Expanded Earthquake Monitoring and Rapid Event 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

15 August 1996

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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 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 seven Ph.D. and four 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. A committee of noted seismologists from outside Nevada provides scientific oversight (Attachment A, page 4).

Resources— The third academic faculty member in the Seismological Laboratory is Associate Professor John N. Louie. The Laboratory currently employs three Research Professors, a Postdoctoral Scholar, five management and engineering professionals, six technical and administrative staff, ten graduate students, and seven undergraduate students (Attachment A, page 48). Laboratory staff are supported by an extensive network of seismic instruments in Nevada and eastern California to monitor and catalogue earthquakes. Including twenty-

two broad-band digital stations and over 100 short-period stations, this monitoring network is the Lab's primary tool for research and public service.

Figure 1 shows the distribution of UNR seismic stations in Nevada and eastern California, as well as regional stations of the U.S. National Seismic Network. Data from these stations is transmitted to the Laboratory almost exclusively through microwave facilities built by UNR personnel (Figure 3). A network of computers running the UNIX and VMS operating systems, with 25 graphic workstations and servers from Sun Microsystems and Digital Equipment, 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 continuous and complete for events as small as Richter magnitude 2.5. Figure 2 is a map showing the distribution of the nearly three thousand earthquakes of various magnitudes located by the UNR Seismological Laboratory during 1994.

The 1995 calendar year was marked by continued interest by the press and the public in local earthquakes, after the widely felt Sept. 12, 1994 Double Spring Flat earthquake (Figure 2). In the Reno metropolitan area, public interest was maintained by the occurrence of the April 22, 1995 magnitude 4.4 Bordertown earthquake. This event, felt throughout the city, was followed by five more earthquakes in the 4.0 to 5.0 magnitude range, extending into early 1996. The 1995 seismicity map (Figure 2) also shows the continuing sequence of aftershocks of the June 29, 1992 magnitude 5.5 Little Skull Mountain earthquake, the largest event recorded in southern Nevada; as well as the long-term continuation of small-magnitude earthquakes near the Delamar Mountains and Rainbow Canyon between Las Vegas and Caliente, which is of unknown origin. The public feedback to the UNR Seismological Lab that resulted from this activity has driven the Lab's staff to significantly increase outreach efforts to the public, the press, and regional industries and governments. Outreach efforts during 1995 were more successful than ever before in bringing accurate earthquake information to thousands of people.

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 operate the Southern Great Basin Seismic Network for DOE's Yucca Mountain Project. Funding for this project will continue above $0.6 million per year over the next five to ten years, including both operations and research. The project has developed one of the most sophisticated seismic monitoring networks in existence, and provides a facility for obtaining funds for a wide range of research projects in addition to those directly related to the Yucca Mountain Project.

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. This 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, E, and F 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 to begin. 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 begun rapid data exchanges with the networks in southern and northern California.

An example of the success of the NSRA is a recent grant of $75,000 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 to the Mackay School of Mines from the Keck Foundation. The NSRA will use the $75,000 to purchase the instrumentation for a new, high-quality network of seismic recorders for the Reno-Carson metropolitan area.

The advanced instrumentation, now being installed, will allow us to more accurately characterize the magnitudes and mechanisms of local and regional earthquakes. In addition, these broadband digital recorders will measure strong ground motions instantaneously, allowing the rapid computation and calibration of ground motion maps. As proposed below, we would like 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 1996 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 work on the Fairview Peak and Mt. Lewis microwave relay stations (Figure 3) has been completed. In addition, the Virginia Peak relay was upgraded to allow the full-duplex transmissions required by the advanced network instrumentation. These relays will allow improved seismic station coverage of northern and eastern Nevada. They are the first two legs of three that will allow continuous data reception from seismic monitoring stations hundreds of miles from UNR in eastern Nevada, without the expense of leased telephone lines. The relays have already improved the reliability of our broadband digital data from the nearby stations WHR, KVN, and BMN (Figure 1). Laboratory Engineer Walter Nicks and his staff are building the entire microwave network.

The receipt of $75,000 in funds from the Keck Foundation to purchase instrumentation has re-directed our efforts in the installation of new stations toward the Reno-Carson metropolitan area as well as the transportation and utility corridors to the north and northwest. Five stations are currently being installed (Figure 1): Beckwourth in the Sierra Valley near the Feather River headwaters; an upgrade to digital station WCN in Washoe Valley just south of Reno; Pah Rah between Pyramid Lake and Interstate 80; an advanced station in Reno to measure sediment site effects within the metropolitan area; and Antelope near the Walker River to better assess seismic activity along the Sierran Front revealed by the Double Spring Flat event.

Each of these stations will feature 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. It is possible that the Keck Foundation may make similar grants to us in each of the next two years, to allow the location of such high-quality stations in eastern and southern Nevada.

Over the past year 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). DOE funds can now maintain only the 24 new digital stations near Yucca Mountain, 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 1), south of Las Vegas, and for a few additional high-quality stations in the area. We propose below to relocate 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 the ELK and WVOR National Seismic Network stations (Figure 1) 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 tests of location and magnitude estimation procedures that incorporate real-time data from the NSN stations (Figure 1). As an additional benefit, the UNIX-based system will more easily and more quickly accommodate real-time transmission of UNR seismic data to other regional seismic networks, and to the USGS. For these reasons we are developing a complete transition of Western and Southern Great Basin Seismic Network stations to the UNIX-based processing system.

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. 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 two years, and currently records two dozen seismic stations at or near 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 requires 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 has 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 expect to have a complete Earthworm system in place and trading data with the USGS and other networks before 1997.

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) is also tied to the VAX-based seismic processing system, with the shortcomings described above. As we move our operations to the Earthworm and UNIX-based systems for improved reliability and flexibility, it is 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 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 NBE software system is built of several components. Some, such as the real-time data examination facilities, are currently designed for the VAX-based system and are requiring extensive re-configuration to work with the new UNIX-based system. Others, such as the notification modules, have already been re-configured for UNIX. The re-configured NBE broadcast is also expected to be available by 1997.

We have for wnearly a year 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 (see below) 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. Recent possible earthquake locations and magnitudes are now available to Internet browsers in plotted map form as well as in text list form. Below we propose 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 (Figure 4), such as the UNRSL Record of the Day, the Nevada Broadcast of Earthquakes, the Helicorder Camera, the earthquake catalog sorting facility, and the weekly maps of seismic activity, 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 Douglas Ring and Russell Brigham, who are adept at developing and maintaining these services. Brigham and Ring have in fact become known widely for their efforts and have designed and implemented Web pages for other organizations, most notably the Seismological Society of

America (see their 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 year the weekly hit count has averaged between 20,000 and 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, on-line searches of the earthquake catalog now produce both maps and simple lists of earthquake locations and magnitudes (at ''http://www.seismo.unr.edu/Catalog/catalog-search.html''). We are further enhancing this interface to allow both simpler and more detailed catalog analysis. Users 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 our Lab brochure (Figure 4). 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 1997 through March 1998. 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. A proposal made by several seismological laboratories and the USGS is to provide 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 have made trial runs that produce a map of the region surrounding candidate earthquakes, with contours or colors that estimate the maximum acceleration or velocity of shaking at any point on the map. They are ready to automate and speed 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 are crucial initial steps that only now allow us to consider 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 pay Drs. Smith and Zeng a few weeks' salary each, totaling $4500, to implement and test the rapid provision of 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 also 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 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.

Maintenance of Internet services

We propose to 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. Current efforts should lead to drastic improvements in the types of information we present, to include more graphical forms of information 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. Aside from the development of rapid, on-line hazard maps proposed above, we thus propose no other significant enhancements to the World-Wide Web interface, or its structure. Currently 7 to 15 student hours per week are needed to keep the server running and updated, so we propose here the bare minimum to maintain its availability.

Recently Douglas Ring, one of the undergraduates who implemented our services, was able to take a full-time position elsewhere in the University. We hope to continue to support Russell Brigham, who has graduated and is entering 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. If any of this support is realized, we will be able to respond to requests for further enhancements 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.

Relocation of SGBSN stations to the Las Vegas area

Examination of Figures 1 and 2 show that the Seismological Laboratory's seismic network in southern Nevada does not adequately cover the Las Vegas metropolitan area, and completely lacks stations to the west and southwest of the city. The existing Southern Great Basin Seismic Network (SGBSN) was configured to monitor a potential nuclear waste repository area at the Nevada Test Site. We propose here to greatly improve seismic monitoring of the urban area by moving a few analog stations from that network to the southwest fringe of Las Vegas Valley.

Although originally owned by the Department of Energy, control of the station equipment has been passed to UNR. We only lack the staff technician support needed to permit and construct new station sites, and relocate the monitoring equipment to them. Our microwave telemetry network is already adequate in the area and will not need enhancement to support the relocated stations. With the $2000 proposed here we should be able to permit and construct two or three new sites, and relocate existing equipment to them. The new sites will vastly improve our ability to detect and measure very small earthquakes in and near Las Vegas. Such information has not been available before, and will help estimate the potential for larger, damaging events. We hope to use the small events to gain attention from other funding agencies interested in urban seismic hazards as well.

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 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 at least one student in getting training on the system, so he or she can then train others.

We propose to send one of the most capable students in our Ph.D. program, Gene Ichinose, to train on the Earthworm system where it is being developed by the USGS in Menlo Park, California. We feel that a training period of a week to ten days will be most effective to allow Gene to learn the details of Earthworm, and we propose to use Foundation funds for his travel expenses for it. Gene is interested in such systems, and will be one of its most frequent users in the course of working on his thesis research. He will be able to use his training to investigate how to improve the reliability of the Nevada Broadcast of Earthquakes, and to assist Drs. Smith and Zeng in developing the rapid ground-shaking maps facility.

Proposed Project Budget, 4/97-3/98

Item	Amount
Network Scientists (Drs. Ken Smith and Yuehua Zeng)	$4500
Undergraduate Wages, Internet Service Development	3000
Southern Nevada Seismic Station Relocations	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, Gene Ichinose, 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. The Keck Foundation is a recent and major benefactor. 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 A. The UNR Foundation has also garnered much additional corporate support, as reported in Attachment D.

Attachment A: Mackay School of Mines Annual Report
Attachment B: UNR Operating Budgets
Attachment C: Directors of the UNR Foundation
Attachment D: Financial Statements of the UNR Foundation (2 parts)
Attachment E: IRS 501(c)3 Letter of the UNR Foundation
Attachment F: IRS 990 Report of the UNR Foundation