2.6 Seismic Applications (SEI)

The Seismic research area has had a tremendously successful year with emphasis on analysis of data captured by the Middle America Seismic Experiment (MASE), redeployment of the equipment in the Peru Subduction Zone Experiment (PeruSZE), and successful completion of the Reftek ENSBox platform for both structural and seismic applications.

MASE and PeruSE
Our cross-Mexico wireless network, MASE, was dismantled in early 2007 and after repairs and refurbishment, the equipment was shipped to Peru to do a similar experiment, PeruSze, across the Andes where the Nazca plate is subducting beneath the west coast generating devastating earthquakes and tsunamis. Graduate and undergraduate students were involved in the installation of the 49 station network over the summer. Most stations at the end of the summer were recording on-site. Subsequently Richard Guy and Igor Stubailo have installed the networking that links the stations across the Andes. The experiment will run for one or two more years. P. Davis will take a class there to do geophysics in May.

The Peru experiment (field work funded by the Caltech Moore Foundation grant) provided an opportunity to redesign our networking protocols based on our 2-year networking experience in Mexico. Our Delay Tolerant Shell (DTS) was improved. A new website for hourly system status was designed and implemented. The data was input to LabView. The various synergies of CENS have combined to make a significant remote area networking product. The data is radioed across Peru to Internet drops. It is then transmitted to UCLA over the Internet. The Atacama desert, where the network is located, is one of the more remote parts of the world. The facility that has been developed to install a remote wireless network over 250 km, and have the data transmit back to the laboratory, as well as duplex control on the instrumentation in the field, has application worldwide where remote network sensing is required.

CENS Development of the Reftek EnsBox with application to GeoNet-SHMnet-ShakeNet-FlexiRAMP
What does this acronymic soup have in common? The short answer is CENS. CENS has provided the infrastructure and technology to link half a dozen departments in a single development with and industrial partner (Reftek Refraction Technology of Plano Texas). It is the culmination of our experience in wireless networking to design a node that satisfies the digitizing and wireless networking requirements of the following groups to improve their science:

- **GeoNet** (geophysical monitoring) Paul Davis, Department of Earth and Space Sciences, UCLA, earthquake and tectonic networks.
- **SHMnet** (Structural Health monitoring) John Wallace, Civil Engineering, UCLA
- **ShakeNet** (Monitoring civil structures for shaking after earthquakes) Monica Kohler, CENS and Caltech, Ramesh Govindan, USC, Department of Computer sciences
- **FlexiRAMP**, A flexible network for Rapid Array Mobilization Procedures, IRIS (Incorporated Research Institutions for Seismology) Richard Allen Berkeley, Marcos Alvarez, IRIS, and Paul Davis, UCLA. {in association with Deborah Estrin, CENS, Computer sciences, UCLA and Bill Kaiser, Electrical Engineering, UCLA}

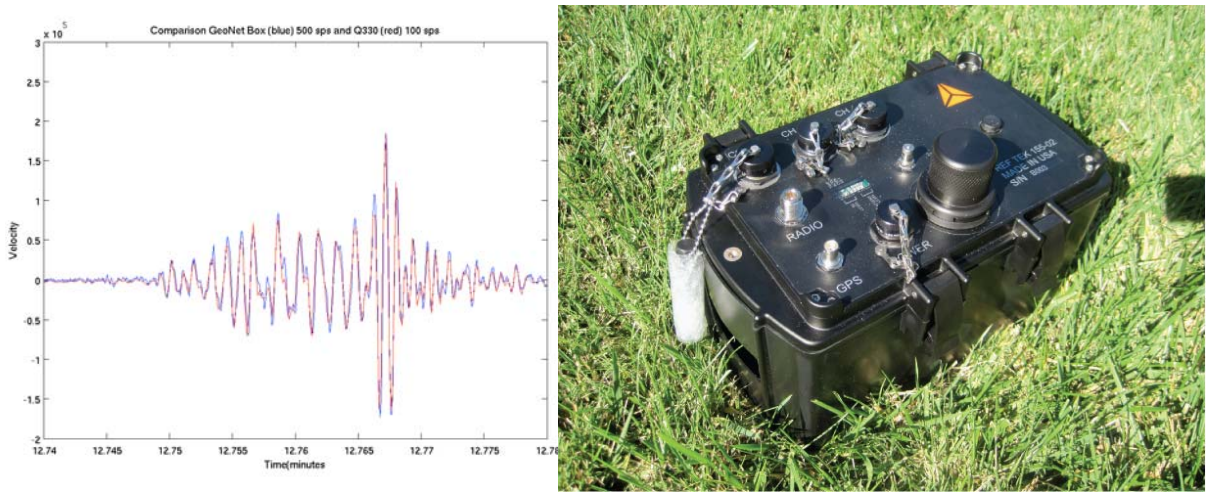

Figure 4. Prototype Reftek EnsBox for GeoNet, SHMnet ShakeNet and FlexiRAMP applications. MEMS seismometer on left. Shielded Circuits include TI A/D, UCLAs LEAP or Crossbow Imote II processor board. Wireless 802.11b card.

The idea of an 'EnsBox' dates back to our CENS retreat in Palm Springs, 2006, where domain, computer, and electrical engineering scientists broke out into design groups to chart the future of CENS developments that would have greatest impact. Among others, the specification of an EnsBox emerged.

For GeoNet and FlexiRamp, the science objective is to use a rapidly installable wirelessly linked seismic network to make near-real time unaliased observations in aftershock or volcanic zones in RAMP deployments or in structures.

The immediate technical objective involved collaborating with Reftek to construct a new generation digital acquisition system (DAS) based on the CENS-developed LEAP (low-power energy aware processing) system and a newly developed low-power A/D converter from Texas Instruments (TI) that became available last year. By using the processor in low power mode for data acquisition, and moderate-power mode for on-site analysis and wireless transmission we reduce infrastructure for nodes, so that, in theory, hundreds can be deployed rapidly and self configure. Costs for the prototype were shared by CENS and NEES (John Wallace's group) who are interested in structural health monitoring (SHM). We used the Mexico and Peru networks to field-test software including improving Disruption Tolerant Shell (DTS), measurement of radio link quality (ETX), improved network logging, a Web interface based on Emstar for deployment and maintenance, network time, a new routing protocol that caches the routes across sleep cycles for a fast startup. Reftek president Paul Passmore and head engineer Phil Davidson have visited UCLA and USC on four occasions since beginning of development. At the last visit (13 Feb, 2009), they brought prototype boxes. A prototype (Figure 4) was displayed at the Earthscope meeting 2008. A one day workshop on FlexiRAMP is supported by IRIS at the Seismological Society of America in Monterey April 7. The Reftek EnsBox will be featured. This meeting is preliminary to an anticipated IRIS MRE application to NSF for a FlexiRAMP national pool of equipment. If the Reftek EnsBox is chosen it will be a satisfying outcome for the CENS development.

The Seismology research area's productive year can be clearly seen in the accomplishments of its students and faculty. Martin Lukac received his PhD, Allen Husker was appointed a faculty member at UNAM, Derek Skolnick defended his PhD and was employed by Kinemetrics. Antonio Dominguez, a Mexican student, funded by the Mexican Government, will take his PhD qualifying exam based on the Mexico data collected by CENS. Several papers have been published both on the computer and Earth science applications including one in Science (Song et al., 2009). Igor Stubailo won and Outstanding Student Paper award from the Seismological Society of America. We took a UCLA geophysics class combined with Caltech to conduct a gravity survey across the Andes in Peru. Our PeruSE seismic network recorded the M=8.8 earthquake. With ~100 stations it is the largest nearby network to record such a giant event. We held an IRIS-sponsored FlexiRAMP workshop. We successfully tested the GeoNet box in the Mojave Desert. The shakeNet box (its twin) was successfully used in a building test. Forty units have been ordered from Reftek. More details can be found in the extended report.