●	●	●		C
Harold Bolton																				obs	obs	obs	obs	obs
Peter Davis																				obs	obs	obs	obs	obs
John Hole																					●	●	●	
Paul Earle																					●	●	●	
Chaitan Baur																					●	●	●	
Bruce Beaudoin																					obs	obs	obs	obs
Meredith Nettles																						●	●	●
Doug Toomey																						●	●	●
Elizabeth Cochran																							●	●
Mike Ritzwoller																							●	●
Bill Walter																							●	●
Catherine Snelson																								●

Global Seismographic Network Committee

NAME	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09
Rhett Butler	●																							
Jonathan Berger	●	●	●		●															obs	obs	obs	obs	obs
Adam Dziewonski	C	C												●	●	●								●
Hiroo Kanamori	●	●																						
Thorne Lay	●	●	●											●	●	●		C	C					
Thomas McEvilly	●																							
Brian Mitchell	●	●																						
Ta-Liang Teng	●	●	●																					
Sean Solomon		●	C	C																				
Terry Wallace		●	●	●				●	●															
Kazuya Fujita			●	●	●				●	●	●													
Donald Helmberger			●	●	●																			
Arthur Lerner-Lam			●	●	●																			
Charles Langston				●	●		●	●	●															
Emile Okal				●	●																		●	●
Donald Forsyth					C		C	C																
Stephen Grand					●		●								●	●	●							
Gregory Beroza						●	●	●																
Heidi Houston						●	●	●																
Barbara Romanowicz						●	●	●						C	C	C	C							
Stuart Sipkin						●	●	●				●												
Douglas Wiens							●	●	●															
Lane Johnson									C	C														
Robert North									●	●	●													
Duncan Agnew										●	●	●												
Eric Bergmann										●	●	●												
Susan Beck											●	●	●											
Alan Chave											●	●	●											
Douglas Dreger											●	●	●											
Göran Ekström											C	C	C											
Thomas Heaton											●	●	●	●										
Anne Sheehan												●	●	●										
Charles Ammon														●	●	●				●				
John Orcutt														●	●									
Harley Benz															●	●	●							obs
James Gaherty																●	●	●						
Cecily Wolfe																●	●	●						
Kenneth Creager																	●	●	●					
Gabi Laske																	●	●	●					
Jeroen Tromp																	●	●	●	●	●	●		
Paul Earle																		●	●	●				
Jeffrey Park																		●	●	C	C	C		
Lianxing Wen																		●	●	●				
Karen Fischer																			●					
Xiaodong Song																				●	●		C	C
Mike Ritzwoller																				●	●			
Robert Detrick																				●	●	●		
Ed Garnero																				●	●			
William Leith																				●	e.o.	e.o.	e.o.	e.o.
Pete Davis																				obs	obs	obs	obs	obs
John Dwyer																				obs	obs			
Charles R. Hutt																				obs	obs	obs	obs	
Alena Leeds																				obs	obs	obs	obs	obs
Miaki Ishii																					●	●	●	
Laura Kong																					●	●	●	
Fenglin Nui																					●	●	●	
Susan Bilek																						●	●	●
David McCormack																						●	●	●
Jeroen Ritsema																						●	●	●
Bruce Varnum																						obs		
David Green																						obs	obs	
Jeff McGuire																							●	●
Shirley Baher																							obs	obs
Lind Gee																							obs	obs
Gavin Hayes																								●
Colleen Dalton																								●
John Derr																						obs	●	obs

PASSCAL Committee

NAME	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09
Keitti Aki	•	•																						
Lawrence Braile	•	C	C	C	C	•																		
William Ellsworth	•																							
Kenneth Larner	•																							
George McMechan	•	•	•																					
William Menke	•	•	•	•								•												
Robert Phinney	C	•																						
Robert Smith	•	•	•	•	•	•	•	•																
Gilbert Bollinger		•	•																					
Peter Malin		•	•																					
Walter Mooney		•	•	•	•						•	•	•											
Paul Silver			•	•	•																			
Anne Trehue			•	•	•	C	C	•																
David Okaya				•	•	•								•	•	•								
Thomas Owens				•	•									•	•	•								
David Simpson					•																			
Thomas Brocher						•	•																	
Diane Doser						•	•	•																
Brian Stump						•	•	•	•	•														
Frank Vernon						•	•	•	•	•										obs	obs	obs	obs	
Thomas Henyey							•	•	•															
Eugene Humphreys							•	•	•															
George Zandt							•	•	•												•	•	•	
Gary Pavlis								C	C	C														
Anne Meltzer									•	•	C	C	C											
John Nabelek									•	•	•													
Richard Williams									•	•	•													
Frederick Followill										•	•	•												
Thomas Pratt										•	•	•										•	•	•
Clifford Thurber										•	•	•	•	•										
Egill Hauksson											•	•	•											
David James											•	•	•	•			•	C	C	C				
Roy Johnson												•	•	C	C	C	C							
Kenneth Dueker													•	•	•									
Kate Miller													•	•	•									
Arthur Lerner-Lam														•	•	•								
Steven Roecker														•	•	•	•	•	•					
Geoffrey Abers															•	•	•							
Kurt Marfurt															•	•	•							
Joan Gomberg																•	•	•						
John Louis																•	•	•						
John Collins																	•	•	•		•	•		
Anne Sheehan																	•	•	•					
John Hole																		•	•	•				
William Walter																		•	•	•				
Colin Zelt																		•	•	•				
Matthew Fouch																			•	•	•	•	•	•
Camelia Knapp																			•	•	•			
William Stevenson																			•	•	•			
Stephane Rondenay																				•	•	•	•	
Rick Aster																				obs	obs	obs	obs	obs
Bruce Beaudoin																				obs	obs	obs	obs	obs
Steve Harder																				obs	obs	obs	obs	obs
Alan Levander																					C	C	C	
Ray Russo																					•	•	•	
Arthur Rodgers																					•	•	•	•
Marcos Alvarez																					obs	obs	obs	obs
Aibing Li																						•		•
Richard Allen																							•	C
Lara Wagner																							•	•
Jesse Lawrence																								•
Doug MacAyeal																								•
Beatrice Magnani																								•

JSP Committee

NAME	90	91	92	93	94	95
Charles Archambeau	●	●	●			
Jonathan Berger	●	●	●			
Jeffrey Park	●	●	●	●	●	●
Paul Richards	C	●	●	●	●	●
David Simpson	●					
Terry Wallace	●	●	●	●		
Göran Ekström		●	●	●	C	C
John Filson		●	●			
Daniel Harvey		●				
Arch Johnston		●				
Charles Langston		●	●	●	●	
Arthur Lerner-Lam		●	●			
Gary Pavlis		●				
Michael Ritzwoller		●				
Paul Silver		●		C	●	
Stewart Smith		C	C			
Brian Stump		●	●	●	●	●
Frank Vernon		●				
Bernard Minster				●	●	●
Keith Nakanishi				●	●	●
Robert Phinney			●	●	●	●

Education and Outreach Committee

NAME	97	98	99	00	01	02	03	04	05	06	07	08	09
Jeffrey Barker	●	●	●	●									
Larry Braile	C	C	C	C	C								
Karen Fischer	●	●											
Michelle Hall-Wallace	●	●	●	●									
Charles Hutt	●	●											
Glenn Kroeger	●	●	●	●	●							●	●
Guust Nolet	●	●	●										
Lind Gee			●	●									
Robert Woodward			●										
John Lahr				●	●	●							
Robert Mellors				●	●	●							
Richard Aster					●	C	C	C	C				
Michael Hamburger					●	●	●						
Susan Schwartz					●	●	●						
Thomas Boyd						●	●						
Alan Kafka						●	●	●	●				
Steven Semken							●	●	●				
Lisa Wald							●	●	●				
Kathy Ellins								●	●	●			
Seth Stein								●	●	●			
Aaron Velasco								●	●	●			
Catherine Snelson									●	●	●		
Susan Eriksson									●	●	●	e.o.	e.o.
Kevin Furlong										●	●	●	
Sue Hough										●	●	●	
Laura Wetzel										●	●	●	
Michael Wysession										C	C	C	C
Ines Cifuentes											●	●	●
Laura Serpa											●	●	●
David Herring											●	●	
Bob Lillie											e.o.	e.o.	e.o.
Gary Pavlis												●	●
Bob Butler													●
Wayne Pennington													●
Christa von Hillebrandt													●

Planning Committee

NAME	98	99	00	01	02	03	04	05	06	07	08	09
Adam Dziewonski	●		●	C	C	C	C					
John Orcutt	●	●	●	●	●							
Barbara Romanowicz	●							●	●			
Robert Smith	●	●	●									
Terry Wallace	C	C	C	●	●							
Anne Meltzer			●	●	●	●	●	●				
Arthur Lerner-Lam				●	●		●	C	C			
Göran Ekström					●	●	●	●	●	●		
Thomas Jordan					●	●	●					
Alan Levander						●	●	●				
Michael Wysession						●	●	●				
David Simpson							●	●	●	●	●	●
Thorne Lay								●	●	●	●	●
Ray Willemann								●	●	●	●	●
Randy Keller									●	●	●	●
Andrew Nyblade									●	●	●	●
Brian Stump										C	C	C
Kate Miller										●	●	●
John Vidale										●	●	●
Susan Beck											C	C

Appendix II

Timeline of Significant Events in IRIS History

	Consortium	GSN	PASSCAL	DMS	E&O
1983	National Academy of Science/National Research Council releases a series of reports on facilities for seismological research.				
	Committee on Science, Engineering, and Public Policy (COSEPUP) recommends support for "a new Global Digital Seismic Array" and "seismic investigation of the continental crust."				
1984	IRIS is incorporated, May 8, 1884, with 26 founding members.				
		Science Plan for a New Global Seismographic Network.			
			Science Plan for PASSCAL.		
1985	IRIS and NSF sign first Cooperative Agreement. First year funding is for $200K for initial planning				
	IRIS Headquarters Office established in Rosslyn VA				
	Federation of Broadband Digital Seismic Network organized with IRIS as Founding Member.				
1986		First GSN very broadband seismometer upgrades at ALQ, Albuquerque, NM, COL, College, AK, and PFO, Piñon Flat, CA.			
		GSN RFP for new data acquisition system.			
		International Deployment of Accelerometers (IDA) at UC San Diego joins GSN.			
			Request for Proposals for PASSCAL Instrument published.		
			PASSCAL funds first two field experiments.		
				Strategies for the Design of a Data Management Center Published	
1987		First GSN dial-up station at HRV, Harvard, MA.			
		The University Network component of the GSN is initiated with HRV, Harvard, MA and PAS, Pasadena, CA.			
		Four IRIS/IDA GSN stations installed in former Soviet Union. GSN goals extended to include high-frequency seismometers.			
			Development contract for PASSCAL Instrument awarded to Refraction Technology.		
				Report developed by TASC for implementation of the IRIS DMS	
1988	Joint Seismic Program established with the USGS and the Academy of Sciences of the Soviet Union to install stations within the US and USSR. Congress provides $29M over next six years to support the JSP program.				
		GSN assumes responsibility for seismic station at the South Pole.			
			First 10 prototype PASSCAL instruments delivered.		
			First experiment supported with instruments from PASSCAL.		
				SEED format version 2.0 defined by the FDSN	
				Interim Data Management Center established at UT Austin	
				University of Washington develops first near real time data collection system.	
1989			First PASSCAL Instrument Center established at Lamont Observatory, Columbia University.		
			First 40 production PASSCAL instruments delivered.		
			First aftershock deployments supported after Loma Prieta Earthquake.		
			Development started on 3-channel active source instrument.		
			PASSCAL ceases funding of field experiments.		
				First SEED formatted data shipped from the IRIS DMC	
1990		Data Collection Centers in La Jolla, CA and Obninsk, USSR are linked by C-band satellite.			
		GSN has installed or upgraded 25 stations globally.			
		AT&T and Japan's KDD donate the Transpacific Cable-1 to IRIS and Earthquake Research Institute, initiating scientific re-use of undersea telephone cables.			
		Technical Plan for a New Global Seismographic Network issued by USGS and IRIS.			
			First portable PASSCAL experiment with broadband sensors.		
			Prototype 3-channel recorder delivered.		

	Consortium	GSN	PASSCAL	DMS	E&O
1991	IRIS and NSF sign second Cooperative Agreement. First year funding is $6.2M. IRIS membership now 69 institutions				
	KNET, a ten station telemetered network in Kyrghyzstan, becomes operational as part of the JSP program				
		First GSN borehole seismic systems at Albuquerque, NM, and Rarotonga, Cook Islands.			
		Low-gain accelerometers are included as standard GSN sensors.			
		Ocean Seismic Network borehole drilled by Ocean Drilling Program near Oahu.			
			First production units of the 3-channel system delivered.		
			PASSCAL Instrument Center at Stanford opened to support 3-channel systems.		
				Data Management Center established at University of Washington	
1992		Satellite link to South Pole for GSN data.			
			Purchase of first 24-bit PASSCAL systems.		
				DMC acquires first mass storage system (6 terabyte capacity)	
				Project IDA GSN stations begin near real time data delivery	
1993		KONO, Kongsberg, Norway is the first GSN site connected directly to the Internet.			
		MoU to cooperate on five joint GSN-GEOFON stations with Germany's GeoForschungsZentrum.			
		The first joint station is installed at PMG, Papua New Guinea, also in cooperation with Japan's POSEIDON Project.			
		Congressional funding begins for accelerating the installation of the GSN for use in seismic research relevant to nuclear treaty verification. In the subsequent three years, over 50 GSN stations are installed.			
				FARM event-windowed waveform data products established	
1994	National Science and Technology Council (NSTC) carries out interagency review of GSN role in as a multi-use facility.				
	Congress provides $42.5M over four years to accelerate installation of GSN.				
		Microbarographs are included as standard GSN sensors.			
		GSN upgrade of China Digital Seismic Network begins with BJT, Beijing.			
				Annual DMC/DCC coordination meetings initiated	
				DMC archive exceeds 1 terabyte	
1995		GSN has 83 stations installed globally.			
		Over 30 GSN sites participate in the Conference On Disarmament Group of Scientific Experts (GSE) Technical Test 3.			
				USGS Contributes GDSN Network data to the DMC in SEED format for archiving and distribution	
1996	IRIS and NSF sign third Cooperative Agreement. First year funding is $8.0M.				
		AT&T donates Hawaii-2 undersea telephone cable system to IRIS for scientific re- use.			
		Over 50 GSN stations are designated in the Comprehensive Test Ban Treaty for use in the International Monitoring System.			
		GSN coordinates funding from National Imaging and Mapping Agency for installation of GPS receivers at GSN stations in Siberia.			
		GSN Affiliate Status is created for other broadband stations to join GSN. BFO, Germany joins as an Affiliate.			
			First broadband PASSCAL data submitted to DMC in SEED format.		
				Networked Data Centers established	
					Development of the Seismic Monitor web display
1997	Following NSTC review, NSF funding to IRIS increased by $3M per year in support of role in nuclear monitoring				
	IRIS Headquarters Office move to Washington DC				
		Implementation Agreement with Japan to cooperate on 9 joint GSN-NIED station in the Pacific.			
		USGS assumes support for O&M of the IRIS/USGS component of the GSN through new funding by Department of Interior.			
			Broadband Array becomes part of PASSCAL instrument pool.		
				ASL establishes real time connectivity to IRIS GSN stations	
				WILBER I established as a Web-based access tool	
				DMC archive exceeds 5 terabytes	
					E&O committee formed
					IRIS/USGS Traveling museum exhibit completed
					First three educational one-pagers published
					First "Teaching the Seismologists to Teach the Teachers" workshop

	Consortium	GSN	PASSCAL	DMS	E&O
1998	USGS established new $3.8 M per year budget line for GSN				
		Internet service is established at Siberian GSN sites with funding from NIMA.			
		The Hawaii-2 Observatory (H20) is installed as the first undersea GSN station midway between Hawaii and California.			
			First Broadband Array deployment by PASSCAL		
			PASSCAL begins support of the Texan active source instruments.		
			The two PASSCAL Instrument Centers are consolidated into one facility at New Mexico Tech.		
				50 terabyte StorageTek Wolfcreek mass storage system becomes operational	
					First E&O program manager hired
					E&O program planning workshop
					First teacher workshop at annual NSTA meeting
					Exploring the Earth poster (Northridge earthquake) published
					First 3 undergraduate summer interns
1999		GSN cooperation with US National Seismic Network for GSN upgrade of RSSD, South Dakota station.			
		Meteorological sensors are co-located at GSN-GPS sites in Russia			
		Satellite telemetry using VSAT technology is established to Galapagos and Uganda GSN sites, in collaboration with NASA/JPL.			
				DMC archive exceeds 10 terabytes	
					First undergraduate faculty workshop at annual GSA meeting
					Museum displays installed at the American Museum of Natural History in New York and the Carnegie Museum of Natural History in Pittsburgh
2000		GSN has 125 stations globally installed.			
				BUD - Real Time Data System becomes operational	
					AS1 school seismograph program initiated
					New museum display installed at New Mexico Museum of Natural History
2001	IRIS and NSF sign fourth Cooperative Agreement. First year funding is 12.6 M				
		VSAT links to Chinese GSN sites are established in cooperation with Chinese National Network.			
			PASSCAL receives the first Congressional funding through DOE to allow for replacement of data systems.		
				DMC archive exceeds 20 terabytes	
				360 terabyte Storage Tek Powderhorn mass storage system becomes operational	
					Educational Affiliate membership category approved by Board of Directors
					Educational 1-pagers translated into Spanish
2002		GSN establishes a satellite earth station at Pacific Tsunami Warning Center (PTWC) on Oahu with funding from NEID, Japan, and US National Weather Service/NOAA.			
		The first GSN station on line to PTWC and Internet is PTCN, Pitcaim Island (the VSAT also serves as Internet access for Pitcaim Islanders).			
		GSN initiates use of Comprehensive Test Ban Treaty Organization Global Communications Infrastructure (VSAT system) on a sharing basis at SJG, Puerto Rico, and LSZ, Zambia.			
				DMC archive exceeds 30 terabytes	
				SPYDER® products derived directly from the BUD real time system	
					Education and Outreach Program Plan published
					First three Educational Affiliate members
2003	IRIS, UNAVCO, Inc and Stanford University funded by NSF MREFC account to initiate EarthScope project.				
				Up to 800 stations flow into BUD in real time	
				DMC archive exceeds 40 terabytes	
				DMS Strategic Plan finalized	
					First 2 IRIS/SSA Distinguished lecturers speak at venues throughout US
					50th AS1 seismograph distributed to a school
					IRIS/USGS exhibit installed at the Smithsonian Institution Museum of Natural History

	Consortium	GSN	PASSCAL	DMS	E&O	USARRAY
2004	Twentieth year of IRIS Consortium					
	IRIS Board of Directors established to replace Executive Committee					
		GSN grew by 4 stations to total 137				
		86% of GSN data in real time				
		Great Sumatra Earthquake confirms GSN performance				
			Acquired 400 new PASSCAL dataloggers with DOE support			
			Broadband pool reaches 400			
				DMS archive exceeds 60 Terabytes		
				All data migrated to new storage media		
				Seamless access to distributed data centers added		
					First Seismographs in Schools training workshop	
					First Active Earth Display installed at Sunset Crater Volcano National Monument	
						DMC capacity expanded to support USArray
2005	Follow-up and lessons from Great Sumatra Earthquake					
	IRIS Board of Directors met for first time					
	Next 5 year proposal begins to take shape					
	Eighteenth Annual IRIS Workshop held in Tucson, AZ					
		GSN grew to 138 stations				
		Real-time telemetry added/upgraded at 11 sites				
			2000 First generation "Texans" delivered			
			New software for in-the-field "quick look" and troubleshooting issued			
			PASSCAL strategic planning workshop rethinks program goals			
				Data Handling Interface enables user applications to interact with DMC data		
				DMS shipped 11 terabytes of data including 540 million seismograms		
					Rapid Earthquake Viewer released (joint project with Univ. South Carolina and DLESE)	
						2007 O&M proposal submitted
						2004 First Flexible Array instruments received
						1998 Occupied new facility at New Mexico Tech
						Student siting of Transportable Array stations began
2006	100th anniversary of San Francisco 1906 earthquake					
	National Science Board authorized NSF to enter new 5 year cooperative agreement with IRIS					
	IRIS participated in training for the Indian Ocean Tsunami Warning system					
		Next generation data logger selected for GSN				
		USGS Caribbean Network added as affiliates				
		Real-time telemetry added/upgraded at 16 sites, linking 94% of GSN stations				
			Instrument loan program began			
			Polar Program s funded a proposal to develop poser and communications systems			
			Seventy experiments supported this year			
			Multi-platform version of PQL released			
				Completed migration of Tier 1 data to disk-based system		
				Archive growing at 14-15 terabytes/year		
				Surpassed 1 billion seismograms served		
				Data Management Workshop conducted in Sao Paulo, Brazil		
				Licensed SAC software for open distribution		

	Consortium	GSN	PASSCAL	DMS	E&O	USARRAY
						First summer intern orientation week
						Extended deployment of Transportable Array stations for Reference Network endorsed
						39 station Permanent Array completed
						Flexible Array plan changed to add broadbands; reduce "Texans"
						DMC began archiving data for all EarthScope components
2007	Participated in coordinators meeting for the China Earthquake Science Protocol					
	4 voting members, 2 Educational Affiliates and 20 new Foreign Affiliates join IRIS					
		First delivery of next generation GSN data logger				
		Three new GSN stations and 5 new Affiliates				
		Real-time links added/upgraded at 13 sites				
			Proposal for Polar instruments funded			
			Retired data loggers loaned to Bangladesh, Argentina, Kyrgyzstan and Costa Rica			
				Active Backup established in Socorro		
				OBSIP data made available		
				Third annual Data Management Workshop in Malaysia		
					First Active Earth Display kiosk	
					SeisMac released	
					Joint workshop for teachers with Africa Array	
						First Transportable Array stations adopted by U. of Washington
						O&M proposal re-submitted; approved
						First footprint of 400 Transportable Array stations completed
2008	IRIS Workshop held at Skamania Lodge					
	Revised IRIS web site launched					
		Two new stations bring GSN total to 152 stations (129 core stations and 23 Affiliates)				
		IDA and USGS adopted common interface box design for new data loggers				
		Fourteen next-generation GSN data acquisition systems installed in the Network.				
		Three real-time links added/upgraded; all but 5 sites now have real-time telemetry				
		Metrozet LLC and UC Berkeley developed new feedback electronics for STS-1				
			NSF conducted thorough review of PASSCAL			
			Instrument Owners Group organized			
			PASSCAL supported over 60 new experiments and 35 ongoing experiments			
			Data archiving process streamlined by new data delivery system			
			8 deployments of International Polar Year experiments in Antarctica			
				SPADE becomes available to make products available in addition to data		
				DMC serving roughly 28 terabytes of data per year; roughly 2 times the 15 terabyte input rate		
				Metadata workshop held near Kuala Lumpur, Malaysia		
					Seismographs in Schools online database launched	
						USArray construction completed on time; on budget
						EarthScope data portal launched
						Animation of seismic wavefield from USArray data available

Appendix III

The IRIS Web Site

In June of 2008 a new and improved version of the IRIS website was launched (www.iris.edu). Some highlights include:

Coordination Between IRIS Programs

All programs of IRIS were closely involved in constructing the look of the new website and also modifying their existing websites.

- All of the GSN pages were merged into the new website.
- PASSCAL has an area on the homepage to highlight their current experiments.
- The DMC revised the look of all of there pages to compliment the new look.
- USArray has a map on the homepage displaying the status of the Transportable Array.
- Education and Outreach completely reorganized and redesigned their pages to match the new look.

Content Management

The new IRIS Website is powered by a Content Management System (CMS). This CMS lets employees at IRIS edit pages on the IRIS website even if they have no background in website design. This allows the people most familiar with the content on the site to directly editing it. This also ensures that information can be quickly posted at anytime.

IRIS Image Gallery

Over the years IRIS staff and community members have compiled a large collection of photos related to IRIS programs and seismology. The IRIS Image Gallery seeks to highlight these images and also use them to help educate the public on the activities that IRIS and seismology researchers undertake. These images can then be used as a gateway for visitors to find out more about various programs at IRIS and experiments that IRIS supports. The Image Gallery also serves as a resource for educators and researchers to help find specific graphics and photos to use in their presentations.

PASSCAL Current Experiments

On the homepage there is a list of experiments that PASSCAL currently supports. This helps to highlight any current projects that IRIS is assisting with and helps educate visitors on how IRIS helps the greater geosciences community.

IRIS News

On the homepage there a list of news stories related to IRIS. These stories are written to inform visitors of anything new at IRIS such as workshops, events, important documents, or stories about IRIS's involvement in various projects.

Calendar

The IRIS Calendar serves to make the general public and IRIS members aware of any events that are approaching such as committee meetings or conventions that IRIS will be attending. This is also being used to highlight special events such as the Distinguished Lectureship Program.

Quick Links

On the left of the homepage visitors can quickly choose a page to go to on the website from the Quicklinks Menu. This lets more experience visitors to the website quickly go to the pages that they are interested without having to navigate to them.

RSS Feeds

IRIS News and PASSCAL Experiments are available as RSS feeds. These feeds lets users stay informed about anything new by using an RSS Feed Reader. These feeds also allow others to incorporate this information into their own website.

Appendix IV

IRIS Publications

Planning Documents

Publications resulting from workshops and community activities that formed the basis for core IRIS Programs

April, 1984	Science Plan for a New Global Seismographic Network
Dec, 1984	PASSCAL - Program for Array Seismic Studies of the Continental Lithosphere
June, 1986	Strategies for the Design of a Data Management System
Sept, 1990	Technical Plan for a New Global Seismographic Network
January, 1993	A National Program for Research in Continental Dynamics
February, 1994	Nuclear Testing and Non Proliferation
2001	Making Waves – the IRIS Education and Outreach Program Plan
2004	The IRIS Consortium: Twenty Years of Support for Seismological Research 1984–2004

Proposals

IRIS Proposals to the National Science Foundation that form the basis for Five-Year Cooperative Agreements

1984 – 1990	The IRIS (Rainbow) Proposal
1990 – 1995	"Understanding the Earth's Dynamics and Structure"
1996 – 2000	"A Science Facility for Studying the Dynamics of the Solid Earth"
2001 – 2005	"Exploring the Earth at High Resolution"
2003 – 2008	"EarthScope: Acquisition, Construction, Integration and Facility Management," MREFC Proposal (joint with UNAVCO, Inc and Stanford University)
January 2003	EarthScope MREFC Proposal
2006-2011	"Cornerstone Facilities for Seismology and Earth Sciences"
March, 2007	EarthScope Operations and Maintenance Proposal
February, 2008	IRIS PASSCAL Review

Regular Publications

IRIS Newsletters – Published 2-3 times per year, 1990-2007, the IRIS Newsletter provides a forum for information on the programs and facilities of IRIS and related organizations and highlights of scientific results of interest to Consortium members.

Annual Reports – Published each December, the Annual Report summarizes of the past year's activities for Consortium members, funding agencies and other interested parties.

IRIS Annual Workshops Abstracts/Programs

Education and Outreach Materials

The IRIS posters and "one-pagers" are concise statements of significant topics in seismology, intended to supplement teaching materials for classroom use, Limited numbers of hard copies are provided free of charge to teachers, and full-resolution versions are also available on the web. The one-pagers are also available in Spanish.

One Pagers

1. Watch Earthquakes as they Occur- An Intro to the Seismic Monitor
2. Why do Earthquakes Happen?
3. How Often do Earthquakes Occur?
4. Seismic Events of Special Interest
5. Exploring the Earth Using Seismology
6. How are Earthquakes Located?
7. H ow Does a Seismometer Work?

Posters

1994	"Exploring the Earth Through Seismology"
1995	"Topography And Seismicity of The Western United States"
1998	"Exploring the Earth Using Seismology"
2003	"The History of Seismology"
2003	"Global Seismographic Network"
2005	"Sumatra - Andaman Island Earthquake"
2006	"A Century of Earthquakes"

Other

Pulsing Earth lenticular
Rapid Earthquake Viewer: Did the Earth Shake Where You Live?
Seismic Tomography (with EarthScope)
Earthquakes DVD (with EarthScope)

USArray and EarthScopeMaterials

March, 1999	USArray Workshop in Albuquerque, New Mexico
September, 1999	USArray 2nd Workshop in Houston, Texas
December, 1999	USArray, A Synoptic Investigation of the Structure Dynamics and Evolution of the North American Continent
2000	A New View into Earth, EarthScope Brochure
2001	EarthScope Project Plan: A New View into Earth
2002	EarthScope: Scientific Targets for the World's Largest Observatory Pointed at the Solid Earth: Workshop Report
2002	EarthScope: An Unprecedented Opportunity for Education and Outreach in the Earth Sciences: Education and Outreach Program Plan
2007	EarthScope Facility Operation and Maintenance, October 1, 2008-September 30, 2018, Vol I-III, Proposal to the National Science Foundation
2006-2009	EarthScope onSite, issues 1-10, quarterly newsletter
2007	Participating in EarthScope: Hosting a Transportable Seismic Station, 2-pager
2008	Hosting Geophysical Instruments for EarthScope Experiments, 2-pager
2008	Developing Cooperative Educational and Research Seismic Stations: A discussion regarding the transition of TA station installations into regional network assets, brochure
2008	Education and Research Network Support Services: Subscription-Based Operations Support for Station Owners, 2-pager
2009	Seismic Tomography, 4-pager

Published Articles

Articles about IRIS projects and facilities authored by staff at IRIS or related facilities and IRIS committee members:

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Bibliography of IRIS-Related Publications

IRIS maintains a bibliography of papers based on the products of IRIS facilities that have appeared on major journals. In addition to containing references that have been provided to IRIS by the authors, this bibliography is updated each year by a search through a subset of the major Earth science publications: *Bulletin of the Seismological Society of America, Geophysical Research Letters, Geophysical Journal International, Seismological Research Letters, Geophysical Research Letters, Physics of the Earth and Planetary Interiors, Earth and Planetary Science Letters, Pure and Applied Geophysics, Tectonophysics, Geology, Tectonics, Science, Nature, The Leading Edge.*

The IRIS bibliography now includes more than 3000 papers citing IRIS or its facilities. A listing of these publications is available from the publications page of the IRIS web site.

Appendix V

Staff

IRIS Headquarters

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Josephine Aka	Business Analyst
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Lisa Green	Senior Accounting Analyst
Michael Hubenthal	Education Specialist
Leslie Linn	Executive Assistant
Patrick McQuillan	Education and Outreach Specialist
Robin Morris	Business Analyst/Contracts
Teresa Saavedra	Office Manager/Receptionist
Candy Shin	Director of Finance and Administration
David Simpson	President
Ruth Sobel	Business Projects Manager
John Taber	E&O Program Manager
Matt Toigo	Web Developer
Russ Welti	Software Engineer - Education and Outreach
Ray Willemann	Director of Planning
Robert Woodward	USArray Director
Rob Woolley	Director of Program Support and Special Projects

Kent Anderson	GSN Operations Manager
Rhett Butler	GSN Program Manager

Robert Busby	Transportable Array Manager
Anthony Gonzales	USArray Lead Construction Engineer
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Graylan Vincent	Reconnaissance Specialist

Data Management Center

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Rick Benson	Director of Operations
Rick Braman	UNIX Systems Administrator
Matthew Canfield	Data Control Technician
Rob Casey	Director of Software Engineering
Mary Edmunds	Data Control Technician
Gale Eschete	Office Manager (travel questions)
Un Joe	Data Control Technician
Peggy Johnson	USArray Data Control Analyst
Lonny Jones	USArray Systems Administrator
Linus Kamb	USArray Software Engineer
Tim Knight	Information Services Coordinator/Webmaster
Chris Laughbon	Senior Software Engineer
Anh Ngo	Operations Programmer
Thani Rojanaparpai	Data Control Technician
Sue Schoch	Senior Software Engineer (database specialization)
Gillian Sharer	USArray Data Control Analyst
Sandy Stromme	Software Engineer
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For complete PASSCAL Instrument Center Staff see:
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Participating Facility Organizations

U.S. Geological Survey

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Lind Gee — Scientist in Charge
(Total of 30 employees and contract staff, 1.6 supported by IRIS subaward)
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IRIS/IDA GSN

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IGPP
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Appendix VI

From: NSF-IRIS Cooperative Agreement EAR-0552316

IRIS: Cornerstone Facilities for Seismology and Earth Sciences

General Programmatic Terms and Conditions

1. Key Personnel: Except for the Principal Investigator(s) (PIs) or Co-PIs identified in this award, requests to make any changes to personnel, organizations, and/or partnerships specifically named in the proposal, that have been approved as part of this award, shall be submitted in writing to the cognizant NSF Program Official for approval prior to any changes taking effect. Requests for prior approval of changes to the PI(s) must be submitted through FastLane for review by the cognizant NSF Program Official and approval by an NSF Grants Officer.

2. Program Project Description: The Incorporated Research Institutions for Seismology is a university research consortium dedicated to exploring the structure and deformation of planet Earth through the collection and distribution of seismological and other geophysical data. With leadership from the U.S. academic research community, and through collaboration with other national and international organizations, IRIS manages facilities and programs in observational seismology that contribute to scholarly research, education, earthquake hazard mitigation and the verification of nuclear test ban treaties, through free and open data exchange. A permanent network of global observatories (the Global Seismographic Network) and a pool of portable instruments (the Portable Array for Seismological Studies of the Continental Lithosphere, PASSCAL) provide seismological data for fundamental studies of Earth structure and earthquakes. A Data Management System (DMS) ensures that all data collected by the GSN, PASSCAL and partner organizations are archived and effectively distributed. An Education and Outreach program (E&O) brings the excitement of earthquakes and exploration of our planet's deep interior to the public and the classroom.

3. Project Governance and Governing Responsibilities: The Awardee will ensure that an efficient and effective project governing structure is in place throughout the award period to support all critical or significant project activities.

The IRIS governance and management structure is an interface between the scientific community, funding agencies and the programs of IRIS. This structure, as defined in the IRIS bylaws, is designed to ensure close involvement of the research community in the development of IRIS facilities, to focus scientific talent on common objectives, to encourage broad participation, and to effectively manage IRIS programs.

IRIS President – chief executive officer of the Corporation, implements the orders of the Board of Directors and ensures that the purposes of the Corporation are carried out.

Board of Directors (9 members) – has full power in the management of the affairs of the Corporation, representing the interests of the research community and the consortium members.

Standing Committees (4 committees) - The four Standing Committees develop policies and provide detailed oversight of the four core programs: the Global Seismographic Network (GSN), the Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL), the Data Management System (DMS), and the Education and Outreach Program (E&O).

Other Committees reporting to the Board of Directors include:

1) Planning Committee – studies strategic problems and opportunities

2) Coordinating Committee – coordinates interaction among the core programs

3) Instrumentation Committee – responds to specific needs for technical advice

In addition, the President and the Board of Directors appoint special advisory committees and ad hoc working groups for specific tasks. It is the role of all appointed committees to develop recommendations for the Board of Directors, which in turn, evaluates and acts upon such recommendations.

4. Reporting Requirements: The Awardee will provide ad hoc and regular reports as designated by the NSF cognizant Program Official with content, format, and submission time line established by the NSF cognizant Program Official. The Awardee will submit all required reports via FastLane using the appropriate reporting category; for any type of report not specifically mentioned in FastLane, the Awardee will use the "Interim Reporting" function to submit reports.

Reporting requirements (in addition to those required by the general FATC):

1) An Annual Program Plan and Budget for the next fiscal year, due May 31 of each year, describing plans, activities, and

requested funding allocations to IRIS and its subawardees for the next year of support. Each IRIS program and all subawards will present individual budget requests on the NSF budget Form 1030 and any necessary attachments thereto. The Annual Progress Report and the Annual Program Plan and Budget will serve, in part, as the basis for IRIS' request for the next year's support and will be subject to review and approval by the NSF Program Officer.

2) A Government Performance and Results Act (GPRA) facilities report.

3) An annual financial report submitted by September 30 of each year showing a comparison between budgeted amounts approved in the Annual Program Plan and Budget and actual expenditures in the major budget categories for all IRIS programs. Significant variances (> $100,000) in the financial report will be brought to the attention of the NSF Program Officer.

Equipment Reporting:

1) Accountability of all equipment purchased with Government funds under NSF Cooperative Agreement No. EAR-0004370 is hereby transferred to this Agreement. An equipment inventory schedule is to be submitted to the Cognizant NSF Program Official by December 31, 2007 to be made a part of this Agreement by amendment.

2) Title to all equipment in excess of $5,000 purchased and/or fabricated with Government funds under this Agreement shall pass directly to the Government from the vendor.

3) The Awardee may request the transfer of title or other disposition action with regard to specific items of equipment. NSF shall issue a response or instructions to the Awardee no later than 120 calendar days after receipt of the Awardee's request. Upon expiration of the Agreement, disposition of the equipment will be determined by the Foundation in consultation with the Awardee (reference OMB Circular A-110).

4) IRIS may purchase and charge to this Agreement general purpose equipment budgeted for in the approved Annual Program Plan and Budget as justified to be used exclusively in carrying out the mission of the Awardee.

5. Awardee Support of Ongoing Management and Oversight: The Awardee will ensure full commitment and cooperation among the governing structure components, and all project staff during all ongoing NSF project management and oversight activities. The Awardee will ensure availability of all key institutional partners during any desk or on-site review as well as timely access to all project documentation.

Routine management and oversight activities of IRIS:

1) 2-3 meetings per year of the IRIS Board of Directors and Coordination Committee

2) 2 meetings per year of Program Standing Committees and Planning Committee

3) Annual Membership Meeting of the Consortium

4) Biannual IRIS Workshop

Special management and oversight activities to be carried out by IRIS:

1) The IRIS Consortium will consult broadly with the research community to develop a new long-range science plan for global seismology that will guide potential future improvements and enhancements to the IRIS facilities. The Board of Directors of the IRIS Consortium will develop a plan for carrying out this review and submit the plan to NSF by March 31, 2007.

2) IRIS will conduct a review of the PASSCAL Program to be completed by March 31, 2008.

3) IRIS will coordinate with EAR and GEO Education program officers to implement an external evaluation of the E&O Program to be completed by September 30, 2007. NSF will work with IRIS on a follow-up review and recommendations for program changes, as required.

Change-over and Phase-Out:

1) The Awardee recognizes that this Agreement may be terminated or that it may be replaced by a successor awardee in the performance of the kind and type of work described herein. The Awardee agrees to use its best efforts to effect an orderly and efficient transition from the Awardee to any successor awardee.

2) NSF will notify the Awardee in writing of any intent to terminate this Agreement six months in advance of the required date of termination unless a period of less than six months is specifically mandated by actions of the U.S. Congress, in which case NSF will give the Awardee as much notice as possible.

3) Further, in the event that the Awardee is replaced by a successor awardee or in the event that there is no follow-on agreement initiated by the Foundation that provides for substantially the work the Awardee is presently performing, the non-renewal shall be treated as Termination for the Convenience of the Government for purposes of reimbursing the Awardee for its costs for accrued employee benefits plus all costs otherwise allowable as of the date of expiration. However, the Foundation shall not be obligated to reimburse the Awardee for the severance pay due its employees who are given offers of substantially similar employment by a successor awardee, if such offers are made prior to the expiration of this agreement, except for the amount of such payments that would equal the salary of the employee involved during any gap in his/her employment and other accrued benefits of the employee

not assumed by the successor awardee. Nor shall the Foundation be obligated to reimburse the Awardee for the severance pay due employees who remain employed by the Awardee if such employment exceed one year after the date of expiration.

IRIS Responsibilities:

The Awardee shall be responsible for establishing, operating, maintaining, and managing the IRIS core programs, which consist of the Global Seismographic Network (GSN), a pool of portable seismic recording instruments (Program for Array Seismic Studies of the Continental Lithosphere or PASSCAL), the Data Management System (DMS), and Education and Outreach (E&O), in accordance with the NSF-approved Annual Program Plans and Budgets.

In addition, IRIS shall:

1) help coordinate access to seismic and other Earth science data collected with support from other national and international organizations.

2) engage in appropriate programs to inform the Earth science community about the potential uses of the IRIS facility and to keep the community informed about its accomplishments.

3) monitor the scientific, technical, and fiscal performance of all subawards made under the terms of this Agreement, ensuring that all NSF requirements are observed.

4) execute the scientific, technical, and fiscal responsibilities of IRIS projects supported by Federal agencies other than NSF and approved as part of this Agreement, ensuring that all NSF requirements are observed.

5) keep NSF informed of all activities carried out under this Agreement and other IRIS activities funded by Federal Agencies other than NSF.

NSF Responsibilities:

In order to facilitate the work done under this Agreement, NSF will:

1) cooperate in the coordination of the IRIS facility's programs and projects with other NSF-supported facilities and projects (e.g., EarthScope; seismology programs within OPP and OCE; educational programs in GEO and EHR) and with other Federal agencies (especially U.S. Geological Survey activities related to the GSN and DMS).

2) provide funding targets and guidelines to IRIS for the next year's program by January 1 of each year.

3) conduct an interim management review during the third year of the Cooperative Agreement. A report of this review will be submitted to the National Science Board (NSB) during the second half of 2009, and will provide more information for the basis of the decision to either allow the submission of a renewal proposal or to recompete the operation of this facility.

4) work with IRIS and other Federal agencies to address the critical issue of STS-1 sensor replacement (GSN refresh). NSF will convene an interagency and international working group during the second year of the Cooperative Agreement and work with IRIS to assess the prospects for support of new instrument design and construction.