A Volksseismometer?

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The impact of the new digital broadband instrumentation is evident to anyone who is even remotely informed about the field of seismology. As so often happens in science, the new information that is provided by broadband seismographs generates even more questions than it answers. One of the pressing problems is the spatial aliasing of the wavefield, in the sense that seismometers are usually placed much farther apart than the correllation length of perturbations in the seismic wavefront. The obvious solution, then, is to put more seismometers on the surface of our planet. At reasonably low frequencies, say 0.1 Hz or lower, the problems of spatial aliasing, at least on a regional scale, could be greatly improved if amateurs and schools take seismometer deployment in hand.

Not everyone is comfortable with the idea of involving amateurs, let alone inexperienced high school students, with real science. Yet there are several nationwide programs, involving science museums, schools and individual amateurs, to provide significant data on issues ranging from measuring ozone (program 'Smog Watch') to the variability of stars ('Hands-on Universe'). So why not on seismic waves? An important reason that amateur seismology has so far led only a marginal existence is the high cost of a broadband sensor. The necessary investment of at least thousands of dollars thus far prohibits any significant participation by nonprofessionals.

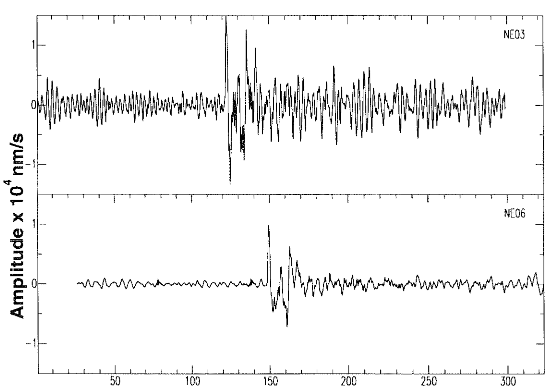

Figure 1. Vertical components of NARS stations NE03 and NE06 for a magnitude 5.9 shallow event in the Aleutians show a very strong difference in noise amplitude between the two stations, as well as in the effect of soil amplification on the P wave.

But this may soon change. Stimulated by the submission of the Princeton Earth Physics Project (PEPP) as an educational proposal to NSF, a meeting of industrial and academic research groups was held at IRIS headquarters on October 9, 1992, where possibilities for a low priced sensor with acceptable noise characteristics were discussed.

Among the most interesting developments reported at the October meeting were:

• Teledyne-Geotech is developing a complete, 3-component

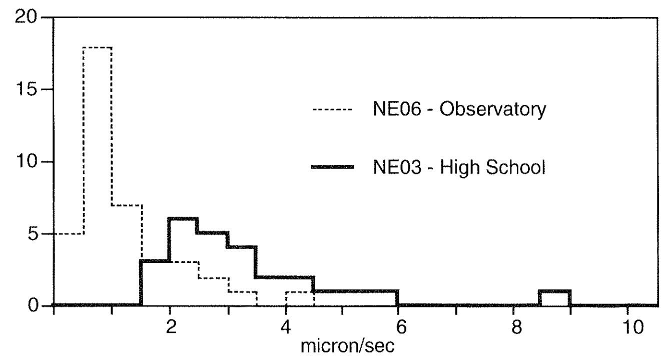

Figure 2. Noise histogram for NE03, the high school station, peaks between 2 and 3 micron/sec, while the observatory site, NE06, peaks below 1 micron/s.

system including A/D conversion and serial output using a solid state accelerometer with a capacitance transducer. The bandwidth would be between 20 Hz and 100 sec or more. This instrument is likely to come out of the development stage by late summer 1993. It will be priced for 'easy budget approval', perhaps around $500.

• Jet Propulsion Lab is developing a miniature sensor for the Mars Environmental Survey mission (MESUR). This instrument is also still under development, and uses some known design elements, such as a high Q silicon spring, reminiscent of the Block and Moore instrument, but combined with new technologies (sensing through use of electron tunneling, or with an ultra high frequency capacitive sensor). Bandwidth (0.05-20 Hz) can probably be extended to cover 100 sec waves, and a simplified sensor with the size of a cigarette package might eventually sell for a few hundred dollars.

• PMD Engineering, a small company with strong ties with the Institute of Physics of the Earth in Moscow, presented the first prototype of a 'molecular seismometer'. This instrument uses the inertial mass of an electrolytic fluid that conducts a small current. When this fluid is accelerated it changes the current. The prototype was tested for several days alongside a Guralp at Lamont, and gave a satisfactory response up to a periods of 15 seconds. With improved electronics and possibly a change in dimensions of the capillary system, the molecular seismometer could be made sensitive to lower frequencies. A revised prototype has just been installed at Princeton University alongside an STS-2 for further testing. The cost of this instrument is expected to be comparable with the other two designs.

How useful can a school network be? Some indication is given by the experience of the NARS array in Europe. In order to obtain a dense station spacing while keeping costs to a minimum, many of the NARS stations have been installed outside official observatory sites, in private homes, wine cellars and even in a catacomb. Figure 1 shows a comparison of the noise and signal levels of the vertical component in station NE03, installed in a high school in Logumkloster (Denmark) with that in the seismological observatory of Dourbes (Belgium, NEO6). NE03 is representative of a station under the worst possible conditions: located near the border between Denmark and Germany in a region of substantial sedimentary thickness, it is subject to large microseismic noise. The seismometer was placed in the basement of the school. It is probably representative of what could be obtained from any U.S. school situated near the Atlantic coast, but much too pessimistic for one located farther inland. Station NE06 is located about 200 km from the North Sea but it is on hard rock. It would be representative of what can be obtained under more moderate conditions. Yet the P wave of this Aleutian event (magnitude 5.9) has a maximum amplitude of 15 microns/sec and rises above the noise even at this high school site. Figure 2 shows histograms of the maximum peak-to-peak noise at each of the stations measured from 2 minute windows in front of triggered P waves. While the noise level at the high school site, Logumkloster, peaks between a level of 2 and 3 microns/s, the peak at Dourbes Observatory is below 1 micron/s. In Logumkloster, the STA/LTA trigger generally failed for P waves with peak-to-peak amplitude below 5 microns/sec.

Such observations help us to formulate minimum criteria for a low cost seismometer. Although a definite limit has not yet been set for the PEPP project, it seems that the following specifications for a 'Volksseismometer' would give useful data for research purposes: - bandwidth 0.015 to 30 Hz - instrument noise level below 0.1 micron/sec (vertical) - clipping level above 500 micron/sec. This would bring the noise level far below the ambient noise for a sensor installed in the basement of a well-founded building. The participants at the meeting generally agreed that such specifications are feasible within a modest budget. The biggest problem so far seems to be the inclusion of an accurate clock. The optimal solution for that is probably dependent on the region. •

the IRIS CONSORTIUM

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frequencies and wavelengths, where so much of the energy is sensitive to the lithosphere and the asthenosphere as well as the crust, should provide a new source of raw material for a host of studies focused on the relationships between crustal and mantle deformation.

Data processing is continuing at Lamont and Oregon, and involves several tens of gigabytes of raw data. The continuous records will be distilled into an event-sorted database with correct time, which should be on the order of ten gigabytes or less. These events will be kept on line on a mass store, along with the metadata describing the array and site characteristics. The availability of the data will be announced coincident with the final data report to PASSCAL. In the interim, questions should be forward to lerner@ldeo.columbia.edu or the other PIs.

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We are on the southwest slope of Mt. Blanca, Saturday night, about 10:30, just after a snowstorm has broken. This is the last station to be picked up and the end of the experiment. We can make out Blanca only by the absence of stars to the northeast. Grinding up through two feet of fresh snow, we have cleverly been counting on the Omega antenna to mark the site. Of course, the antenna would have to be white and difficult to pick up. We go by the odometer, the portable GPS, and breaks in the vegetation until Sean spots the solar panels mounted on a small tree. It takes about an hour to dig out the instruments and winch out the vault, and about another 15 minutes to pack everything away for the drive back to Bergen Park. We pack a truck the next day, reducing the field lab from organized clutter to an empty room. The drive back to Lamont seems longer than the drive out, even though we're trying to make it back for Christmas. None of us wants this to end. •

*Rocky Mountain Front Participants:

PIs: Steve Grand (Univ. of Texas, Austin), Gene Humphreys (Univ. of Oregon), Tom Jordan (MIT), Art Lerner-Lam (Lamont-Doherty).
Participants: Univ. of Texas, Austin: Duk Lee, Mark Riedesel; Univ. of Oregon: Ken Dueker, Randy Palmer, Pat Ryan, Chris Bryant, Bill Vediker, Arlo Guthrie; MIT: Jim Gaherty, Steve Shapiro; Lamont-Doherty: Anne Sheehan, Sean Chen, Hong-Sheng Guo, Joe Greer, Jonathan Schwartz.
Undergraduate interns: Russ Silver (UCSC-NSF), Jacob Lawrence (UNC-NSF), David Jones (Harvard- NSF).
IRIS: Larry Shengold, Jim Fowler.
Others: Dick Hilt (Colorado College), Paul Passmore (REFTEK), Jim Spurlin (Colorado School of Mines), Rick Knapp (Science Teacher, Ramapo Central School District), 6 high school juniors funded by Earthwatch.
With assistance from: Martha Savage and Craig Jones (Univ. of Nevada, Reno), and Geoff Abers (LDEO).