Expanded Earthquake Monitoring and Rapid Hazards Notification in Nevada

a project proposed to the

Union Pacific Foundation

by the

The University of Nevada, Reno Foundation
for the
Seismological Laboratory of the Mackay School of Mines

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Table of Contents

Project Summary 2
Project Description 2
The UNR Seismological Laboratory 2
The Nevada Seismic Research Affiliates (NSRA) 4
Accomplishments from previous awards 5
Proposed project 9
Project budget 11
Project staff 11
Figures 12
Resumes of NSRA management and project staff 14
Seismological Laboratory Budgets 21
Corporate Support of the Seismological Laboratory 22
Attachment: Percentage of UNR Income from Government Sources ..... A
Attachment: UNR Financial Statement ..... B
Attachment: IRS 990 Report of the UNR Foundation, including list of Officers, Directors, and Trustees C
Attachment: Financial Statements of the UNR Foundation ..... D
Attachment: IRS 501(c)3 Letter of the UNR Foundation ..... E
Attachment: Mackay School of Mines Annual Report ..... F

Project Summary

The Seismological Laboratory of the Mackay School of Mines, The University of Nevada, Reno (UNR), is a state-wide research institute chartered to investigate the origins and effects of earthquakes within Nevada, and to inform the State and the public on seismic hazards. The Laboratory seeks funds from the Union Pacific Foundation to continue to expand earthquake monitoring to areas of Nevada not of interest to current Federally supported projects, that the State has also been unable to support. This project will increase the Lab's cooperative efforts with the operators of other regional seismic networks assessing eastern and southernmost Nevada, allowing more accurate characterization of earthquake hazards in these areas. In addition, this project will continue development of the Nevada Seismic Research Affiliates (NSRA) program of the UNR Foundation. The NSRA seeks to disseminate information on earthquake occurrence and hazards much more rapidly than has been possible in the past and, with public agencies and lifeline industries, to jointly research methods of reducing the economic and social impacts of earthquakes. Continued support from the Union Pacific Foundation will enable the UNR Seismological Laboratory to develop additional government and private funding for these publicly beneficial programs.

Project Description

The UNR Seismological Laboratory

The Seismological Laboratory at The University of Nevada, Reno (UNR) is a state-wide public research laboratory, created in 1974 by action of the University of Nevada Board of Regents. The Laboratory is responsible for monitoring seismicity and carrying out research on seismic hazard, tectonics, and earth structure in Nevada. In addition, the Laboratory carries out research nationally and worldwide through Federal funding. Our research activities contribute to the understanding not only of earthquake hazard, but also of natural resource occurrence, environmental hazards and waste containment, geothermal energy, water resources, and international efforts to monitor underground nuclear explosions. Although quite small in terms of state-funded personnel and operating budget, the Laboratory has been one of the most successful units of the University in terms of obtaining government grant support. Our academic and research staff are recognized worldwide.

The Seismological Laboratory plays an important role in graduate education. We provide graduate training in seismology and seismic hazard. In recent years eight Ph.D. and six M.S. students have graduated from our program. These students and their research contribute to the activities of the UNR Geological Sciences Department, especially to studies of tectonics and earth structure.

Governance— The Seismological Laboratory is directed by Professor James N. Brune, on behalf of the UNR President and the Dean of the Mackay School of Mines. Professor John G. Anderson is Associate Director.

Resources— The third academic faculty member in the Seismological Laboratory is Associate Professor John N. Louie. The Laboratory currently employs four Research Professors, five management and engineering professionals, six technical and administrative staff, ten graduate students, and seven undergraduate students (Attachment F). Laboratory staff are supported by an extensive network of seismic instruments in Nevada and eastern California to monitor and catalogue earthquakes. Including thirty-five broad-band digital stations and over 100 short-period stations, this monitoring network is the Lab's primary tool for research

and public service.

Data from this monitoring network is transmitted to the Laboratory almost exclusively through microwave facilities built by UNR personnel (Figure 1). A network of computers running the UNIX and MS-Windows operating systems, with 22 graphic workstations and servers from Sun Microsystems and Gateway, allows our staff to collect and interpret data from the Laboratory's seismic network. All of these computers have fast connections to the Internet. One of the principal results of our personnel's analysis of the seismic network's data is a catalogue of earthquakes occurring in the region. Within the area covered by the monitoring network, this catalog is now continuous and complete for events as small as Richter magnitude 2.0. Figure 2 is a map showing the distribution of the nearly 1400 earthquakes of various magnitudes located by the UNR Seismological Laboratory during 1996.

The 1996 calendar year was marked by continued interest by the press and the public in local earthquakes, with continued aftershocks of the widely felt Sept. 12, 1994 Double Spring Flat earthquake south of Gardnerville, Nevada (Figure 2). In the Reno metropolitan area, public interest sparked by the occurrence of the April 22, 1995 magnitude 4.4 Bordertown earthquake continued as it was followed by five more earthquakes in the 4.0 to 5.0 magnitude range, extending into early 1996. The 1996 seismicity map (Figure 2) also shows the sequence of magnitude 4-5 events near Ridgecrest, California that began November 27 and continued into 1997; a series of felt earthquakes in central Plumas County, California beginning with a magnitude 3.7 event on February 2; several felt events in northeastern Nevada, including a magnitude 4.4 earthquake on June 2 north of Ely; as well as the long-term continuation of small-magnitude earthquakes near the Delamar Mountains and Rainbow Canyon between Las Vegas and Caliente, which are of unknown origin. The public feedback to the UNR Seismological Lab that resulted from this activity has continued to drive the Lab's staff to increase outreach efforts to the public, the press, and regional industries and governments.

Outreach efforts during 1996 were increasingly successful in bringing accurate earthquake information to thousands of people. For example, our World-Wide Web pages now offer automatically updated maps of the most recent earthquakes interpreted by an analyst (Figure 3), and detected automatically (Figure 4).

The Yucca Mountain Seismic Monitoring and Analysis program, sponsored at the Seismological Laboratory by the U.S. Department of Energy (DOE), is a further example of the result of the Lab's strong history in seismic research, and its faculty with world-wide reputations. For this project we undertook a major expansion of our facilities and personnel to design and implement a new digital seismic network for Yucca Mountain, Nevada, that pushes the technological state-of-the-art. An old seismic network established 25 years ago to measure nuclear test effects in southern Nevada (Figure 5) is now being replaced with a broad-band digital network that monitors the microseismicity of the proposed high-level nuclear waste repository at Yucca Mountain, Nevada (Figure 6). Depending on decisions of congress regarding the disposal of nuclear waste, funding for this development may continue at $0.5 million per year over the next several years, largely covering development and operations.

Although the Seismological Laboratory has been very successful, its research and public service activities in the State of Nevada are limited and not well-balanced. Note the heavy concentration in Figure 7 of federally funded stations monitoring volcanic activity at the Long Valley Caldera, near Mammoth Lakes, California. This imbalance stems from the small amount of State funding we receive, and our consequent responsibility to concentrate our

seismic research activities in areas of current interest to Federal funding agencies. These areas have shifted with time, and have left the northern, eastern, and southernmost parts of the state poorly covered, resulting in a lack of uniformity in our understanding of earthquake hazard throughout Nevada.

The Nevada Seismic Research Affiliates— To address this imbalance created by the Seismological Laboratory's heavy reliance on Federal projects, the Seismological Laboratory initiated the Nevada Seismic Research Affiliates (NSRA) as a project within the UNR Foundation. Attachments C, D, and E describe the UNR foundation. The purpose of the NSRA is to promote research in seismology and earthquake hazard reduction activities in cooperation with public and private institutions and individuals.

One of the immediate functions of this program is to extend the Seismological Laboratory's high-quality earthquake monitoring and hazard-characterization activities to the areas of Nevada that are not of Federal interest. The northern and eastern region of Nevada may be of interest to the transportation, lifeline, and mining industries. Of interest to the public and to the tourism industry as well is the populous and rapidly growing southernmost region of Nevada encompassing Clark County. Neither region is currently covered by Federally funded monitoring projects, but new private funds have allowed modest efforts at expansion. In addition, some regions that can only be poorly monitored by UNR alone can be better characterized by increasing the sharing of data with other regional seismic networks. We have improved our rapid data exchanges with the networks in southern and northern California, and in Utah.

Example of the success of the NSRA are two recent grants totaling more than $150,000 to the Seismological Laboratory from the Keck Foundation. The UNR Foundation, working with the Mackay School of Mines, identified the NSRA and the Seismological Laboratory as one of six research centers of excellence within the School. After identifying the centers, the Foundation was able to win a $750,000 grant in 1996 to the Mackay School of Mines from the Keck Foundation, and two continuing grants of $1.125 million in 1997 and 1998. The NSRA will use the funds allocated by the School to the Seismological Lab to continue the purchase of instrumentation for a new, high-quality network of seismic recorders throughout Nevada and eastern California.

The advanced instrumentation, now in operation in northwestern Nevada and eastern California, is allowing us to more accurately characterize the magnitudes and mechanisms of local and regional earthquakes. Figure 2 shows how the accurate detection of earthquakes in eastern Nevada and the northern Sierra of California is now possible. In addition, these broadband digital recorders are measuring strong ground motions instantaneously, allowing the rapid computation and calibration of ground motion maps. As proposed below, we would like to continue to develop this capability into a facility to generate ground-shaking maps very soon after the occurrence of any earthquake, and transmit them to public agencies, industries, and the public. With such maps, the owners of critical sites can immediately identify those most at risk.

A Seismological Laboratory team comprised of J. Anderson, J. Brune, J. Louie, K. Smith, D. Von Seggern, and Y. Zeng will manage the activities of the Nevada Seismic Research Affiliates. One of the initial activities of the NSRA was to implement methods of rapidly disseminating earthquake information to affiliated researchers, and to the public. Such data are available at no charge. Some of the activities of the NSRA, such as joint research projects, development of the Nevada Broadcast of Earthquakes (described below), technology transfer,

internships, and student fellowships, are costly. Thus the Seismological Laboratory invites industries and individuals to contribute toward these costs to the Nevada Seismic Research Affiliates. All of the activities of the NSRA will be to the general and public benefit.

This proposal describes a $10,000 one-year continuation of a seismic research project to improve seismic network data quality, cooperation efforts, and the dissemination of earthquake and risk information in Nevada and eastern California. The UNR Seismological Laboratory respectfully requests continued support from the Union Pacific Foundation toward this publicly desirable effort. Any contributions may be made to the UNR Foundation, on behalf of the Nevada Seismic Research Affiliates, or on behalf of the Seismological Laboratory. In either case, the NSRA Management Team will assure that all funds are dedicated to these seismic research and outreach purposes.

Accomplishments from previous awards

In March of 1997 the Union Pacific Foundation generously granted $10,000 to the UNR Foundation, on behalf of the Seismological Laboratory, to underwrite seismic research and the development of rapid earthquake response. These grants have allowed significant broadening in the activities of the Seismological Laboratory beyond the interests of Federal agencies. The Nevada Seismic Research Affiliates Management Team has planned several activities for the one-year period following the most recent donation. Some of these activities have been completed, or are underway.

Monitoring network expansion— The Seismological Laboratory's expansion of microwave data-transmission facilities to north-central Nevada is now complete (Figure 1). These facilities are allowing improved earthquake detection coverage of northern and eastern Nevada. The relays have greatly improved the reliability of our broadband digital data from stations in central Nevada (Figure 7), and we are able to detect additional earthquakes in that region (Figure 2). Laboratory Engineer Walter Nicks and his staff have built the entire microwave network.

The receipt of more than $150,000 in funds from the Keck Foundation to purchase instrumentation has directed our efforts toward the installation of new stations in the Reno-Carson metropolitan area as well as the transportation and utility corridors to the north and northwest. Four stations are currently in operation (Figure 7): Beckwourth (BEK) in the Sierra Valley near the Feather River headwaters; an upgrade to digital station WCN in Washoe Valley just south of Reno; Pah Rah (PAH) between Pyramid Lake and Interstate 80; and Antelope (WAK) near the Walker River to better assess seismic activity along the Sierran Front revealed by the Double Spring Flat event.

Each of these stations features a sensitive, broadband seismometer linked to a 24-bit digital field recorder from Refraction Technology, Inc., a configuration standard among the most advanced seismic networks. While our DOE-funded Yucca Mountain seismic monitoring project has already developed the software and data analysis system to interpret the data, neither government nor Keck Foundation funding are available to install these new stations or their communications links, or to operate the network and interpret or disseminate the results. The newly received funds from the Keck Foundation should allow us to make similar equipment upgrades at 5-10 additional sites throughout Nevada and eastern California (gray ovals on Figure 7).

Over the past two years our state-wide monitoring efforts suffered serious setbacks due to cuts of 70% in U.S. Department of Energy funding of the Southern Great Basin Seismic Network (SGBSN; Figure 5). DOE funds can now maintain only the 24 new digital stations near Yucca Mountain (Figure 6), and provide no coverage of the Las Vegas metropolitan area. As the cost of maintaining a network in southern Nevada for earthquake hazard purposes is above $50,000, we are currently seeking funding for this effort from both government and private sources, through the Nevada Seismic Safety Council. Further Keck Foundation grants may provide equipment for an upgrade of station NEL (Figure 7), south of Las Vegas, and for a few additional high-quality stations in the area. With our current Union Pacific Foundation funds, we are relocating one or two of the existing SGBSN stations to better observe seismic activity in Las Vegas.

Processing conversion to UNIX and Data exchange— One goal of previously funded projects was to improve communication with the U.S. Geological Survey (USGS) and the National Seismic Network (NSN), by integrating real-time data from NSN stations (squares with crosshairs on Figure 1) into the event detection and location procedures we use. Routine inclusion of data from National Seismic Network stations in eastern Nevada would greatly increase our ability to detect and locate earthquakes in northern and eastern Nevada. The NSN is also considering installation of stations that would assist with earthquake characterization in the Las Vegas region.

However, the limited nature of the data input interfaces of our existing DEC VAX-based seismic processing system had prevented routine merging of outside data. Implementation of the UNIX-based processing system is now allowing location and magnitude estimation procedures that incorporate real-time data from the NSN stations, which Figure 2 shows has already improved our ability to locate events in eastern Nevada. As an additional benefit, the UNIX-based system has more easily and more quickly accommodated real-time transmission of UNR seismic data to other regional seismic networks, and to the USGS. USGS bulletins now include Nevada data and earthquakes.

The Department of Energy funded this development as part of the creation of a new network of broadband digital seismometers to monitor the proposed high-level nuclear waste repository at Yucca Mountain, in southern Nevada (Figure 6). The UNIX-based system is more robust, easier to adapt to new needs, portable to a large range of computer hardware, and much cheaper to maintain than the DEC VAX-based system. The Seismological Laboratory's new system has been in operation almost three years, and currently records two dozen seismic stations at Yucca Mountain, and the new Reno-area stations funded by the Keck Foundation, with exceptionally high quality and reliability. At the Laboratory, Drs. Ken Smith, David Von Seggern, and Glenn Biasi led the development of the new system, with software engineering assistance from consultants.

The transition of WGBSN stations to the UNIX-based processing system required that we adopt existing software into the system to provide for seismic wave arrival detection and measurement. This software was developed by the U.S. Geological Survey and is known as ''Earthworm.'' It is particularly designed to promote data exchange among seismological laboratories, and to allow rapid earthquake location at any institution using the best data from all networks. The remainder of the UNIX system, as currently running, includes all other necessary components such as data gathering, real-time archiving, and retrospective location and magnitude refinement. The USGS provided a $25,000 grant for us to purchase the equipment needed to bring data from existing WGBSN and SGBSN analog stations into

the UNIX system, and for completion of the software integration. We now have a complete Earthworm system in place have been trading data with the USGS and other networks for several months.

The Union Pacific Foundation has seeded an important improvement in the reliability and flexibility of our seismic monitoring operations. By funding the initial integration of the Earthworm seismic arrival detection and measurement software and the isolation amplifier design, the Foundation enabled us to seek funds to complete the conversion for more than 100 stations, providing effective seismic monitoring of much of Nevada. We have also been able to install and operate the equipment granted by the Keck Foundation.

Nevada Broadcast of Earthquakes development on UNIX processing system— At present, the Nevada Broadcast of Earthquakes (NBE; Figure 4) is also tied to the VAX-based seismic processing system, with the shortcomings described above. As we moved our operations to the Earthworm and UNIX-based systems for improved reliability and flexibility, it was imperative to also develop an equivalent system on the UNIX platform that will supply the NBE data stream. This will have the additional advantage that the NBE data will not need to suffer the delays of translation between the VAX and UNIX systems that it currently does. Importing the NBE facilities to UNIX using the ''Earlybird'' additions to the Earthworm system developed by the USGS is now underway, and will have the NBE data available immediately and natively in the Internet e-mail and World-Wide Web formats that we will use to disseminate the data to users and to paging systems. The re-configured Earlybird version of the NBE broadcast is expected to be available by the end of 1997.

We have for nearly two years offered the NBE broadcasts to the public via our World-Wide Web Internet interface (Figure 4; the address is ''http://www.seismo.unr.edu/Catalog/nbe.html''). Despite the large proportion of false events, public reaction to the broadcasts have been more balanced than expected. This reaction may be due to the availability of a large amount of warning and explanatory material within our Internet offerings and may also be due to the fact that the browsing public has become (partly through Foundation sponsorship of our services) more educated about the uncertainties of rapid earthquake response.

Given our increased ability to educate the consumers of our information broadcasts, we are continuing to enhance the availability of the NBE. Below we propose to continue efforts to make the NBE much more useful, by instantaneously computing ground-shaking intensity maps after each earthquake and offering them with our Internet services.

Internet services— We have continued and greatly expanded our Internet services to industry and the public. Several of the services already implemented, such as the UNRSL Record of the Day, the Recently Located Nevada Earthquakes (Figure 3), the Nevada Broadcast of Earthquakes (Figure 4), the Helicorder Camera, and the earthquake catalog sorting facility (e.g. Figure 2), require periodic updating and maintenance. In addition, the services require constant supervision to assure availability, and corrections for accuracy. We have employed undergraduates, such as Russell Brigham, who are adept at developing and maintaining these services. Brigham has in fact become known widely for his efforts and has designed and implemented Web pages for other organizations, most notably the Seismological Society of America (see his work at ''http://www.seismosoc.org'').

In late 1995, public notice of the UNR Seismological Laboratory's Internet services zoomed with publication of the availability of the Helicorder Camera and the Nevada Broadcast of Earthquakes. They were described in articles in the *New York Times* (vol. CXLV no. 50,258, Nov. 27 1995, p. C-5) and other national publications, and the weekly ''hit count'' exceeded 80,000 in a number of instances. Over the past two years the weekly hit count has averaged above 40,000. Our interpretation of these hit counts is that perhaps 2,000 to 4,000 different people access our Web site each week, from all over the world. There would simply be no other way for the Seismological Laboratory to make contact with this many people.

Thus our Internet services appear to be providing the public with increased awareness of earthquakes and their hazards, judging from hundreds of comments received from the browsing public. After adding and then upgrading an interactive form for people to describe their experiences during earthquakes they feel, we now receive dozens of reports after any event in the U.S., many within five minutes of the event. We also receive many reports after earthquakes felt in other parts of the world. This information has at times been our first notice of earthquakes in Nevada and California, and it has become so useful that USGS and other seismologists have subscribed to its distribution list. Since the Union Pacific Foundation provides virtually the only funding for our Internet developments, it deserves credit for seeding quite a far-reaching educational effort.

We continue to expand and improve our Internet services. For example, users searching earthquake catalogs will be able to make very simple queries (e.g.: ''get major events near Las Vegas'') as well as quite sophisticated ones (e.g.: ''get events within the stated region having the stated quality and station coverage''). This flexibility is needed because the users of the World-Wide Web interface range from school children to fellow seismologists. The output of a catalog search will be more flexible as well, ranging from simple maps to cross sections, volume visualizations, cross-plots with geologic and geophysical data maps, data bases of seismograms and time picks, etc. The serving of such data products, given the present access load, will likely require the implementation of distributed processing capabilities. Guided by John Louie, undergraduates have shown themselves capable of such developments, and we will be announcing new services frequently.

Other enhancements are scheduled to improve the quality and interpretability of most of the other maps (geological, seismicity, hazard, zoning, etc.). Russell Brigham is preparing maps that are functional and easy to interpret, from available data sources with existing software. Further improvements have been made in the range of topics covered by tutorials, examples, and lessons in seismology. We are developing additional material geared toward the K-12 audience, as well as detailed descriptions of our operations and research methods for our seismological colleagues. John Louie is overseeing the conversion of existing Seismological Lab materials into the World-Wide Web databases, in a manner similar to the on-line offering of earthquake preparedness information from the Nevada Earthquake Safety Council (at http://www.seismo.unr.edu/nesc/eamw/eamw.html). Creating additional explanatory materials on the Internet is assisting us in our task of informing the public, and of transferring seismic knowledge and technology to regional industries and agencies. The Foundation, by supporting this activity, is making an essential contribution to the welfare of the people and the industries of Nevada.

Proposed Project

The UNR Seismological Laboratory proposes to essentially continue and expand the above activities, made possible by previous grants from the Union Pacific Foundation. Continued funding will make possible some critically needed tasks that have no other source of support, during the proposed project period from April 1998 through March 1999. All of these tasks will contribute to the goals of expanded network coverage and rapid earthquake response articulated by the Nevada Seismic Research Affiliates.

Rapid maps of ground-shaking potential

The experience of the UNR Seismological Laboratory with public, Internet accessibility of the Nevada Broadcast of Earthquakes (NBE) encourages us to offer information that will be more useful for emergency response. Several seismological laboratories and the USGS are now testing the provision of on-line maps of ground-shaking potential within a few minutes after any potentially damaging earthquake. The NBE, whether in map, list, or pager form, currently offers only the estimated location and magnitude of recent earthquakes. Any interpretation of the hazard associated with a broadcast event is up to the user, who is unlikely to have the seismological training needed to properly evaluate any hazard.

There exist well-established methods of projecting the maximum acceleration of ground shaking of any locality due to an earthquake of known magnitude and location nearby. At the Seismological Laboratory, Drs. Ken Smith and Yuehua Zeng have become adept at these computations, and are producing maps of the regions surrounding candidate earthquakes, with contours or colors that estimate the maximum acceleration or velocity of shaking at any point on the map. They are now automating and speeding up these computations, so that a map will be generated for each significant event posted to the NBE, and available to anyone who may be interested. The reliability of the shaking estimates is closely tied to the accuracy of the earthquake's location and magnitude, and thus to the quality of the seismic network that records it. Our current efforts to upgrade seismic stations with foundation funds, and to improve reliability by moving to the UNIX and Earthworm system were crucial initial steps that are allowing us to implement these more quantitative informational broadcasts.

Such ground-shaking intensity maps can be very useful in hazard response because structural engineers can evaluate or design any structure for known limits in its ability to resist ground-shaking accelerations or velocities. They can also estimate the potential for rockfalls and landslides at particular locations, given the ground-shaking potential. Thus an industry or agency that knows the ground-shaking resistance capabilities of crucial structures could very quickly inspect a rapidly available ground-shaking map to see if any of their structures may be at risk. Their response to an earthquake will be much more effective, because they can target it to those facilities most at risk after the event.

We propose to continue to pay Drs. Smith and Zeng a few weeks' salary each, totaling $4500, to improve upon our initial attempts to provide ground-shaking maps to the public via our Internet server. Working with the USGS, the Nevada Seismic Safety Council, the California Seismic Safety Council, and NSRA industrial members, Smith and Zeng will continue to gather a list of the locations of sensitive and critical sites. They will develop an additional broadcast that, after each earthquake, sends out an ordered list by email or pager of the sites most at risk, to agencies and industries that request the service. We believe that continued U.P. Foundation funding of this effort is crucial to its success, as Federal and State agencies

have not provided such funding when we proposed it in the past. By fostering a more directed and concentrated response to the facilities most likely at risk after an earthquake, we hope the provision of ground-shaking maps will greatly reduce the economic and human impacts of earthquakes in our region.

Improvement of Internet services

We propose to improve as well as continue to maintain the Seismological Laboratory's Internet information services. We hope to use $3000 in Foundation funds to pay wages to undergraduate and graduate students who will maintain the World-Wide Web server, update its contents, and enhance its presentation of information. New efforts should lead to drastic improvements in the depth of information we present, to include more details on current earthquake activity, and more interactivity in the way the public can access and sort the information. These improvements will put a heavy burden on those maintaining the services to keep them available, and to regularly update a larger proportion of the server's content. Currently 7 to 15 student hours per week are needed to keep the server running and updated. Aside from the improvements in the rapid, on-line hazard maps proposed above, we propose several other significant enhancements to the World-Wide Web interface, and to its structure.

We propose here additional funds above the minimum needed to maintain our current Internet services. Several enhancements are badly needed in how we distribute earthquake data to our colleagues in seismology as well as to the public. The automatic maps we are now generating (e.g. Figures 2, 3, and 4) need to be enhanced to allow users to click on individual earthquakes for additional information. We would like to provide client-side image maps that will key a comprehensive page (also generated automatically) giving access to more detailed maps, seismogram data, and data from other institutions garnered through our Earthworm links to other seismological labs. Provision of real-time seismogram data and truly interactive images will require extensive programming of server scripts, and Java-language client software. This effort will require increased student and scientist hours for programming, and will require the configuration of an additional WWW server to answer the data requests. We will add hard-disk space and other enhancements to one of our existing UNIX machines to adapt it for heavy use as an Internet data server.

We hope to continue to support Russell Brigham, who has graduated and would like to enter graduate school in our program, as long as he remains a resident student. Russell, who is of Native American ancestry, also helped to implement our Internet services and was able to complete his Bachelor's degree in large part thanks to U.P. Foundation sponsorship.

We are seeking additional funds to support our Internet services through the Nevada Seismic Safety Council and proposals to Federal agencies. Some support for placing earthquake preparedness information on our WWW servers has been obtained from the Federal Emergency Management Agency. We are now better able to respond to requests for preparedness information that we receive regularly from the public. In any case we will maintain these services as one of our most important public outreach and educational efforts.

Graduate student training in the USGS Earthworm system

As the Seismological Laboratory makes its transition to a UNIX-based seismic network data-collection system developed by the U.S. Geological Survey (known as ‘‘Earthworm’’), we will continue to need to train our staff and students in the details of its maintenance and use. While our professional staff (e.g.: Smith and Zeng) are effectively receiving this training as they help to integrate the software, we need to assist additional students in getting training on the system, so they can then train others.

Proposed Project Budget, 4/98-3/99

Item	Amount
Network Scientists (Drs. Ken Smith and Yuehua Zeng)	$4500
Undergraduate Wages, Internet Service Development	3000
Hard Disks and Other Equipment to Configure Added WWW Server	2000
Travel for Graduate Student Training at USGS	500
Total Requested	$10,000

Project Staff— The proposed project will partially employ two UNR Seismological Laboratory Ph.D.-level scientists, and two undergraduate or graduate students. A graduate student will be funded to spend a week or more in training at the USGS on a software system. A number of Seismological Laboratory personnel will also contribute through technical work and student supervision.

Seismological Laboratory Budgets

Corporate Support of the Seismological Laboratory

As the tables above show, corporate and foundation support of seismic research in Nevada has recently risen dramatically. Corporate benefactors to the Seismological Laboratory (through the the UNR Foundation) in the last three years have been the Union Pacific Foundation, and William Lettis & Associates of California. William Lettis & Associates donated $37,000 over the past year to support the Consortium for Economic Migration and Tomography, and projects a similar level of support for the coming year. The Keck Foundation is a recent and major benefactor of the Mackay School of Mines, including the Seismological Laboratory. The Nevada Seismic Research Affiliates is channeling new outreach and seismic information products to the public as well as to interested corporations, and the NSRA will gain new participants in time.

Corporate support for other activities within the Mackay School of Mines has been continually strong, as outlined in Attachment F. The UNR Foundation has also garnered much additional corporate support, as reported in Attachment D.

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