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IRIS - A University Consortium for Seismology

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IRIS is a university consortium organized to provide modernized seismographic networks and data distribution facilities for the university research community and funded by the National Science Foundation (NSF). There are currently 50 member institutions, each of which is represented on the Board of Directors. Overall policy and scientific guidance is provided by this Board acting through a 7-member Executive Committee and three 9-member Standing Committees representing each of the program elements. Technical and management support is provided by the President, and a Program Manager or Director for the three operational programs which are 1) Global Seismographic Network (GSN), 2) Portable Array Studies (PASSCAL), and 3) Data Management Center (DMC). This paper presents the historical background of development of IRIS and a review of current operational programs.

INTRODUCTION

The concepts for a university consortium in seismology developed in in early 1983 along two parallel but independent paths. One path was leading to an upgraded global digital seismographic network and the other to a revitalized national effort in seismological studies of the continental lithosphere. Recognition of common interests and improved opportunities for funding led to the merging of these two efforts beginning in late 1983 and culminating with the incorporation of IRIS in May, 1984.

HISTORICAL DEVELOPMENT

Path to the Global Seismographic Network

In the early 1980's, reductions in the U.S. Geological Survey (USGS) budget threatened the operation of the World Wide Standard Seismographic Network (WWSSN). Although this network had a history of being vulnerable during periods of budget contraction when it had been the responsibility of other government agencies, it had always survived. This time, however, it was more seriously threatened. Options that were discussed and presented to the community of seismologists that used this important resource included, for example, cutting back to only one component for long and short period seismometers at each station and abandoning or seriously delaying the modernization program that was already underway to convert selected stations to digital recording. As part of the seismological community's response, the National Academy of Sciences published a report [Committee on Seismology 1983a], urging the continued support and upgrading of the WWSSN. Considering the landmark significance that the WWSSN had played during the previous two decades, university seismologists were galvanized to action. The objective became not only to save the network but to take the initiative in insuring that it would be expanded and modernized.

In July 1983, an *ad hoc* group of 20 scientists representing 10 academic institutions met at Harvard University to discuss a major new initiative in Earth Sciences, whose key element would be the establishment of a standardized global network of digital telemetered seismographic stations. Following that meeting, an embryo organization formed to bring these ideas to a wider audience.

At about the same time, but independent of these activities, the Committee on Science, Engineering, and Public Policy (COSEPUP) of the National Academy of Sciences (NAS) briefed George Keyworth, then Science Advisor to President Reagan, on five broad "targets of opportunity" that had the capacity to provide a rapid advance in the near future and that would contribute most to our understanding of Earth's interior and history. These ideas came to be known as the COSEPUP Initiatives. Two of the initiatives presented were global seismographic networks and crustal seismology.

On September 29, 1983, a briefing was held at the National Academy of Sciences to acquaint representatives of some nine government agencies and the National Academy Committee on Seismology with the plans of the academic group. Then, October 20 and 21, 1983, a workshop was held in La Jolla which was attended by some 90 participants representing academic institutions, government agencies, national laboratories and other interested organizations. Several participants came from overseas, indicating a very broad interest in these plans.

At this meeting, presentations were made describing existing networks, the scientific requirements for the new global network, and some concepts as to what this new network might look like. The attending group then decided to organize itself more formally as the Senate of an organization they named the Associated Research Institutions for Earth Sciences (ARIES). They elected a Board of Trustees, and charged an Executive Committee with the task of preparing a draft of a proposal to implement these ideas.

Path to the PASSCAL Program

The parallel and complementary Lithospheric Seismology Program of the NSF was the outgrowth of more than three years of study by a NAS Committee on Seismology panel charged with defining scientific needs and objectives and assessing instrumentation requirements for high resolution three-dimensional seismic studies of the continental lithosphere. The panel's deliberations included two major open meetings on the technical means required to implement these proposed studies. Some 60 scientists from universities, industry and government agencies attended an NSF-sponsored workshop at the May 1983 meeting of the Seismological Society of America in Salt Lake City. A second workshop held in the fall, with NSF and IASPEI support, brought the international community (over 25 non-US par-

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ticipants) into the process of working toward appropriate instrumentation [Commission on Controlled-Source Seismology, 1983].

A comprehensive scientific justification and technical basis for a major new research program to study the continental lithosphere was contained in a report by the Committee on Seismology [1983b]. In this report was a recommendation that a consortium of research institutions be formed to undertake large-scale array seismic studies of the continental lithosphere. Following this recommendation, an informal organizational meeting was arranged under the auspices of Carnegie Institution on November 21 and 22, 1983. At that meeting plans were made for an open national meeting to be held in Madison, Wisconsin, in early 1984.

The Merger

The ARIES Executive Committee worked diligently during the month of November preparing a draft of a science plan for the new global network and exploring the possibility of merging this effort with the developing continental lithosphere group. At the next meeting of the ARIES Senate and Board of Trustees on December 7, 1983, the following resolution was adopted.

"The Senate resolves that a corporation of research institutions be formed to seek funding for major research efforts in the earth sciences, which will include the development and deployment of a permanent global digital network and a portable regional digital network, and the establishment of one or more national seismic data and computational centers, and the Senate empowers the Board of Trustees to begin the process of incorporation."

Work continued on the plan defining the scientific objectives of the global network. This was reviewed again by the Board at a meeting on January 5 and 6, 1984, resulting in a document entitled *Science Plan for a New Global Seismographic Network,* [IRIS, 1984a]. At about this time discussions were held leading to a new name for the organization. In anticipation of its subsequent incorporation, ARIES was renamed as the Incorporated Research Institutions for Seismology (IRIS).

Meanwhile, the national organizational meeting of those concerned with seismological studies of the continental lithosphere, which was held in Madison on January 13 and 14, 1984, marked the formal beginning of the Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL). The purpose of the national meeting was to review the field of lithospheric studies and to establish a consortium of institutions which would form the nucleus of a major new program in seismology to carry out studies of the earth using a large mobile seismic array. By the end of the two day meeting that objective had been achieved.

The meeting was attended by 78 scientists and engineers representing 54 educational and governmental organizations plus substantial industrial representation. A Senate for the consortium was formed, consisting of one member from each institution represented at the meeting, and a Senate President was elected. On the second day of the meeting the Senate elected an eight man Board of directors empowered to carry out the formal tasks of the consortium.

The Senate noted the Dec. 7, 1983 resolution of the renamed IRIS group, and authorized its Board to undertake the task of joining with that group and to take the appropriate steps to form a non-profit corporation for seismology. That Corporation would have as its combined objective to serve the seismological community by coordinating large-scale experiments, acquiring and maintaining large numbers of portable seismograph instruments, implementing a global digital network, and overseeing a center for data archiving and distribution.

With this motivation IRIS was incorporated in the state of Delaware on May 8, 1984, with 26 founding members. At the initial meeting of the Board of Directors on May 13th, Thomas V. McEvilly was elected Chairman of the Board and Acting President, Shelton Alexander as Vice Chairman, Gilbert Bollinger as Secretary, and Brian Mitchell as Treasurer. As of that date IRIS began to function through an active committee structure, with standing committees for each of the program elements. Adam Dziewonski was appointed Chairman of the GSN Standing Committee, Robert Phinney as Chairman of PASSCAL, and Shelton Alexander and Stewart Smith as Co-Chairmen of the DMC.

During the summer of 1984 there were a number of committee meetings, and workshops, including one held at Princeton July 12-19 at which 22 participants worked on development of the PASSCAL Science Plan, [IRIS, 1984b], and on plans for the Data Management Center. The culmination of these and all previous activities of the group was the preparation of a 10-year proposal to the National Science Foundation [McEvilly and Alexander, 1984], submitted in July 1984. Support for the ideas in this proposal was reflected broadly in the scientific community. Particularly timely and supportive were a number of National Academy of Science reports including that of the Committee on Opportunities for Research in the Geological Sciences [1983], the Committee on Seismology [1983a] the Panel on Data Problems in Seismology [1983], and the U.S. Geodynamics Committee [1983].

In the plans for development of the GSN, from the outset there has been close cooperation with the U. S. Geological Survey (USGS). In early 1984, a letter of agreement was signed by IRIS and the USGS specifying the individual and joint responsibilities of both organizations. Briefly summarizing this agreement, IRIS will be responsible for plans and priorities, scientific guidance, technology studies, and a scientific data center. USGS will be responsible for test and evaluation, station agreements, installation and training, network support, data collection, and earthquake information. The intent is to use the resources of both IRIS and the USGS so as to maximize the scientific benefits of the GSN. To facilitate this, the USGS is represented on the Standing Committee of GSN, and all its subcommittees, and each organization has designated both a program coordinator and a technical coordinator.

In response to these initiatives, NSF approved a small grant in April of 1985, for planning purposes, which made it possible to proceed with the development. Stewart W. Smith was appointed President and Chief Executive Officer in July 1985, and in October a corporate office was established in Arlington, Virginia. At this point the IRIS program finally began its transition from an all-volunteer committee operation to fully operational organization charged with developing the seismological facilities needed by the university seismological research community. Further details on operations and development from this point onward can be found in the IRIS Annual Reports [IRIS, 1985 and 1986]

Current Program

There are currently 50 member institutions in IRIS, each of which is represented on the Board of Directors. Overall policy

TABLE 1. IRIS Member Institutions, 1987

INSTITUTION	REPRESENTATIVE
University of Alaska	Nirendra N. Biswas
University of Arizona	Terry C. Wallace, Jr.
Boston College	John Ebel
California Institute of Technology	Don L. Anderson
University of California, Berkeley	Thomas V. McEvilly
University of California, Los Angeles	Paul M. Davis
University of California, San Diego	John A. Orcutt
University of California, Santa Barbara	William A. Prothero, Jr.
University of California, Santa Cruz	Karen C. McNally
Carnegie Institution of Washington	Selwyn I. Sacks
Columbia University	Paul G. Richards
Cornell University	Bryan L. Isacks
University of Colorado, Boulder	Carl Kisslinger
Georgia Institute of Technology	Leland T. Long
Harvard University	Adam M. Dziewonski
University of Hawaii at Manoa	Charles Helsley
University of Illinois at Urbana-Champaign	Wang-Ping Chen
Indiana University	Gary L. Pavlis
Massachusetts Institute of Technology	Thomas H. Jordan
Memphis State University	Jer-Ming Chiu
University of Michigan	Thorne Lay
Michigan Technical University	Gordan E. Frantti
University of Minnesota	F. R. Schult
University of Missouri	Thomas J. Owens
New Mexico Inst. of Mining & Tech.	John S. Knapp
State Univ. of New York, Binghamton	Francis T. Wu
State Univ. of New York, Stony Brook	Clifford H. Thurber
Northern Illinois University	Phillip Carpenter
Northwestern University	Seth A. Stein
University of North Carolina	Christine A. Powell
Oregon State University	William Menke
Pennsylvania State University	Shelton S. Alexander
Princeton University	Robert A. Phinney
Purdue University	Lawrence W. Braile
Rice University	Alan R. Levander
Saint Louis University	Brian J. Mitchell
University of South Carolina	Richard T. Williams
Southern Methodist University	Eugene T. Herrin
University of Southern California	Ta-Liang Teng
Stanford University	George A. Thompson
Texas A&M University	Melvin Friedman
University of Texas at Austin	Arthur E. Maxwell
University of Texas at Dallas	George McMechan
University of Texas at El Paso	G. Randy Keller, Jr.
University of Utah	Robert B. Smith
Virginia Polytechnic Institute	Gilbert A. Bollinger
University of Washington	Robert S. Crosson
University of Wisconsin - Madison	Robert P. Meyer
University of Wyoming	Scott B. Smithson
Washington University, St. Louis	Douglas Wiens

and scientific guidance is provided by this Board acting through a 7-member Executive Committee and three 9-member Standing Committees representing each of the program elements. The makeup of the Board is shown in Table 1.

Technical and management support is provided by a staff consisting of the President, and a Program Manager or Director for each of the three operational programs. The status of each of these programs and the plans for the future are reviewed below.

Global Seismographic Network (GSN)

A site selection subcommittee of the Standing Committee for the Global Seismographic Network prepared a report [SCGSN, 1986] recommending specific sites for 51 new or upgraded digital seismograph stations over the next five years. To provide international coordination for this plan, IRIS has become a founding member of the recently organized Federation of Broad Band Seismic Networks described by Dziewonski and Romanowicz [1986]. This organization should provide an effective means for coordinating station siting, establishing instrumentation standards, and facilitating international data exchange.

The basis of the GSN siting plan was to have uniform global coverage to the extent that is feasible. For this purpose, the Earth's surface was divided into 128 equal area regions, corresponding to squares with dimensions of 18 degrees at the equator. An exercise that was carried out demonstrated that about 90% these blocks are suitable for seismograph stations, and made clear that if uniform global coverage is the objective, a good deal of emphasis needs to be placed on Pacific island sites. The list of sites that was recommended includes 39 existing stations as well as 12 new stations. Ten of the new stations would be located on islands in an attempt to improve oceanic coverage. In addition, a higher density of deployment is envisaged in the continental United States, with perhaps 10-12 GSN stations to be deployed there.

A development contract will be in place by March 1987 for production of prototype data-logging systems that satisfy the requirements put forth in *Design Goals for a Global Seismographic Network,* [SCGSN, 1985]. These systems will provide greatly improved data when they become available in 1988. In order to move ahead with upgrading the global network, some interim steps are being taken that will provide additional high quality digital data from selected stations.

DWWSSN Upgrades. Five sites have been selected for upgrading with Streckeisen seismometers in 1986 and early 1987. They are all DWWSSN sites, with digital data logging facilities available, so that the upgrade can be made with only minor modifications to the existing facility. Since the original sensors at these sites along with their normal analog recording will no longer be available, systems for digital simulation to produce visible recordings with the characteristics of these familiar instruments will have to be provided. This work is being funded by IRIS and implemented by the Albuquerque Seismological Laboratory of the USGS. The stations are Afiamalu (South Pacific), Quetta (Pakistan), Kevo (Finland), Toledo (Spain), and College (Alaska).

WWSSN Upgrades. Several sites may be upgraded in 1987 using data loggers similar to those developed at Harvard, [Steim, 1986]. These systems, designated as IRIS-I, include many of the features described in the IRIS Design Goals and should provide high quality new digital data for an interim period while the final IRIS-II systems are being developed. They feature 24-bit analog to digital converters with a 68020 based computer for digital filtering, data buffering, and dial-up capabilities for data transmission.

Effective in 1987, IRIS will take over the responsibility for funding the International Deployment of Accelerometers (IDA) project operated by the University of California at San Diego (UCSD) with the objective of upgrading it and integrating it into the GSN. The IDA equipment [Agnew et al ,1986] installed at many WWSSN stations as well as at some independent sites, has provided an important basis for much of the research work in low frequency seismology over the past decade. Since the equipment consists of a single vertical component instrument (LaCoste-Romberg gravimeter), which is sampled only once per 10 seconds, these instruments will be replaced with 3-component broad band systems as soon as is practical.

A new station in the IDA network of gravimeters is currently being installed on Easter Island. IRIS is cooperating with the UCSD and is providing additional funding such that the piers and facilities here can be made suitable for an eventual installation of a 3-component set of seismometers. Work is currently underway in constructing the vault. Since this is a fairly remote station, full development of an IRIS/IDA station will await an evaluation of the initial operating experience and technical support that is available on the island. This experience is of particular importance, since an early priority for IRIS is the development of other Pacific island stations such as Wake, Johnston, Kwajalein, and Midway. Noise conditions for horizontal component instruments are likely to be such that borehole installations may be necessary at these island sites.

A Data Collection Center to process data from this new network is being jointly developed by IRIS and the USGS at the Albuquerque Seismological Laboratory. When complete, it will be capable of processing a high volume of continuous broadband data from 100 stations, arriving either by telemetry or by mail, and transmitting it to the IRIS Data Management Center.

Portable Array Studies (PASSCAL)

Instrument Development. The PASSCAL Science Plan [IRIS, 1984b] spelled out in detail the need for an advanced portable seismograph system. The instrument envisaged would be digital, with high dynamic range and very low power requirements, and most importantly, it would be flexible and modular so as to be able to adapt to changes in technology that are likely to occur over the lifetime of the instrument. Since the plan is to make a major national commitment through the purchase of 1000 instruments, it is clear that we should not freeze in place the technology available at this particular point in time. The rapidly changing field of mass storage illustrates the most obvious example of this problem, but comparable changes in encoder technology, timing systems, and virtually every other part of the system are very likely over the next decade. To avoid obsolescence resulting from changing technology, a plan was made to evaluate the feasibility of communications bus approach to the design. With this concept, the seismic instrument might functions as a local area network, with each module being independent and able to communicate with the other modules in the system. A successful system of this sort could stave off obsolescence for a long period of time, by simply accommodating new modules as both the requirements for experiments and the technology change.

A development program was undertaken, with NSF support through the Carnegie Institution of Washington, in the year before IRIS obtained its first funding. The approach taken, under contract with the University of California at Los Angeles was a micro-power adaptation of a standard industry communications bus. The hardware for this system, referred to as the PASSCAL Bus Interface (PBI), was completed in the fall of 1985, and a demonstration of a modular system using the PBI was successfully carried out in September, 1986.

A request for proposals for development of the PASSCAL field instrument was released in October 1986. It was written with sufficient flexibility that bidders were able to make their own judgments regarding whether or not to use the PBI in the systems that they proposed. Although as of the date this manuscript was prepared, final decisions on the instrument procurement have not been made, it was clear that the PBI as originally envisaged would not be used by manufacturers. Suitable industry sponsored approaches to the problems of low-power, modularity, and upgradeability emerged, due in part to the participation of industry in the PBI project. Final evaluation of industry proposals is expected to be complete by February 1987.

Ouachita Experiment. Since the development time for PASSCAL instruments is foreseen as at least 3 years, in order to avoid a significant loss of momentum among the researchers in this area, a plan was developed for interim field experiments utilizing existing equipment. The first of these was carried out with leased equipment during May, 1986, in the Ouachita Mountains of southern Arkansas. The objective here was to study the deep structure of the buried Ouachita orogenic belt. In this experiment, the full wavefield was recorded with two deployments of 400 digital group recorders over a 200 km profile. The data collection featured wide bandwidth, 250 m station spacing, long offsets, and multiple explosive sources. With this data, and modern processing and interpretation methods, we can address some fundamental questions in this region concerning the Paleozoic continental margin, the presence of oceanic or continental crust, and the possibility of an ancient remnant of subducted lithosphere.

Basin and Range Experiment. The Basin and Range Province of western U.S. is a major continental rift zone, characterized by widespread Cenozoic volcanism and extension. It is a composite of individual grabens and half-grabens rivaled in extent only by the East African Rift. A number of plate tectonic models have been proposed to explain these features, but the data with which one can test and evaluate competing hypotheses is not yet available. To explore the crust and mantle structure in this area, PASSCAL co-sponsored a seismic reflection-refraction experiment in July, 1986, together with the USGS and the Air Force Geophysical Laboratory. Twenty eight shots, as large as 2500 kg, were detonated along a 300 km E-W line through Lovelock, Nevada, and along a 200 km cross line. Seventeen organizations participated in this experiment, involving nearly 200 independently recording systems and 384 channels of reflection recording equipment. Preliminary results of the experiment were presented by Keller et al [1986] and by Thompson et al [1986] together with a large number of papers at a special poster session held at the 1986 AGU meeting in San Francisco.

Data Management Center (DMC)

A workshop was held at NCAR in February 1986 for the purpose of defining the IRIS requirements for a data management system. The workshop report [Minster and Goff, 1986] was then used as an element of a solicitation for a detailed design study. This design study is now underway, with an expected completion date of March 1987. To serve the diverse needs of the user community, it seems clear that neither a fully centralized system nor a fully decentralized one is appropriate. With advances in low cost mass storage, communications, and computing capabilities, interest is focusing on the possibility of a hybrid system making use of the best features of both types of systems.

International Data Exchange. An important element of the IRIS Data Management Center will be to provide a convenient means of interchange of data with operators of other national and international networks such as the French effort known as GEOSCOPE [Romanowicz et al, 1984], and data centers such as that proposed by the Observatories and Research Facilities for European Seismology [Nolet et al, 1986]. Coordination between these and other international efforts will be facilitated by the recently organized Federation of Broad Band Digital Seismographic Networks [Dziewonski and Romanowicz, 1986], an organization affiliated with both International Lithosphere Program and and IUGG. This Federation will provide a forum for coordination of global station siting, recommendation of standards for data formats, and other important matters affecting the quality of the international data set.

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