2. BACKGROUND AND MOTIVATION

2.1. Introduction

This proposal represents the collective request from the U.S. seismological community for a set of modern research tools. The tools, or national facilities, will serve the earth sciences, as primary data sources, well into the next century. Replacement of the present vintage equipment with modern instrumentation and data management systems is a necessary step in achieving a major improvment in our ability to understand the earth's interior. The collective nature of the request reflects the unique requirements for extensive spatial coverage in seismological data acquisition. Present facilities are outmoded. Study after study by numerous review panels has pointed to the needs for modernization of equipment, data archives, and computational facilities in seismological research.

Our knowledge of the earth's interior is now limited by data quality and quantity. Theory and analysis techniques exist to improve substantially our view of the subsurface, beneath the thin skin accessible to the drill. Important questions in geodynamics, resources, and geological hazard demand this improved understanding of our earth. The IRIS program will provide the next generation of geophysicists with the means to address these questions.

2.2. Seismology A Quarter Century Ago

Today's facilities for seismological research are largely outgrowths of major U.S. multi-agency initiatives in the late fifties. The years following the International Geophysical Year saw several important new developments in the earth sciences, with major changes in seismology.

Twenty-five years ago plans were being formulated to deploy, at U.S. government expense, a network of 125 standardized seismographic stations. They were to be globally distributed, with long- and short-period recording of conventional photographic type, employing the then widely-used Benioff short period seismograph with a to-be-specified version of the newly developed Press-Ewing long-period instrument. A modern data archiving and distribution system was included, based upon state-of-art high-resolution photographic reduction of large paper seismograms to 70 mm film chips. Operation and maintenance facilities were to be developed at the U.S. Coast and Geodetic Survey facility in Albuquerque. Impetus for this major step was set out in a document(1) generated by a high level panel established by the President to address the needs for improving seismological research in the U.S. Implementation was effected by establishing specifications for the new network(2), which became the remarkably productive World Wide Network of Standardized Seismographs, known as WWSSN, and which still represents a primary data source for seismological research.

Twenty-five years ago in Denver, Colorado, the U.S. Geological Survey was operating a facility for crustal structure studies, supporting seismic refraction surveys using a ten-vehicle field system capable of deploying ten 5-element recording arrays at any time. Driven by the lack of information on crustal structure across the U.S., surveys were conducted in major tectonic provinces. Over several years' operation new models were developed for coastal California, the Sierra Nevada, the Basin and Range province, the mid-continent, and other regions, revealing substantial differences in the upper 50 km of the earth's interior throughout North America.

Twenty-five years ago seismologists in oil exploration were implementing two major new concepts in seismic reflection technology. In one, conversion was beginning to the new digital recording equipment, destined to revolutionize the way the industry processed, archived and exchanged data. The other concept involved a radical new approach to data acquisition and display; one which used the signal enhancement offered by stacking, or combining individually recorded data traces in such a way to improve reflected signal strength while reducing the amplitudes of unwanted signals, or noise. The advances achieved in the quality of seismic imaging of the shallow crust have been no less than phenomenal.

Twenty-five years ago the Department of Defense, through its new Vela-Uniform program for research on methods for the detection and identification of underground nuclear explosions, began a major program of university research support, also in response to the Berkner Panel Report(1). Among the completely new research tools spawned by this program were fixed networks of telephone-telemetered seismographic stations for investigations of local earthquake occurrence in the seismically active regions of the U.S. In addition, the program fostered the use of arrays of long-period seismographic stations in studies of the variations in crust and upper mantle structure, to depths of 100– 200 km, throughout the world.

With only moderate changes, these tools have served seismologists in making basic observations for the past quarter century. The stepwise expansion in the number of telemetered local networks during the seventies, in response to needs of the Earthquake Hazards Reduction Program and the growing questions on seismic risk in the siting of critical facilities, involved largely the use of well-established equipment and standard methods of analysis.

The effectiveness of these tools over the last twenty-five years is unquestioned in improving the state of knowledge in the earth sciences. Unprecedented advances in our understanding of the earth were achieved. Plate tectonic theory, inner core properties, earthquake source mechanisms, crustal deformation, continental accretion processes, and mantle dynamics concepts developed rapidly, fueled by the stream of new data.

2.3. Seismology Today

Seismology has taken full advantage of the infusion of resources seen a quarter-century ago. However, the tools are aging and becoming obsolete. It is time again to think in terms of new approaches which incorporate the many advances in instrumentation and computer technology. Seismology is a dynamic science, providing man's vision into his earth with which to address questions of pure and applied scientific importance. Several recent publications of the National Academy of Science/National Research Council address problems and opportunities in seismology(3,4,5,6,7). Appendix 3C presents extracts of summaries and recommendations from some of these documents. The recurring theme is our need to understand more fully the nature of our earth and the processes which have and continue to shape it, and the fact that significant resources are required in terms of new and improved seismological facilities if we are to gain such understanding. All these studies allude to the challenge in understanding the earth's lithosphere, and the bold new approaches required in seismology to undertake the mission. Specific recommendations are given in the referenced reviews. Some general statements from the various studies follow:

> "Man's expanding use of the earth as a habitat, as a source of water, mineral and energy resources, and as a receptacle of wastes cannot continue indefinitely at the current pace. Resources are becoming depleted, portions of the environment have become contaminated, and construction projects continue into areas that are potentially hazardous or that would be better used for agriculture, resources or recreation. Inevitably, we must have better understanding for resource discovery, waste disposal, and geologic hazard reduction. In many of these areas the need is immediate."(3)

> "The understanding of the earth's history must be focused on the continents, where resides the only evidence for 95 percent of earth history. The continents are the part of the earth on which we live, and are the terranes from which we will continue to derive the bulk of our natural resources. We are subject to natural hazards that are both the direct result of modern plate motions, such as earthquakes and volcanic activity, and the indirect results of processes far from modern active boundaries, such as earthquake activity that is apparently unrelated to plate motion and for which we have no process on which to base prediction theory, or the sinking of continental margins long after they cease to be a part of an active system."(7)

> "In the 1960s we accepted the conclusion that the earth's lithosphere moves horizontally. In the 1970s we developed theories to explain this movement and tested these

ideas against the present velocity pattern. In the 1980s we can and should determine the relative velocities of the plates as far back in time as the Mesozoic era and test our dynamic models against these data. In this way we can hope to understand more clearly the earth's most important present tectonic process."(6)

"The nature of the subducted lithosphere determines the amount and kind of material carried downward into the mantle, becoming a part of the convective pattern envisioned in the plate tectonics model. This subducted material bears directly on the evolutionary history of the earth's crust and mantle and on the sources of the earth's crust and mantle and on the sources of volcanic and plutonic rocks that arise from the mantle."(6)

"Seismological studies of the lithosphere can be expected to produce new concepts and data that are of fundamental interest to those involved in mineral and energy resource exploration and develpment."(7)

"Global seismic networks are as basic to seismology as the telescope is to astronomy and the accelerator is to physics. Without this instrumentation, seismologists are 'blind' to subsurface earth processes and properties and the very survival of the science would be threatened. Support of a modern global network of seismic stations is clearly in the national interest."(8)

"The study of earthquakes requires observatories that can measure them. Seismology is no different from any of the sciences in that both understanding and ability to respond to society's needs depend on reliable and precise measurements. If seismology is to make an effective contributin to the nation, it most employ the latest technology available to measure earthquakes. A special feature of seismology is that it not only provides the most detailed information about the structure of the Earth's interior, but it also relates to fundamental problems of economic importance and social well-being."(9)

"The rapid development of digital seismographic equipment and the increased availability of computers suitable for processing the digital data have led to demonstrations of the power of digital data for the solution of major problems that have been previously unapproachable. Calculation of the kinematic and dynamic properties of seismic sources and resolution of details of the structure of the earth's interior in three dimensions are two areas in which the use of digital data is already yielding significant new knowledge. These developments make it timely to evaluate the global seismographic observatory system and take remedial actions as needed."(3)

Seismologists from most of the major research universities in the U.S., some 60 institutions, have in the past nine months come together for the purpose of putting seismology on a sound course in terms of resources for the next twenty-five years' resarch. This response grew out of briefings on the solid earth sciences by the 1983 Committee on Science, Engineering, and Public Policy (COSEPUP), which contained the following conclusions:

"The Briefing Panel has identified five research areas in which significant dividends can be expected as a result of incremental federal investment in FY1985. These five research areas are:

1. Seismic Investigations of the Continental Crust
2. Continental Scientific Drilling
3. Physics and Chemistry of Geological Materials
4. Global Digital Seismic Array
5. Satellite Geodesy"

2.4. Motivation for IRIS

IRIS represents a realization that the seismological facilities needed in coming decades to conduct proper research lie beyond the operational resources and management capabilities of any single university. In particular, the equipment and associated support facilities required to put in place a capability for advanced study of the continental lithosphere (crust and upper mantle), or to establish and operate a modern global digital seismic network, would represent capital investment of several tens of millions of dollars plus a large annual operation/maintenance expense. Parallel develoments began in the areas of global and seismology, and these eventually led to IRIS as now structured and put forward under the new NSF program for lithospheric studies..

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 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.

Independent of these activities, a committee selected by the National Academy of Sciences (NAS) briefed the Science Advisor to President Reagan on five broad "targets of opportunity" that have the capacity to provide a rapid advance in the near future and that will contribute most to our understanding of the Earth's interior and history. Two of the subjects 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 network, and some concepts as to what this new network might look like. The attending group then decided to organize itself more formally into the Associated Research Institutions for Earth Sciences (ARIES)—naming members, electing a Board of Trustees, and charging an Executive Committee with the task of preparing a draft of a proposal to implement these ideas.

This committee worked diligently during the month of November and presented a draft to a meeting of the ARIES Board of Trustees on December 7, 1983. Further revision and input was reviewed again by the Board at a meeting on January 5 and 6, 1984, resulting in the document entitled *Science Plan for a New Global Seismographic Network(10)* prepared by the (renamed) Incorporated Research Institutions for Seismology (IRIS).

As these activities were taking place, much discussion was held on the organizational aspects of IRIS. Several models were studied including JOI (Joint Oceanographic Institutions), UCAR (Universities Corporation for Atmospheric Research), and USRA (University Space Research Association). In addition, the opinions of the full membership were sought at the two meetings of the general membership (October 20—21 and December 7, 1983). At this latter meeting 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."

The model adopted was essentially that of JOI, where the member institutions incorporated to form the umbrella organization under which the various activities take place.

The parallel and complementary Lithospheric Seismology Program is the outgrowth of 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 deismic 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.(11) A second workshop held in the fall, with NSF and IASPEI (Commission on Controlled-Source Seismology) support, brought the international community (over 25 non-US participants) into the process of working toward appropriate instrumentation.(12) A comprehensive scientific justification and technical basis for a major new research program to study the continental lithosphere is contained in the recently published NAS/NRC report on seismological studies of the continental lithosphere.(7)

The NAS/NRC panel report on lithospheric seismology(7), the Committee on Science, Engineering, and the Public Policy (COSEPUP) briefing to Presidential Science Advisor Keyworth, and the NAS report on Opportunities for Research in the Geological Sciences(3) all reflect broad community consensus that a major challenge for the coming decade is to describe and understand the composition, structure, dynamics and evolution of the continental lithosphere. To achieve that end, a bold new initiative in seismology is required; scientifically and technologically the time has come for a major step forward. The new program will entail instrumentation and computational requirements beyond the capacity of a single academic institution. The program is therefore multi-institutional in scope and will involve the cooperative efforts of a large sector of the seismological community.

The Academy report on lithospheric seismology(7) recommended that a consortium of research institutions be formed to undertake large-scale array seismic studies of the continental lithosphere. Following the recommendations contained in the Report, an informal organizational meeting was arranged under the auspices of Carnegie Institution and was held at the Department of Terrestrial Magnetism on November 21 and 22, 1983. At that meeting plans were made for an open natinal meeting to be held in Madison, Wisconsin, in early 1984.

The national organizational meeting 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).(13) 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 (January 14) the Senate elected an eight man Board of directors empowered with carrying out the formal tasks of the consortium.

The Senate authorized the Board to undertake the task of joining with the consortium for the Global Digital Network to take appropriate steps for forming a non-profit corporation for seismology (IRIS). That Corporation is intended to serve the seismological community by coordinating large-scale experiments, acquiring and maintaining large numbers of portable seismograph instruments, and overseeing a center for data reduction and archiving.

With this motivation IRIS came to be as a corporation on May 8, 1984 and through its initial meeting on May 13th of the Board of Directors of the 26-member consortium, IRIS began to function through an active committee structure. Reactions to the IRIS plan from prominent earth scientists have been very positive. This proposal represents the first step in implementing the IRIS science plan through a consortium structure.

2.5. Relation to Other Agencies

The IRIS program is closely related to seismological elements in several federal agencies. An inter-agency Memorandum of Understanding is presently being developed among NSF, USGS, and DARPA, with probable later incorporation of DOE. This MOU will set out the areas of interest and anticipated participation among the agencies. IRIS has already begun negotiations with USGS on implementation of the global seismographic network and portable array. In general terms, the relations of the IRIS program with the agencies is as follows:

USGS. The Survey has responsibilities for operation and maintenance of the present WWSSN and GDSN networks plus initial data acquisition, archive creation and distribution. The organization will be closely involved in implementing the new network (see the IRIS/USGS Letter of Understanding, Appendix 1D). In addition, elements in the Survey research programs require better definition of earth structure, as well as high quality data on earthquakes and tectonic processes. These programs will benefit substantially from the PASSCAL element of IRIS.

DARPA. DARPA supports initiatives in seismology which improve the national means for monitoring the occurrence of underground nuclear explosions worldwide. Part of this interest relates to the maintenance of effective convenient data bases for global seismographic data. IRIS improvements in global data quality and developments in data archiving and dissemination are of high interest to DARPA. Conversely, IRIS will benefit substantially from experience gained by DARPA in data base studies. Studies of the earth's lithosphere, under PASSCAL, bear heavily on the DARPA need for well-determined global crust and upper mantle properties.

NSF. IRIS impacts directly on COSEPUP-sponsored initiatives in the earth sciences. Two of the elements — The Global Seismographic Network and the Lithospheric Studies Program — form the basis of the IRIS scientific plan. A third new NSF initiative — CSDP, the Continental Scientific Drilling Program — is intimately related to the IRIS/PASSCAL element, in that crustal imaging by the seismic methods embodied in PASSCAL will guide CSDP site selection.

DOE. This Department has many connections to the IRIS program, though traditionally DOE efforts have continued in the National Laboratories. DOE has demonstrated the use of satellite telemetry in modern wideland seismographic observatories, in its RSTN stations now operating. IRIS global stations will complement the RSTN experiment. CSDP was proposed by DOE several years ago, and a substantial drilling program exists in thermal regimes. PASSCAL-type investigations will guide the drill in these areas. In fact, the Long Valley caldera, a feature of prime interest to DOE, is a proposed prototype test area for PASSCAL. The DOE geothermal program will benefit from improved methods of crustal studies to be pioneered PASSCAL.

Other agencies have peripheral connections to elements of the IRIS program, due to interests in some facet of earth structure or geophysical data. NASA, ONR, and the Department of Commerce are ready examples.

International interest is high in IRIS, and cooperative involvements have already been established in global network operations and in PASSCAL equipment and experiments planning. Initial steps have been taken with European, South American, and Canadian seismological organizations withinterests in working with the global network as both suppliers and users of data. Inquiries have come from individuals in other countries (i.e., Mexico, USSR) regarding possibilities of involvement. The committee on Controlled Source Seismology of IASPEI and The International Commission on The Lithosphere will provide important ties to the international community for PASSCAL.

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