

U.S. Educational Seismology Network

A Buyer's Guide for Educational Seismographs

SUMMARY

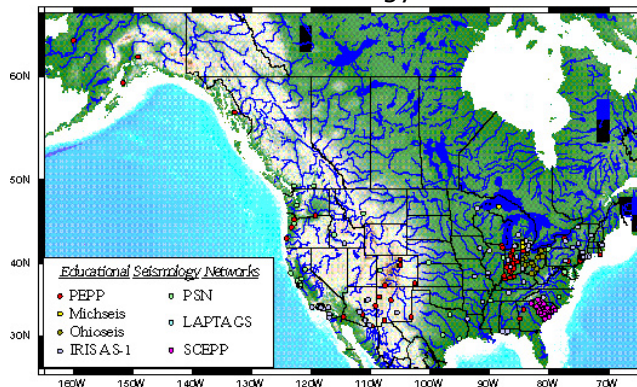
This document provides background information for teachers, administrators, and technology support staff involved in acquisition, installation, and operation of a seismic instrument in schools. We provide background information on the U.S. Educational Seismology Network, information on educational opportunities afforded by educational seismographs, and technical information designed to help you get started with purchase and installation of a seismic instrument for your institution.

BACKGROUND

The U.S. Educational Seismology Network, or USESN, is a consortium of educational institutions whose mission is to promote the use of seismographs and seismic data for science education. Our vision is to develop a vibrant national network of academic researchers, college faculty, and school teachers, whose common goal is to enhance science education through the study of seismology. We envision development of a robust network of educational seismographs, recording and networking software, together with pedagogical resources, that allow teachers and students to utilize state-of-the-art seismological data and tools in a wide variety of educational settings. We seek to enhance students' exposure to high-caliber scientific research for students in Physics, Earth Science, and Environmental Science classrooms across the country, and to provide a new resource that can be used for seismological research.

The primary goals of the organization are to:

- (1) promote the installation and effective use of educational seismographs and seismic data;
- (2) disseminate high-quality curricular materials and educational services that promote the use of seismology in science education; and



- (3) provide an organizational framework for coordination and advocacy of educational seismology across the country.

USESN efforts now include regional seismic networks in Michigan, Ohio, Indiana, Oregon, South Carolina, Georgia, Arizona, Colorado, Massachusetts, California, and Nevada, as well as distributed seismic efforts across the country.

Additional information on the USESN can be obtained from <http://www.indiana.edu/~usesn/>

RATIONALE

Educational seismology offers a special opportunity for capturing a student's innate curiosity about natural phenomena in the world around them—and this curiosity can be used as a platform from which a wealth of fundamental principles of physics and earth sciences can be taught. Earthquakes, by virtue of their awesome power, their unpredictability, and the

broad, sometimes tragic, impact they can have on the daily lives of people, have tremendous potential to capture the attention of students of all ages. If teachers are prepared, they can use this interest to enhance their teaching of mathematics, physical science, earth science, and even social studies. Seismology can be used as a 'hook' and a starting point for teaching fundamental concepts and skills through investigation of real scientific problems with real data. Seismology encompasses a broad array of scientific concepts, ranging from energy flow and elasticity, waves, resonance ... graphing, logarithms, averaging, statistics ... measurement, scientific instrumentation, ... electricity, magnetism, current, voltage, ... use of computers for data collection and communication, ... hazards awareness, preparedness, community response, and government, ... Educational seismology provides a mechanism by which our community can harness the power of earthquakes to educate our students.

By operating a seismograph in your school, you can open to your students many opportunities for hands-on studies in physics, earth science, computers, and geography. Because seismographs record ground motion from nearby and distant earthquakes, they can be used to examine a wide variety of Earth phenomena, from plate tectonics to wave propagation to deep Earth structure. Even a research-quality instrument is affordable, with a little help from friends of your school's science program. A demonstration instrument can even be built from a kit. When connected via your PC to the Internet, your seismograph becomes a part of a global community of stations that share data for the study of earthquakes and the study of Earth's interior. The seismograph provides a vehicle for teaching at different levels and in different contexts, for classroom instruction, as well as for project work. The topics taught cut across disciplines, but have documented connection to science standards. Operation of an educational seismograph can bring the school science program into collaboration with university or industrial mentors, as well as with teachers and schools around your region—and around the globe.

Teaching across the disciplines

The seismic instrument at your school provides a tangible focal point for teaching many topics that are a core part of middle and high school science curricula. A seismic station in your school will bring into play many different topics in science. It provides classroom and project topics for General Science, Physics, Earth Science, Environmental Science, and Computer Science. It brings Mathematics and Physics into the realm of a 'real-world' application. It brings your class into contact with the research community, both through the utilization of global earthquake data and the possibility of providing data to the world of research.

A few specific examples of seismology-related curricular topics are noted below:

Earth Science, Geography, and Environmental Science:

- World geography: earthquakes, volcanoes, oceans, mountains
- Scientific research methods: maintaining a record of scientific observations
- Phenomenology of earthquakes and volcanic eruptions
- Computer applications: Use of the internet to access scientific data
- Mitigation of Natural Hazards
- Plate tectonics
- Seismic waves, Earthquake location, magnitude determination
- The earth's crust: continental and oceanic.
- Common rock types in the earth.

High School Physics:

- Force, velocity, acceleration
- Electromagnetism: current, voltage, electromotive force
- Simple recording circuit with oscillographic display
- Damped pendulum
- Simple wave motion
- Optics (refraction and reflection)

Seismology and Science Education Standards

A curriculum that incorporates a seismic station and its related tools and technologies addresses a number of the key pedagogical aspects of the National Science Education Standards, as well as providing many opportunities to address the content standards for your state. These newly emphasized aspects are:

- Hands-on projects.
- Problem-solving activities
- Cooperative activities
- Relationship with the real world

Resources for classroom use in the school continue to be developed by several University groups (see, for example, the Seismological Society of America's compilation at [URL???]), providing the teacher with appropriate tools for adapting their course syllabi to the context of a seismograph.

Furthermore, a seismograph involves students and teachers in an authentic utilization of the Internet, going well beyond mere access to the Web. It requires data to be exchanged with data centers and with other school sites, and makes it possible to develop on-line collaborations with other schools within a region and across the globe.

Participating schools should consider bringing a professional scientist into their seismometer program as a mentor and technical resource. This is a strongly recommended method for strengthening the school's overall science teaching.

Using curriculum tools which have been developed, and which are continuing in development, you will put together your own mix of seismology-related classroom topics into the courses you teach. These topics demonstrably address many of the content standards of the National Science Education Standards.

Student Research Opportunities

Schools participating in educational seismology programs will open their students to extraordinary opportunities to take part in scientific research about the world around them. Access to a seismograph and seismic data offers students an opportunity to utilize material that they have explored in earth science, physics, mathematics, and computer science classes—and apply them to visible problems that affect our world. It allows them to explore data, develop hypotheses, design experiments that test these hypotheses, and present their scientific research. In short, educational seismology offers students an opportunity to experience first-hand the world of scientific research. Research opportunities range from

small, research questions developed in the context of a single laboratory session to larger, independent or group research projects that lead to science fairs, regional research symposia, or even presentation at national scientific meetings.

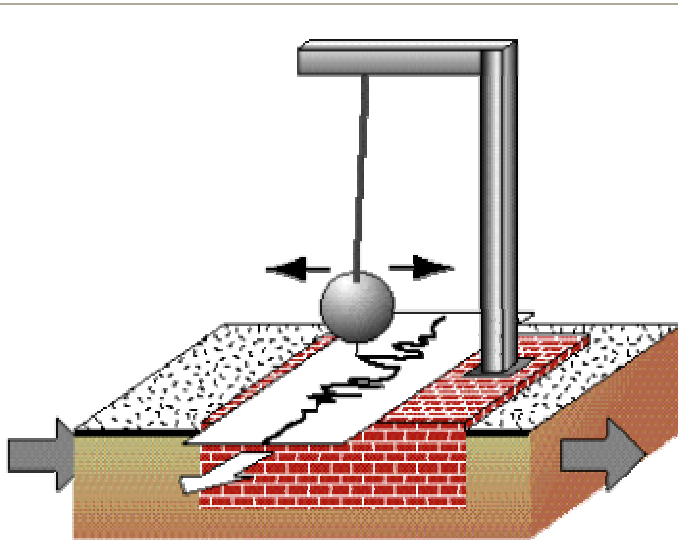
Value to the Research Community

The educational seismology movement provides value not only to the educational community, but for the research community as well. A new generation of research-quality seismic instruments is being deployed around the country and around the globe. These seismographs provide valuable new data on earthquake location and magnitude, on Earth structure, and on wave propagation that would otherwise be unavailable to the scientific community. Particularly in areas of limited seismographic coverage, such as the central and eastern U.S., educational seismographs can provide the core of regional monitoring efforts, and their data can be critical when earthquakes unexpectedly occur in intraplate seismic zones.

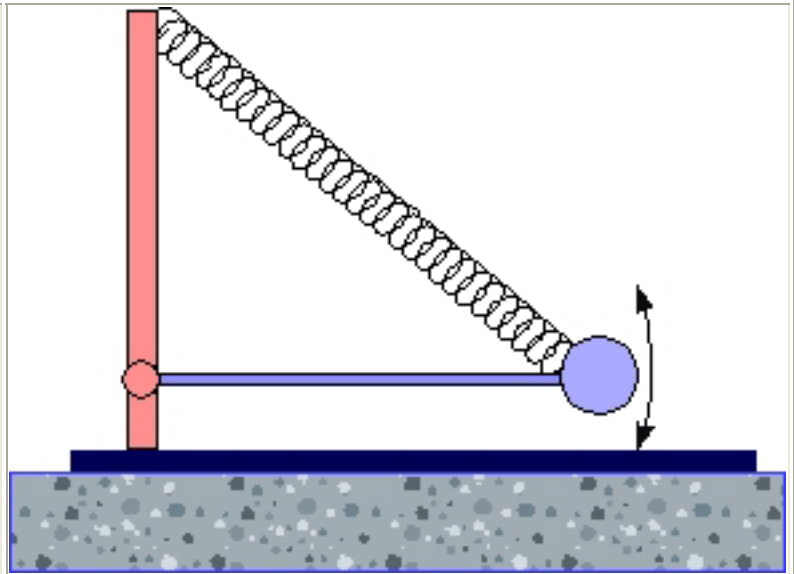
TECHNICAL BACKGROUND

A seismometer is nothing more complex than a sensitive detector of ground vibrations. The mechanical core of the system is usually a spring + mass system, with associated electronics; it may be regarded as the same sort of device as a sensitive microphone. A seismometer may be also thought of as a electrical generator, in which the ground vibrations are converted into a electrical voltage. It responds to frequencies below the audible range, from 20 Hz to below 0.05 Hz. These frequencies are readily transmitted through the earth as vibrational waves, with speeds ranging from 2.5 to 13 km/sec [for comparison, sound travels in air at 300 m/sec]. The instrument produces a time-varying voltage, which can in turn be displayed as a seismogram.

Conceptual sketches of a simple seismometer.

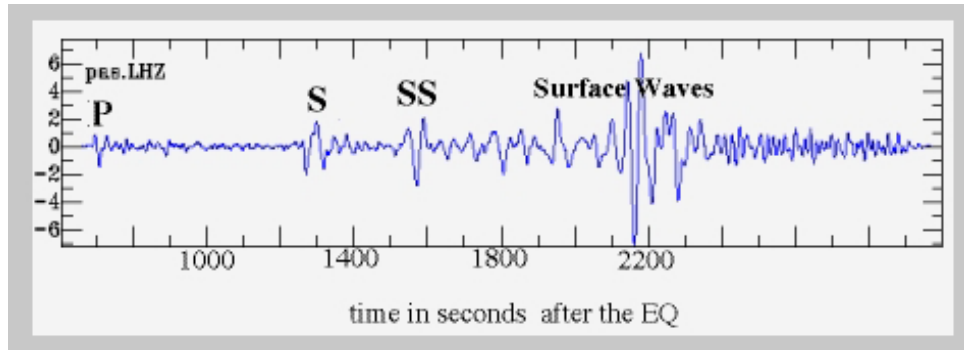


Horizontal Instrument

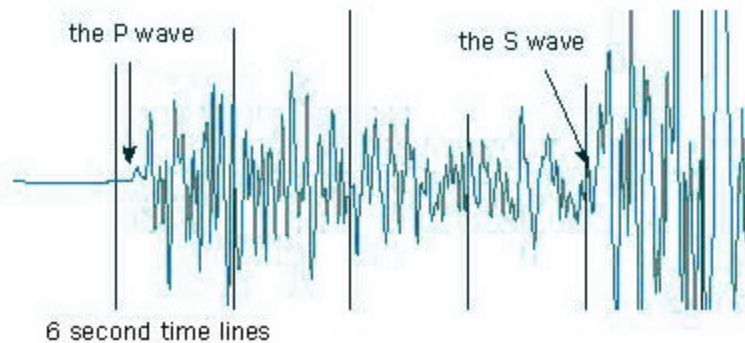


Vertical Instrument

Examples of seismograms are shown below. In the first example, the waves from this large earthquake arrive first at 11 minutes after the event, and continue to rumble on for over an hour. This recording in Pasadena, CA is at a distance of 77° (or 8500 km) from a large earthquake in Chile. At your single station you can normally see signals like this from 50-100 earthquakes which occur (annually) around the world.... normally on active plate boundaries. These are events with magnitudes greater than 5.5.



Much smaller earthquakes occurring within a few hundred km of the seismometer are easily seen. The second example shows a signal from an earthquake in central California, recorded at a station 200 km from the earthquake.



By combining the arrival times of the first signal (P-wave) at several seismic stations, you and your students can locate the earthquake, by a form of triangulation. By measuring the amplitude of the signal, you can estimate the magnitude of the earthquake. By studying the direction of first motion of the P-wave at several stations, can study the movement on the fault that produced the earthquake.

The complicated-looking seismograms are made up of a large number of signals that have traveled through the Earth by many different paths. For example, some of these provide critical evidence for the existence and structure of Earth's iron core.

Seismographs also record a broad array of other local seismic 'events', many of which are human-induced. Examples include quarry or strip-mine blasting, construction or traffic vibration, and explosions and sonic booms. These events provide for a rich variety of small-scale research projects appropriate for student research.

A graduated set of options

Each school can approach a seismometer project with an effort which is graduated to the school's resources, the experience and depth of its science faculty, and to the adaptability of its curriculum. Curriculum options include:

1. High School Physics Concentration
2. High School Earth Science Concentration
3. Middle School Concentration on Earth and Space Sciences

The most effective use of a seismic instrument is for your seismic station to serve several different courses and grade levels. The curriculum modules which are distributed under our sponsorship reflect the diversity of the options.

The available instruments cover a range of technical performance and cost. A near-research quality sensor can cost upwards of \$3000, a quality classroom demonstration model \$500, and parts for a kit can be acquired for \$50. You can start off with a demonstration instrument and subsequently upgrade once your school's strategy for this project has taken form. Any of these instruments may optionally be connected with the internet and with the other educational seismic stations.

It is also possible to participate without your own seismometer. Your internet connection gives you access to real-time and archived data from other schools. This option can bring the program into several schools in a large district or city, without the need to install an operating instrument everywhere.

For example:

1. School A is interested in educational seismology, but lacks resources to develop its own educational seismic station. Instead, it operates a 'virtual seismic station', recording and displaying seismic data recorded by other seismic stations. Cost is essentially limited to the availability of a recording computer.
2. School B has a home-built kit seismometer (~\$50), which serves as the basis for demonstrations of how a seismometer works. It can be attached to a computer that shows the seismic motion as a wiggly line trace for any period the instrument is operating. This instrument seldom is used for recording and archiving actual seismic data
3. School C has an AS-1 seismometer (~\$500), which serves both for classroom demonstrations and for recording of local and regional earthquakes. The data from this instrument may be shared with other schools over the internet or sent to a central data repository.
4. School D has a Guralp vertical broadband seismometer (~\$2700, research-quality instrument), which allows effective recording of local, regional, and global seismic events. It is connected to the internet via the classroom computer. Automatic data transfers can be established to and from this school.
5. School E has a 3-component seismometer (~\$6500) with the same functioning as School C. Its three-component recording capability allows study of a broader range of seismic wave phenomena. The quality of the data allows it to serve as a core station for a regional educational seismology network.

At any of these schools, the availability of an educational seismograph opens opportunities for curricular expansion, advanced teacher development, and independent student research.

The schools effectively can become part of the growing national (and international) network of school seismograph stations.

Networking of seismic instruments

The single-station recordings of an earthquake (examples above) are often useful in their own right for teaching purposes, but the real value of seismometer stations comes when many seismograms from some earthquake are considered together. Research seismologists use such a collection of traces in the computer generation of images of Earth's interior or the detailed study of the source processes involved in generating earthquakes.

Schools operating educational seismographs and sharing their data with other schools can use the data for:

- Sharing data between multiple recording computers within a given school system or regional network
- Watching an earthquake signal come in from somewhere remote around the globe, and comparing data with those collected by other participating educational stations.
- Detailed comparison of data from a network of regional stations for study of wave propagation characteristics
- Provision of educational seismology data to the research community
- Accessing the collected data traces from an earthquake and studying them using seismology data analysis software.

All of these activities involve some type of networking of your seismograph station, perhaps to other PCs at your school, perhaps via Web service from a central data archive, or perhaps via a real-time data flow from a central site. When your seismometer is operated as an observatory, you automatically become part of a national network of educational seismology observatories—and eventually, part of the global seismological research infrastructure.

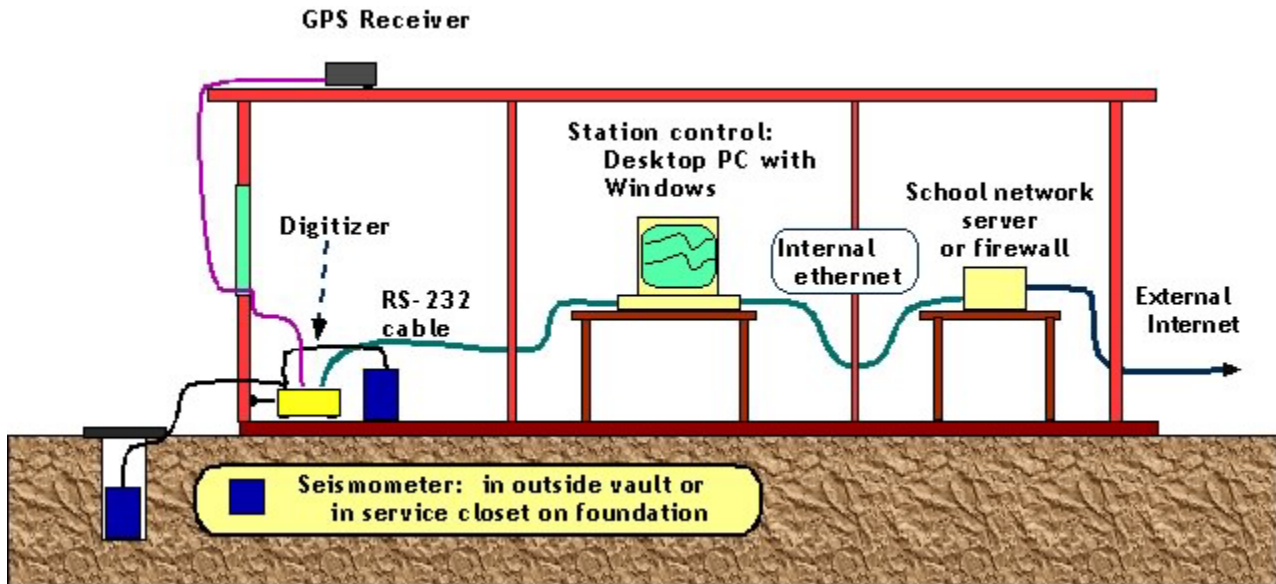
Your networking configuration will vary, depending on your school's particular configuration. Here is a brief list of recommended internet access configurations:

- Internet service to the school. Fast connections via ISDN, cable, DSL, T1, or the like are vastly preferable to dial-up service.
- Service through your firewall for http (World-Wide-Web) functioning. Needed for access to data from other schools, real-time earthquake lists, educational collaboration with other participating schools.
- Service through your firewall for email. Needed for inter-school communication, technical support, and earthquake notifications.
- Service through your firewall for ftp data transfer service. For manual transmission of recorded seismic data
- Ability to open a dedicated port for data to flow in and out to allow real-time data communication and archiving at a central data repository.

Instrument Configuration

This section describes an idealized recording configuration for seismic instruments in a USESN school. The exact layout and organization of instruments will vary considerably depending on the layout of your school, your educational goals for the instrument, and technical and financial considerations. We will work with you to identify a setup appropriate for your school's particular needs. The figure below shows the idealized configuration of a

school seismic instrument, with real-time connection to the internet. A simpler configuration (e.g., with a benchtop display instrument) would be considerably simpler.



You can purchase a seismometer from the manufacturer or manufacturer's sales representative [see Appendix A on instrument acquisition]. Ordinarily, the seismometer will be delivered with the digitizer, GPS timing system, and cabling. Your school should provide the desktop PC, which will serve for station control and for display of seismograms. You will be provided with recording software for the PC, which will control the digitizer and format the incoming digitized data stream on the PC hard disk. The station control PC can be networked with other computers on your school's internal net—allowing, for instance, real-time display of the recorded data on a classroom computer and on a prominent display unit. This infrastructure must be installed and maintained by your school. The data from your station automatically appears on the Internet, through the school's network server or firewall.

You will need to determine the physical locations for the seismometer, the GPS receiver, the digitizer, and the station control computer. You will need to determine how much cabling is required to connect these parts, before ordering.

Seismometer Deployment

The seismometer will work from any stable site on the school grounds, including a lab bench or classroom floor. However, for the higher performance instruments, siting the instrument outside the school building will substantially minimize background vibration. Any seismometer site within a school building—even far from noise sources—will often pick up vibration from any mechanical equipment (air handlers, elevators, cleaning equipment, etc.), as well as human activity (foot traffic, doors, etc.). A seismic recording vault, even a few feet away from the school building, gives the best performance by minimizing extraneous vibration. The ideal recording setup would be a site set up inside the building but isolated from the foundation of the building. Details on construction of a seismic vault are provided in Appendix B.

Timing Systems

Because one of the goals of research seismology involves comparison of seismic traces on different locations, precise timing is critical to operation of a seismograph station. There are a variety of approaches to provide precise timing for your recording system. One of the most precise and cost-effective methods involves the use of a Global Positioning System (GPS) receiver, which can provide universal time to a precision of well under 1 msec. The GPS timing unit requires a small satellite antenna, which must be in open view of the constellation of GPS satellites: consequently, a location on the roof is normally needed. Occasionally, a location just inside a classroom window may work, but you must check this out. You will need to obtain the willing cooperation of your building services office to run these cables where needed. Be sure this arrangement is made before you commit to your program.

Software Installation

You will need to obtain the willing cooperation of your network manager for the following services:

- Installation on the recording computer of specialized software for collecting data from the instrument and for streaming data outbound (and sometimes inbound) on the internet.
- Installation on other computers in your science teaching rooms of applications software for analyzing seismic data.
- Configuration of the school network server or firewall to permit the modes of data transfer needed to obtain full internet service.

You should plan your site and its installation with the assistance of a mentor from a participating USESN or PEPP network. This is discussed further in this document.

GETTING STARTED

1. Finding a mentor

Installing and operating a station and participation in internet activities are quite uncomplicated on the face of it. In practice, however, many details, both technical and scientific, have proven quite daunting to participating teachers. We have found that the most successful school seismograph programs are those who have close collaboration and mentorship from a nearby sponsoring institution. Your mentor can provide assistance of the following sorts:

- Visit your site to assist in site planning and installation
- Provide technical advice on the configuration and use of the internet services
- Organize teacher training and workshop activities
- Visit your school to help establish an understanding with your administration regarding their support for the program.
- Work with you to plan and carry out fund-raising.

Ideally, your mentor should be located within a 2-hour driving radius of your school.

After you have registered with us your desire to be involved in this program, we will try to broker a mentorship agreement. This may involve a current USESN network provider or another institution which is willing to serve as a local sponsor. We have found that 4-year liberal arts colleges and community colleges represent an educational community that can be tapped into for scientific support. You may wish to ask around in your own community or region to find a college-level institution with a science department whose faculty may be interested in collaborating with you.

You may wish to start in "learner" mode. This means that you will have no seismometer or perhaps a demonstration instrument (e.g. AS-1) for your classroom, without networking. In this case, the mentorship may not involve much commitment. In any case, however, you will benefit significantly by having a personal connection with a teacher or research scientist somewhere out on the net. Eventually, teachers should plan on receiving training from their mentor. This may be through a workshop funded by grant or through more informal one-on-one training. Curriculums for training workshops have been developed by several of the USESN institutions, and can be adapted for use by a local mentor. Commonly, workshops run for about one week.

Other services are organized by USESN and funded at the national level through the joint efforts of USESN institutions. These include the external networking and data management services necessary to weld the network of schools together.

School Support

Putting a seismograph in your school is innovative in many ways. By virtue of this novelty, however, many of the people you deal with in your school may put up some resistance. Without their cooperation, it is unlikely that you will be able to get your program on the road. Here are some suggestions for developing critical collaborations within your school:

1. Fellow science teachers. The educational seismology curriculum cuts across the conventional subject areas: physics, earth science, mathematics, and computers. You will get the most out of the program if you are able to incorporate into these courses the relevant activities from the earthquake studies curriculum. It is also likely that during the lifetime of this project either you or a colleague will leave, be reassigned, or otherwise be unavailable for the work with the seismograph. Thus, we urge that a group of at least two science teachers in your school undertake the project as a team. This would include participation in training programs, workshops, and student projects. Naturally your science department head will need to be brought in as a player-stakeholder.

2. School Administration: Principal and other relevant administration. Your principal should come aboard this project as a sponsor and supporter. His/her approval will be necessary to facilitate financial, technical, and administrative issues that come up during the course of installation and operation of a seismograph.

3. Superintendent and Board of Education. The top of your governance pyramid will want to be informed, and, in most cases, will sign on as enthusiastic supporters. A seismograph station can be one of the most visible efforts of school participation in academic endeavor, and can make an important connection between the school and its community. Administrators are often most supportive when they can see the good public relations benefits of school system investment in innovative science programs.

4. Building maintenance department: The installation of the station and the monitoring of its physical configuration will require participation by the maintenance staff. Their assistance will be absolutely critical in the installation stage. Make friends with the director of your maintenance department! It will be important to work closely with the maintenance support people through the planning, installation, and initial operation of the seismic instrument.

5. Computer system manager. Your station control computer will require specialized software, and its internet connection will require that certain services be able to operate through the school's network server or firewall. In many schools, you are not permitted to set up the computer and network configuration, but must request these services from the system manager. You will need to bring this person into the planning process early, so that you can elicit his/her cooperation.

5. Community: Many community organizations and businesses will be happy to provide support—either financial or in-kind—for the sort of high-profile science education opportunities afforded by a seismograph station. Tap into local community resources when you are seeking funds, materials, and in-kind support for your station. You will be surprised at the outpouring of support that can be mounted from your community!

You may be able to propose the idea of a seismic station informally, in order to "test the waters" with these colleagues. Alternatively, you may find that your external mentor can be most helpful in explaining to colleagues and administrators the nature and purposes of the project, and in putting to rest concerns which might arise.

Since the funding of your station will need to come from local and regional sources (see following section), the most productive format will be to elicit from your list of colleagues the desire to help raise these funds. We have found that schools that commit to raising their own funding are much more committed to maintaining a strong program.

Funding

USESIN promotes "grass-roots" stations and networks. That is, the initiative for new stations comes from the schools themselves or from a local mentoring institution. The cost for hardware and teacher training is not great, on a per-school basis. Consequently, the responsibility for funding the local cost of a new station resides locally. It may come through the efforts of your school to fund from the budget or from local companies who support the school. It may come through a grant proposal to a community foundation or statewide program, such as the Eisenhower grants. Your mentoring institution may initiate a block funding proposal for a few schools.

The station costs depend on the technology selected and the networking plan adopted. The most costly seismometer we list here is \$6800, with lower-performance instruments ranging from about \$1500-\$3000. The bench-top demonstration instrument is \$500. To this should be added marginal costs, such as commitment of a recording computer, modification of space, power cables, displays, construction of a vault, and possible travel by the teacher.

Outreach programs of this sort are most successful when the client institutions are partially responsible for planning their program, developing its justification, and obtaining funding. This establishes each school as a stakeholder with a commitment to the success of the program.

CHECKLIST FOR PROSPECTIVE SEISMOGRAPH STATION OPERATORS

Here, in approximate order, is a checklist of things you need to consider when starting up a new seismograph station.

- ❑ Gather information. Check through our website. [Email](#) us to let us know you are interested. We can suggest names of active teachers you may want to contact for more information, and help with identification of a mentor near your school.
- ❑ Discuss thoroughly with your fellow science teachers the possibility of being involved. Try to solicit the participation of 2-3 people who are enthusiastic. Try in particular to find representatives from Physics and Earth Science faculty. A solid curricular plan will help you and us to obtain funding for the equipment.
- ❑ Take your idea to your science faculty chair and principal, and go over it with them. You will need enthusiasm and support from these administrators.
- ❑ With our assistance, locate a mentor. It may be someone already involved, or a geologist or physicist at a nearby higher education institution.
- ❑ Get your stakeholders to work through the options for obtaining funding for your station. Some schools will find it very easy, others nearly impossible. If it looks hard, we will try to help you get started, along with your mentor.
- ❑ Figure out which of these technical options is most appropriate for your school setting, ranging from a 'virtual seismic station' to a 'bench-top' demonstration instrument, such as the \$500 AS-1, to a "research-quality" instrument, such as the \$2700 PEPP-V, which will detect many more global earthquakes than the bench-top instrument. In reality, your choice of instrument should also take into account the instruments already installed in your region, and at your mentor's site.
- ❑ Prepare a layout diagram for instrument site, computer site, and satellite clock. Be sure that your Principal obtains the cooperation of your maintenance department to see that this layout works, and the installation can be done.
- ❑ Obtain the cooperation of your network manager to insure that the networking functions are able to work properly in the context of school regulations regarding the internet and of the network firewall.
- ❑ Place your order. Delivery could run several months. While waiting, work on your installation and network configuration, and consider a 'virtual seismic station' operation. Most of the network functions can be put through "dry-run" before your instrument arrives.
- ❑ Consider a display in the school lobby and publicity in your local media. You can install additional PC's for display of the data coming in at your school and others. Put one in the Principal's office or the local public library.

Throughout, keep in close contact with us. You will start out with one of the USESN University sponsors, and probably move to a relationship with a nearby mentor. Use email most of the time; this permits us to cc your messages and keep everyone informed.

APPENDIX A: GUIDE TO SEISMOGRAPH PURCHASE OPTIONS

APPENDIX B: CONSTRUCTION OF A WEATHERPROOF SEISMIC VAULT