

## SUMMARY

### Scientific Earthquake Studies Advisory Committee (SESAC)

July 31-August 1, 2008

Menlo Park, California

### Meeting Participants

#### SESAC Members

Mark Zoback, *Chair*, Stanford University, Stanford CA

Jim Dieterich, University of California at Riverside and Chair, National Earthquake Prediction Evaluation Committee

Art Lerner-Lam, Columbia University, Palisades NY

Vicki McConnell, Oregon Department of Geology & Mineral Industries, Portland OR

Stu Nishenko, Pacific Gas & Electric, San Francisco CA

John Parrish, California Geological Survey, Sacramento CA

Ellen Rathje, University of Texas, Austin TX

Garry Rogers, Geological Survey of Canada, Victoria BC

Ralph Archuleta, University of California at Santa Barbara and Chair, Advanced National Seismic System Steering Committee (unable to attend)

#### USGS Staff

David Applegate, Earthquake Hazards Program (EHP), Reston VA

Mike Blanpied, EHP, Reston

Tom Brocher, Earthquake Hazards Team (EHT), Menlo Park CA

Mike Carr, EHT Menlo Park

Ken Hudnut, EHT Pasadena CA

Lucy Jones, Multi-Hazards Demonstration Project, Pasadena CA

Jill McCarthy, GHT, Golden CO

Walter Mooney, EHT Menlo Park

David Shelly, EHT Menlo Park

Ross Stein, EHT Menlo Park

#### Guests

Susan Newman, Seismological Society of America, El Cerrito CA

### Welcome and introductions

The committee reviewed the minutes from its February 2008 meeting. Two minor corrections were made, and the minutes were approved as amended.

The committee reviewed action items from the same meeting. Of those, the draft hazards section of the new Geologic Discipline strategic plan has not yet been released but will be shared with the committee when it is, and the committee produced its annual report with cover letter from the chair. Zoback noted that the committee has a standing offer to be available to assist the program with guidance as needed.

## **Update on Earthquake Hazards Program**

Applegate gave a presentation on recent program activities and the state of program finances. At the outset, he noted that he began a three-month detail acting as director of the USGS Central Region the previous week. Bill Leith is acting program coordinator during this period except he is on three weeks of annual leave, so Mike Blanpied and Elizabeth Lemersal are acting during his absence. Despite the musical chairs, the work of the program goes on. Applegate discussed the USGS response to the magnitude 5.4 Chino Hills earthquake earlier in the week, described current coordination activities of the National Earthquake Hazards Program (NEHRP), including the soon-to-be-released interagency strategic plan and plans for reauthorization of the program. NEHRP Director Jack Hayes (at the National Institute of Standards and Technology) led a delegation to meet with Chinese officials in Beijing, which it is hoped will lead to an invitation from the China Earthquake Authority to allow teams of US government and academic scientists into the epicentral area. USGS information was heavily used in the wake of the Wenchuan earthquake, including Chinese translation and posting. Following a presentation to the InterAction coalition of disaster relief organizations, the relief director for Save the Children stated that the USGS Prompt Assessment of Global Earthquakes for Response (PAGER) system was speeding up their response activities by several days by quickly identifying the hardest-hit areas. USGS also supplied imagery and interpretation to the Chinese through the International Charter for Space and Major Disasters, and the Chinese embassy requested USGS assistance on a number of technical issues.

Applegate also reported on a May 22nd oversight hearing on the USGS Earthquake Hazards Program by the House Subcommittee on Energy and Mineral Resources. The hearing took place only days after the Wenchuan earthquake and included presentations by former SESAC chair Lloyd Cluff and former SESAC member Tom Jordan along with Central U.S. Earthquake Consortium executive director Jim Wilkinson and Applegate. The SESAC's current and previous annual reports were cited in several of the witnesses' testimony.

Applegate reported on the program's fiscal year (FY) 2008 appropriation from Congress, which included a \$2 million increase for the multi-hazards initiative, which was being used to enhance activities in Southern California and begin activities in the Pacific Northwest and Central U.S. The appropriation also included a \$0.5 million increase for the Global Seismographic Network (GSN). Although the President's FY 2009 budget request proposed eliminating these FY 2008 increases as well as a further \$3 million cut to the program's external grants, the program received a favorable budget mark from the House Appropriations Subcommittee on Interior and the Environment with a \$2 million proposed increase over the enacted FY 2008 level for the multi-hazards initiative, a \$1.5 million increase for GSN. The subcommittee report criticized the Administration's "reckless budget request to reduce earthquake science grants," which were restored. Mark-up of the bill by the full committee was delayed as has Senate mark-up of its bill, in both cases due to Democratic reluctance to hold a vote on ending the moratorium on oil and gas development on parts of the outer continental shelf, a Republican campaign

priority. A continuing resolution is expected at least until February and perhaps for the entire fiscal year.

The committee discussed the impacts of the expected funding delay, in particular on the external grants and cooperative agreements, including the funding for external geodetic networks.

***Action Item (USGS Staff): Ask Elizabeth Lemersal to report back before the committee's next meeting on whether the program should shift the clock on grant start dates in light of the uncertainty over the program's budget for external research support. Also report on impacts to cooperative agreements.***

### **Update on the Geologic Hazards Team**

Jill McCarthy provided a presentation on the current status of the Central Region Geologic Hazards Team and in particular its interactions with the U.S. Nuclear Regulatory Commission (USNRC). Overall team funding went up in FY 2008 almost entirely due to increased revenue from other federal agencies, which is for collaborative work that supports the earthquake program's primary mission. The team received \$0.5M from the Air Force Technical Applications Center to support GSN instrument calibration and testing. Support from USNRC is growing. The biggest challenge is getting the work done, because the team is people-short. It has enough program funding to cover base salaries, and OFA brings in funds for more operating expenses and for temporary staff. The salary coverage by base funds is fragile since there is no guarantee that uncontrollable costs will be covered. The team is turning down some externally funded work in part because recruiting is slow and difficult. The national seismic hazard mapping and PAGER projects in particular need staff. The most immediate challenge is replacing Buddy Schweig in Memphis. The team has had some retirements and been slow to backfill in part because the people with those skills are in hot demand. A number of positions are currently being advertised. Twenty percent of the team's is staff eligible to retire, which will rise to 35 percent in five years. A major challenge is getting U.S. citizens. The team has gone through an enormous number of staffing changes in the last five years. One positive change is that there are now 25 students working for the team in various capacities. Lerner-Lam asked who the competitors are for people with these skills, and McCarthy replied that loss-modeling companies and USNRC were both major draws.

For the GSN, McCarthy noted the installation of several new and improved GSN stations: TARA and Kanton (Kiribati) are new and XMAS, WAKE, and JOHN are revived. Dataloggers for all GSN stations are being integrated and upgraded. Instrument testing is a growth area, and the USGS Albuquerque Seismological Lab (ASL) is taking over as the ANSS depot, providing faster turnaround for equipment and improving network data stream completeness.

She described new response and research efforts at NEIC. The USGS earthquake web site received half a billion hits from April 23-May 23, including the magnitude-5.2 Illinois-Indiana border earthquake and the Wenchuan earthquake. Hiroo Kanamori recently

visited NEIC to assist in implementing his new W-Phase algorithm. NEIC staff are working with Steve Kirby (USGS Menlo Park) and colleagues to improve 3-D subduction zone mapping with implications for tsunami warning. Ray Buland is developing a statistical analysis method (M module) for rapid summary magnitudes. Because analysts now have so many magnitude types to choose from, there is a need to build a method for rapidly deciding what is the best solution. The ShakeCast version 2 demonstration module has been released.

***Action Item (USGS Staff): Provide ShakeCast memory sticks to SESAC members.***

The Los Angeles Unified School District has adopted ShakeCast, and during the Chino Hills earthquake, two schools had light damage at a time when 130,000 students were in summer school classes. They still need to develop their own structural inventory to fully make use of ShakeCast capabilities. Keith Porter has used USGS and FEMA support to make the Applied Technology Council criteria for inventorying structural damage available on a Personal Digital Assistant and feed that into ShakeCast databases as well as HAZUS. PAGER was used by *The New York Times* as a front-page graphic for its reporting on the Wenchuan earthquake. That earthquake will be a seminal one for study of earthquake-generated landslides, and USGS experts will be part of a team going over to the affected area. PAGER has a research module for spatial likelihood of earthquake-induced landsliding, which provides the capability to look at secondary effects in addition to ground-shaking.

The team recently released the newest version of the national seismic hazard maps as well as participating in development of the California-wide earthquake rupture forecast. The team's research structural engineer, Nico Luco, has played a key role in shaping the direction of design maps derived from the national seismic hazard maps. Previously, the design maps used the hazard maps with a deterministic overlay, but the new hazard maps incorporate a risk-coefficient map trying to build for a uniform risk, a key input for performance-based seismic design. So far it looks like it is being accepted for the NEHRP Provisions, which feed the model building codes. This approach may better reflect the hazard from distant sources based on fragility of structures. In addition, Mendenhall postdoctoral fellow Erdam Karaca and Luco developed a web tool implemented in Google Earth for seismic risk maps for different structure types making it possible to look at a specific structure in a specific place.

***Action Item (USGS Staff): Have Nico Luco give a presentation at the next SESAC meeting.***

Lerner-Lam noted that deteriorating infrastructure may be a big issue for the next Administration, and this work speaks directly to that. Archuleta asked about discussions with regulatory agencies. McCarthy replied that USGS was working closely with USNRC, and cooperation with FEMA on this topic is a key milestone in the program's Office of Management and Budget Program Assessment Rating Tool (PART) annual improvement plan, and the two agencies have worked out a joint plan for strengthening the hazard to risk information handoff. Discussions are happening to varying degrees with FERC, the Bureau of Reclamation, and the U.S. Army Corps of Engineers.

McCarthy described two different areas of effort with the USNRC, which has two organizational entities supporting USGS: the research and new reactor licensing offices. The latter requests USGS reviews of new reactor license applications. Four reviews were completed from 2003 to 2007. There have been five new ones since December 2007, and nine more are expected by October 2008, all for sites east of the Rockies. This increased licensing activity is being driven by the Energy Policy Act of 2005, which set a deadline by the end of this calendar year for new reactor incentives. Each review can take a year to run to completion, but the bulk of the work is in the first quarter in which it is received. The reviews are staffed with a mixture of permanent staff, university contractors, and one cooperative agreement with the University of Memphis.

Nishenko asked how the controversy over seismic hazards in the Central U.S. affected the license applications. McCarthy replied that the other side of USNRC is the research office, which is grappling with this issue. She distributed a one-page handout of the table of contents from the USNRC's FY 2008-2011 seismic research plan showing where they are supporting USGS. USNRC is providing USGS with \$0.5 million over two to three years for research in Central US source characterization (Mmax), attenuation relations (Next Generation Attenuation-East), site response, uncertainty analysis, external grants, strong-motion monitoring at power plants. NRC support may also augment ANSS monitoring in this region.

***Action Item (USGS Staff): Distribute electronic version of USNRC FY 2008-11 Seismic Research Program Plan to SESAC.***

Zoback noted that he recently spent two days at an Electric Power Research Institute (EPRI) meeting at which USNRC indicated that it is seeking to streamline methods of seismic characterization so that each license application is not unique. He expressed concern that studies from late 1980's were being dusted off with same cast of characters. He asked how USGS could help evaluate what the industry is doing. In reply, McCarthy noted that USNRC has asked USGS to sit on an evaluation panel for EPRI.

McCarthy closed by expressing frustration in the team's ability to get its work done and perform its mission due to fundamental erosion in USGS support services related to personnel, grants and acquisitions, and facilities. All of these services have been flat funded for years with the result that purchasing deadlines keep being moved up earlier and earlier in the year; there is no guarantee to get contracts in place in time; and human resources are months behind. She sees this happening in all three regions. The ASL lease is expiring in March 2009, but the agreement is currently stuck in Reston because the acquisitions group now thinks that sole-source is inappropriate. The clock is down to eight months and ticking. She also expressed concern for how the Survey's regional realignment will work in practice, noting the danger of creating a new set of different stovepipes in the organization.

**Update on Earthquake Hazards Team**

Mike Carr, who is currently acting as the chief of the Western Region's Earthquake Hazards Team, and Tom Brocher, who has been selected as the next chief, gave a joint presentation. Carr discussed how the transition is going, noting the January decision to rotate out the previous team chief, which took place in May due to concern over a crisis in business practices at which point Carr became acting chief, and the Geologic Hazards Team associate chief Linda Pratt came to act in that role for the earthquake team to ensure that team finances were on a path to balance, and they expect a successful close-out for FY 2008. In parallel, selection of a new team chief went forward in order to provide stability with Tom Brocher being selected. Carr will stay on until the end of the fiscal year to keep the trains running so that Brocher can focus on getting to know all parts of the team and focus on information gathering for future planning: science priorities and the staffing plan needed to meet those priorities. The Earthquake Hazards Team is money-poor and staff-heavy at this time. There is great talent in the team, but it is an inch deep and a mile wide. The key is to identify core capabilities and focus people there. The team's overall budget is approximately \$29 million of which roughly \$3 million comes from reimbursable work, an amount that is up slightly from last year but that was largely due to a one-time influx of funds to allow the Northern California Seismic Network to transition off microwave frequencies that have been auctioned off in spectrum sales. The only way to erase the salary deficit is to increase reimbursable funding or reduce workforce. Of total salary burden, currently \$1 million comes from reimbursables. A roughly \$1.1 million salary hole has been filled through contributions from program and multi-hazards project, but the team still has a \$200K deficit.

Efforts to get more reimbursable funding have not led to more reimbursable funding. The team is starting out FY 2009 with an \$800K problem that is exacerbated by cost-of-living increases of at least \$500K. Carr emphasized the need for strong workforce management.

Archuleta requested an age/time of service distribution to give a better idea of the long-term planning. Given the talk about core priorities, he asked what are the current priorities and what is the mechanism by which you get the scientists to buy in if those priorities are changed and how they will be set.

Brocher noted that 44% of the earthquake team's permanent staff is retirement-eligible today. Five years out, the figure is 60% if no retirements take place. McCarthy noted that this is what the Geologic Hazards Team looked like when she arrived in Golden five years ago. Brocher stated that one of the reasons for not starting as team chief until October is commitments he has made to the Hayward commemoration in October. He expressed appreciation to Carr for staying on through the transition. He noted that the earthquake program provides 85% of the team's salary load with 5% coming from other USGS programs, 5% from other federal agencies, and a 5% hole that needs to be picked up through additional reimbursable funding or through staff trimming. He recognized the need to look at both the revenue and expense side and indicated his intention to be aggressive in using management tools to provide incentives to employees. His first job is to put together a team staffing plan. He planned to approach priorities by talking to megaproject chiefs and senior scientists to see how they see the landscape, then distribute that to the earthquake program and Geologic Hazards Team to get broader coordination, then go back to megaprojects with a coordinated plan. He recognized that total consensus

was not possible but would try to get as much as possible. The team will have to do less with less, but at the same time pursue external funding. The team just submitted a large proposal to the USNRC looking at intensities and magnitudes in the Central US and the 2007 Niigata earthquake in Japan. He hoped to continue California Earthquake Authority support, the Cooperative Research and Development Agreement with Pacific Gas & Electric, and cooperation with the multi-hazards demonstration project. The team currently has \$700K in firm reimbursable support for next year and will work to expand that.

Noting that the committee would be hearing more about the work of the team in the presentations to come, Brocher noted some highlights including the release of the Unified California Earthquake Rupture Forecast, the upcoming Great Southern California Shakeout, work on episodic tremor and slip/slow earthquakes, the Global Earthquake Model project, and science being done in support of the Hayward Fault commemoration. He noted that geodetic network capabilities are a strength of the team, and also noted that NCSN has converted radios to the new frequencies under schedule and under budget. He mentioned Walter Mooney's role in coordinating the US response to the Wenchuan earthquake, and the work on extreme ground motions being done for the Department of Energy's Yucca Mountain project.

Questions from the committee focused on reimbursable funding, priority setting, alignment with the strategic plan, and the state of morale. Dieterich noted that the problems being discussed were program problems, not just team ones. He noted the vast contraction of staff in the program since the 1980's, emphasizing the program's need to focus on what is truly important. McCarthy added that the one-deep problem is worse than in the past, because more groups are depending on USGS for information. McConnell cautioned that chasing more reimbursable work runs the risk of becoming captive to where work can be found, which in turn starts driving the workforce decisions. She described this as exactly what a state agency goes through. John Parrish emphasized the need for a transition plan to handle the impending retirements. Zoback emphasized that with a new Administration, it was imperative to raise the level of discussion beyond simply what we can convince the Department of the Interior not to cut, and Archuleta noted that the time was ripe to go on offense.

### **Report on Chino Hills Earthquake**

An agenda item was added so that Ken Hudnut could provide an update on the Chino Hills earthquake that took place earlier in the week, which virtually everyone in the Los Angeles region felt. He described it as a good dry run in that it gave people, especially those who were new to the region, a sense of their role in a major earthquake. He noted interesting differences in the felt reports (over 35,000 and counting) and ShakeMap. He noted that the city summaries provided by PAGER are helpful, bringing the information down to a level that people can use. The earthquake also helped underscore to users of ShakeCast how it can work for them. Archuleta asked about the drop from an initial magnitude of 5.8 to a final magnitude of 5.4. This represents the trade-off between speed and accuracy with the initial automatic ML 5.8 replaced by the more accurate moment magnitude (Mw), which was ready in 10 minutes. The earthquake may have been on a

northeast-oriented cross-fault. There are concerns about the relationship to the Whittier Narrows earthquake and the Puente Hills scenario earthquake. Because of the ShakeOut, there have been lots of questions about the relation to the San Andreas Fault. There is an ongoing debate about whether this took place on the Yorba Linda trend or another structure.

### **Multi-Hazard Demonstration Project Update**

Lucy Jones provided an overview of the project, and its philosophy of providing the scientific information needed to support risk-reduction and response strategies with a better understanding of costs and outcomes. The project is organized with a planning committee of the 12 USGS science centers involved in the project. Tasks are set up by hazard-focused working groups with both hazard-specific research (Earthquakes & Tsunamis, Winter Storms, and Wildfires & Debris Flows) and communication activities through the Integration and Implementation Interface. All tasks are multi-hazard and multi-center. The major effort in 2007 was on wildfires and subsequent debris-flow warnings based on probability maps for burned basins. FEMA turned these maps into flood hazard maps based on projected volume, and the National Weather Service issued flash-flood and debris-flow warnings.

Scenarios were identified as a priority by the stakeholder community. The first one focused on earthquakes, and the next one will be on winter storms. Earthquake scenario development was done with many partners, including the California Geological Survey, which jointly published the scenario. The project took the unique approach of generating both a full report and a story of the scenario, which has been quite effective in the community. Part of the Shakeout is the Golden Guardian emergency preparedness exercise, which is using the scenario as injects into the exercise. Seismologists are able to use the scenario seismograms to test early warning algorithms.

For the scenario, losses were derived from HAZUS runs with experts brought on as contractors to refine the results. Deaths are relatively low at 1,800 but injuries are over 50,000 as determined by the UCLA School of Public Health. Damages are \$213 billion of which half is business disruption, \$60 billion is due to fire (largely insured), \$45 billion in structural losses (of which 12% is insured). The Rocky Mountain Geographic Science Center was able to pull out the demographic data to determine that 250,000 people cross the San Andreas Fault to get to work each day. The California Department of Transportation calculates that 21% of freeways would be down for three days. Aftershock simulations show that a Northridge-sized earthquake would be an aftershock to this earthquake.

The fundamental message of the Shakeout is that what we do now determines the outcome after the earthquake. It will be a week of special events, including the Golden Guardian drill. A regional public-involved earthquake drill has never been done in the US. Over 1,500 organizations with nearly 2 million participants have registered on the Shakeout.org web site. The Los Angeles International Earthquake Conference will be hosted by the City of Los Angeles, which is inviting mayors of at-risk cities. There will be a "Get Ready Rally" in downtown Los Angeles. Counties, cities, businesses, universities,



and utilities are all developing exercises and other activities. Jones said that she has seen a level of engagement that she has not seen before with tangible changes taking place in preparedness and infrastructure improvements.

Archuleta asked if it was clear that the USGS has a leading role in the Shakeout. Jones replied that the approach is to position USGS and CGS as creating the scenario and then the Earthquake Country Alliance (of which USGS and CGS are both members and in which the Southern California Earthquake Center has a leading role) as using the scenario for the Shakeout drills and exercises.

All of this activity is part of the implementation interface component of the demonstration project, but the project also received funds this year specifically to support earthquake work. Twenty percent of all new money goes to shared operations, but the rest is research. For FY 2009, it is important that the demonstration project earthquake activities which are currently running in parallel with the Earthquake Hazards Team are brought together more effectively. Options should the additional funding proposed in the House appropriations bill come to pass include support for the Southern California component of the California Integrated Seismic Network to support network tools and early-warning development; real-time fault offset monitoring (GPS); earthquake statistics/triggering in conjunction with SCEC; crustal structure in Coachella Valley; user tools for microzonation database with CGS similar to what was done in Seattle. SCEC provides a mechanism to see new data incorporated and used.

Parrish acknowledged Jones's role as the catalyst for the demonstration project and ShakeOut from day one. McConnell sought clarification on Lucy's relationship to the earthquake team. It was explained that Lucy's position is based in the office of the Southwest Regional Executive, who is responsible for all science centers in the region.

Lerner-Lam made the point that USGS is in a powerful position to take ownership of evidence-based risk analysis. Jones noted that this role was accomplished for the ShakeOut scenario by contracting with Keith Porter of the University of Colorado through SCEC to pull in the needed expertise. At the outset, the economists thought they did not need the geology and vice versa, and there were tensions, but that changed as the project went forward.

Zoback stated that the ShakeOut scenario and exercise were a unique opportunity to identify future research needs. Jones agreed, indicating that this was a big part of the reason for issuing the scenario documentation as a preliminary open-file report, because the plan is to have the final report reflect the lessons learned from the exercise.

Dieterich observed that as a science agency, it is useful to have very specific holes in the science uncovered by the process. Jones and Hudnut noted a number of interesting and important papers that will be coming from the scenario development, including modeling, how to reconcile physics-based models with NGA; and a compilation of liquefaction from which ground-water levels can be derived.

*Action Item (USGS Staff): SESAC emphasizes the importance of scientific learning from the scenario and its use for identifying future research paths.*

LUNCH

### **Science from the Hayward Fault Commemoration**

Tom Brocher gave a presentation on the plans for commemoration of the magnitude-6.8 Hayward earthquake that struck on Oct. 21, 1868. The ShakeMap developed from the actual reports of shaking intensity from the 1868 event are being effectively used to make this event real to people. He emphasized the infrastructure impacts. USGS worked with the Bureau of Labor Statistics and the California Geological Survey looking at the number of employees and amount of their wages exposed to a Hayward Fault earthquake, which are several times higher than in Hurricane Katrina with Alameda County being the most heavily impacted. Tom Holzer has examined the areas that are most likely to liquefy, including major East Bay infrastructure. USGS has worked with PG&E and the San Francisco Public Utilities Commission to fly lidar along the urban segments of the Hayward Fault, extending the lidar acquisition by the National Science Foundation's EarthScope facility. As part of the UCERF work, the Rogers Creek/Hayward Fault system was identified as being the second-most likely fault to rupture with a magnitude-6.7 or greater earthquake. Trenching results show evidence for 11 events in the past 1600 years. Earthquake program funding is being used to improve dating of the earliest events identified by trenching. Geophysicists at Menlo Park have generated a three-dimensional geologic model for the Hayward Fault, and rock mechanicians have studied the impact of having different materials across the fault, indicating that serpentinite against granite has the lowest frictional resistance. Brad Aagaard has been leading an effort to develop ground-motion simulations for a Hayward Fault earthquake, which has the added challenge of accounting for creep, resulting in more patchy source models. For the 2007 Alum Rock earthquake and its aftershocks, there is research suggesting that the Hayward and Calaveras Faults may be connected at depth.

In public presentations, Brocher and colleagues show damage from the 1868 Hayward earthquake to make the event more real. They also relate it to the 1995 Kobe earthquake with correspondence between the geography of the region and the style of faulting. Working with the Hayward Earthquake Alliance, loss estimates for a Hayward Fault earthquake have been updated, showing \$120-165 billion economic loss due to shaking alone (comparable to Hurricane Katrina), damage to infrastructure and fires after the quake could significantly increase the total loss. Unlike Katrina, only 5-15% will be insured. A fact sheet about the earthquake has been developed.

The anniversary activities will take place on Oct. 20-24, 2008, including a commemoration at Mission San Jose, Bay Area-wide school drills (over 60,000 signed up so far), a three-day conference on seismic hazards, the regional Silver Sentinel earthquake drill involving 70 emergency response groups organized by Alameda County, a public forum, and meeting of Bay Area governments. They have formed an alliance of 126 organizations, similar to what was done for the 1906 earthquake commemoration.

***Action Item (USGS Staff): The next meeting will be after these preparedness events have happened; so have a briefing recap of how they went on the next SESAC agenda.***

## **Global Risk Identification Programme**

Lerner-Lam gave a presentation on the Global Risk Identification Programme (GRIP), which emerged from a series of UN, World Bank, and Inter-American Development Bank reports on hotspots and vulnerability. The Natural Disasters Hotspots report identified priority regions for action by international development organizations. The World Bank's internal evaluation group noted that there was not much activity in this area by the Bank, and that the Bank's disaster assistance programs were underutilizing what was available at the time. A numerical evaluation of social vulnerability was developed. The goal is to "mainstream" disaster risk reduction into the primary development programs. The effort is multi-hazard with a focus on national programs, and there is a linkage to climate-change adaptation. Like PAGER, it generates risk by city.

GRIP is now a project under the UN Development Program based in Geneva. It developed out of the three reports and the international programmatic framework of the International Decade for Natural Disaster Reduction (IDNDR), the International Strategy for Disaster Reduction (ISDR), and the Hyogo Framework. It gained momentum after the Sumatra earthquake and tsunami. Core support comes from UNDP as well as donors with the primary donors being Norway, Sweden and England. GRIP includes a global risk update, risk analysis, accumulation of post-event loss data, and pilot projects in specific demonstration countries. The first three are Nicaragua, Sri Lanka, and Mozambique, identified as priorities based on risk calculations and lack of significant experience in risk assessment and its applications. GRIP's main activities are national risk assessments, design strategies, pilot projects in identified hotspots, and strengthening national institutions (e.g. geological survey, emergency management). Proposals have been submitted in response to a UN request for proposals.

Loss data enhancement recognizes lack of standards for loss data acquisition and the need to get that information back out to committees. There is a regional-scale proposal for the Southern Peruvian Andes, national-scale for Nepal, and a sub-national proposal for \_\_\_\_\_. The Global Risk Update subprogram focuses on 10 hazards, looking to improve loss exposure and elements of physical and social vulnerability, especially those correlated with poverty since the purpose of development is to reduce poverty and increase resilience. The first update is planned for 2009.

For earthquakes, GRIP started with the 1999 Global Seismic Hazard Assessment Program (GSHAP) calculations to develop a consistent cross-border methodology. To do this at a regional/national scale to build a global model, there may be a vetted and understood methodology but it still data dependent resulting in inhomogeneous application based on data and assumptions; hence he sees the need for a project like the Global Earthquake Model (GEM) under consideration by the Organization for Economic Cooperation and Development (OECD). Discussions to date include the need to develop a pipeline from GRIP to GEM and similar efforts in other hazards; assess and use national catalogs for high-risk nations; and national hazard maps where they are

developed. Specific opportunities are close UN cooperation with international stakeholders, inclusion of a PAGER-type approach to the 2009 GRU publication, PAGER “intensity buffers” for new exposure and loss calculations, high-resolution country hazard assessments produced by the USGS National Seismic Hazard Mapping Project team could be folded into global assessments, a GEM product pipeline, white paper reviews from the science and engineering community in parallel to what is being done by the development economists, standards discussion, and pipeline for full inclusion in 2011 including funds for foreign fellowships to assist with some of the calculations.

The UN will be perfectly happy to do this in a technical vacuum being driven by development objectives. They need some guidance when they parachute into the technical data products, which could link to USGS objectives.

Zoback thanked Lerner-Lam, indicating that he had asked for this presentation because he wanted to learn more about GRIP and to consider the role and opportunities for USGS. He asked about the origin of the project, and Lerner-Lam replied that Columbia University’s Earth Institute held discussions with the UN regarding climate change and other hazard risks and developing global vulnerability maps came up. Columbia developed a program with World Bank to develop maps and has become the sole-source supplier of technical information to the UN in this arena.

### **Global Earthquake Model**

Continuing the session on risk, Ross Stein provided SESAC with an overview of the GEM project. It’s goal is to establish an independent standard to raise risk awareness to promote mitigation. He sees it as a \$50 million, 5-year project, and the fund-raising is about a third to a half way there. The need is clear: A quarter of the world’s cities face substantial risk from earthquakes. We are likely to experience an earthquake in our lifetimes that reduces a megacity to rubble and takes a toll of 1 million people. For that to happen, we as scientists have to say that we have failed. As it stands, the death rate in the undeveloped world is 10 times higher than in the developed world, and seismic hazard information is not widely accessible. Everyone should have access to information about their seismic risk, and we should be able to provide that. GEM seeks to raise risk awareness or nothing will change. Stein stated that he has no illusions that a risk model will raise awareness, but when an earthquake strikes, people need a credible place to go for information. There is a need to build in not just earthquake hazards and building inventories but also financial tools in order to help answer policy questions such as whether Istanbul should spend money to retrofit schools, increase insurance capacity, or establish reserves for recovery. Currently, the tools do not exist to say where scarce money is best spent.

GEM must be as uniform and comprehensive as possible, including both land and seafloor faults. It must be open, international, and independent – politically, commercially, and scientifically. USGS cannot do this alone but can be part of an international non-profit organization. USGS is in a position to contribute to new open-source software, standards, and open datasets; global active fault files; building inventories; and historical earthquakes. A key hurdle is inventories, but there is lots of

progress to be made with Google's effort to catalog all buildings in the world's 30 largest cities. There is a need to engage scientists in other countries: GEM can provide the tools, technical support, guidance and encouragement. We all want to contribute to something larger than our own work, but GEM has larger ambitions still: It needs to be an authoritative voice for the global seismic threat. GRIP will be limited by its constraints within the UN system. Such international bodies are good-meaning paper organizations. He is impressed with what the Intergovernmental Panel on Climate Change has done, and GEM can aspire to that. The second larger ambition is the realization that nothing will change unless bring new money can be brought to the table; real money for people to retrofit, move, buy insurance, and build reserves. Insurance is only available in a small number of developed countries; developing risk maps can help allow insurance to begin elsewhere and foment national risk pools as in Turkey. We must bring money from the capital markets to this stage. Insurance reserves today are around \$250 billion. The amount invested in Tokyo is 5% of what is at risk. Capital markets are vastly larger, and they need to place their bets on earthquakes. The mechanism for doing so is catastrophe bonds, which provide a good rate of interest like a junk bond, but if a specified earthquake occurs, then money becomes available immediately for recovery. Institutional investors are now putting 1-2% of their investments into cat bonds since earthquakes are uncorrelated to markets – it's a hedge to investors. If we build GEM so that earthquake risk is available everywhere, then anyone can put cat bonds into market, and the market can then package them into mutual funds. Information is available to buyer and seller both, so symmetrical information. New Orleans did not get on its feet because insurance money did not show up.

Stein described GEM as a public-private partnership. He is very pleased that Munich Re, Zurich Financial Services and AIR Worldwide have pledged 9 million Euros to the project. The Swiss, German and Singapore governments have come forward with pledges. The GEM organizers, Stein included, are pitching a proposal to the Inter-American Development Bank. GEM is being managed as a program of OECD with the plan being that it would eventually become a non-profit organization in a host country.

Questions from the committee included when the project would start work, how to achieve standardized tools and procedures, and who would do the work. Stein stated that GEM had before it a proposal from Ned Field to develop OpenSHA as GEM's hazard engine so that it can be taught and technical support provided. The idea is to provide very good tools, not to rebuild the Japanese map or the dozen or so maps that the USGS National Seismic Hazard Mapping Project team has done in developing world with USAID support. The key is to take advantage of such efforts where they exist. Stein sees PAGER as a tool with many innovations that he would like to have imbedded into GEM, and there is possible postdoc interest from both David Wald and Art Frankel. Stein cautioned that GEM is not going to be a funding agency for developed nations but will be responsive to requests for postdocs, travel, workshops, and training expenses.

Dieterich asked whether the goal is a uniform map or just uniform tools. Stein replied that they do want one website where anybody could look at their area, time period and criteria of interest. It should be as seamless across borders as possible. He went on to note that one of the big problems for seismic hazard assessment is that we have no real way of

validating whether these assessments are right: it's quantified but cannot be proved wrong. We will not overcome that except globally because we will never capture enough earthquakes in the US or Japan to know whether we are doing it right, hence need to capture the earthquakes. Everything GEM does will be captured by SCEC's Collaboratory for Scientific Earthquake Prediction (CSEP) project, comparing models.

McConnell asked how GEM would integrate areas that are not data-rich. We can do activity rates like UCERF based on what we have but how well can we predict fatalities? Jones encouraged Stein to think about connections with the Shakeout and Los Angeles investors. She added that another big barrier to a truly global model is magnitudes, especially for smaller quakes where different magnitudes used in different countries have big error bars; b-value means something different in different countries.

Zoback asked Stein to comment on the capacity building/training aspect of GEM. As an example, Stein noted that they have approached IADB in cooperation with the CERESIS consortium of seismological organizations in South America. With GEM as an umbrella, the proposal is for CIRENIS to do the seismic maps with 90% of the IADB funding to go to CERESIS. GEM would make sure the work was done in a uniform manner with help from USGS. The proposal is for 5 million Euros. He emphasized that the goal is enabling other people to do hazard and risk assessment and underscored the need to raise the ante in order to obtain the resources that are needed to do a proper job.

Archuleta sought clarification on the role of the USGS, noting that as a federal agency USGS has a social responsibility but given the state of the teams, it also needs to be paid. Stein suggested that USGS would be a catalyst because so much of the talent is here. He sees GEM as a mechanism by which USGS diffuses itself and raises its international stature. We do all this beautiful important work after an earthquake occurs but nothing beforehand about the likelihood of that occurring: Standards, software, training, and helping people. Archuleta then asked why the reinsurance companies are not doing this already. Stein argued that the companies were in fact putting real money down despite the fact that GEM is non-proprietary and open source.

Applegate provided some background on the OECD involvement, which stemmed from an OECD Global Science Forum workshop on earthquake science in Potsdam two years ago. Redoing GSHAP was one of the principal recommendations from the workshop, and GEM became the approach for achieving that end through the efforts of workshop organizer Jochem Zschau of GFZ Potsdam, Domenico Giardini of EHT Zurich, and Stein. The US representative to the OECD Global Science Forum is White House Office of Science and Technology Policy Associate Director Sharon Hays, who attended a Forum meeting this spring at which Zschau gave a presentation on GEM, thus putting USGS in the position of briefing the White House on this project and the role US should have going forward. In turn, OSTP has encouraged involvement by the National Science Foundation, USAID and other federal agencies. Since then USAID has been briefed, but NSF has indicated that they do not see this as their issue. USGS has not been in a position to make a direct financial contribution to GEM but rather has offered the in-kind services of Stein and potentially others. Ideally, this would be augmented by GEM support for temporary research staff.

Zoback asked about intellectual property issues, and Stein responded that there were still bridges to cross in that regard but that there are ways to work with anonymized datasets. Lerner-Lam pointed to the hedge fund model, where cat bonds are there to cover losses. Modeling companies will take open information and then price bonds based on proprietary loss; by contrast, development banks focus on what is off-book for the insurers, and they are exploring some international trust fund mechanism to set up reserves. For open-source information, data standards are not as good as what is available within the insurance company holdings, so GEM could motivate global data acquisition. Zoback clarified that the data generated by GEM would be open but that data given to GEM might have terms, which Stein corroborated, describing GEM as potentially the Kelly Blue Book for disasters. With respect to the USGS role, Stein noted that when he first put forward development of GEM as a venture capital proposal to the Geologic Discipline, it was initially rejected but then reconsidered. He argued for the appropriateness of public/private funding given that we have mutual interests, and those companies are putting money on our work.

Jones asked how to get the information in a form that will be used and will contribute to safety, noting that we do not usually take that extra step. She emphasized that we cannot expect non-specialists to translate what we are doing. At same time, she noted that there are people within USGS who feel we should not be doing it. She considers this to be a fundamental philosophical issue: Where is our role once the science is done; do we just hand it to someone else?

McCarthy stated that the issue of an international role for USGS is not if but at what level. The NEHRP authorization language is quite clear that that USGS has a role to play in information transfer and technical assistance, which is the statutory origin of NEIC. What we need to decide is what can we afford to contribute, how many people, and what do we get back. Stein emphasized that GEM is not supposed to be a drain on the USGS but a benefit. Dieterich noted that there could be significant scientific returns from GEM. Any increased uniformity in our understanding of global seismicity and ways of addressing forecasting hazards would be a major benefit. McConnell noted that there are other models for USGS assisting with international issues, citing the successful USAID-supported Volcano Disaster Assistance Program. Rathje sought to clarify that most of the funds would go to developing countries, which Stein said was the case, but that there was also a recognized need for tool development, including a historical catalog and global fault database. Other countries would need to populate the database, but USGS could set the standards to enable the science. Lerner-Lam emphasized the importance of USGS being at the table. GRIP needs something like GEM. Not having an authoritative international voice like the World Meteorological Organization is for hydrometeorological hazards is a real stumbling block for the geologic hazards, and USGS is well placed to take a leadership role and generate standards that we know work.

Zoback noted that in many ways GEM and the multi-hazards demonstration project were taking different approaches to achieve the same end. He indicated that national insurance pools for developing countries was a worthwhile goal. Archuleta added that GEM could

achieve what GSHAP was not able to do: Incorporate time dependence, add a risk component, and create a legacy environment.

### **White Paper on Future of USGS Earthquake Geodesy**

Applegate introduced the next topic, a draft white paper prepared by a team of USGS geodesists as a SESAC-requested follow-up to the presentations given at the committee's Paso Robles meeting in October 2007. As the earthquake program's geodesy coordinator, Ken Hudnut (Pasadena) led the writing team, which also included Jessica Murray-Moraleda (Menlo Park), Nancy King (Pasadena), Yuehua Zeng (Golden), and Evelyn Roeloffs (Vancouver WA). Hudnut briefed SESAC on the draft, which was circulated to committee members earlier in the week. The earthquake program office charged the writing team with looking at current capabilities and help define a vision for where the unique role of the USGS is going forward in consultation with other geodesy experts supported by the program and the program council. The writing team was asked to consider both flat budget and slightly increasing funds. The draft is currently going through internal review, being shared with SESAC members as special government employees with input welcomed.

#### ***Action Item (SESAC) – Provide comments on draft geodesy white paper by August 15th if possible.***

According to Hudnut, key conclusions are that geodetic data must be further integrated into both real-time earthquake information products and long-term earthquake forecasts, USGS must maintain knowledgeable oversight of all available data with an eye specifically attuned to urban hazards, and a very strong research element remains essential to the program. Zoback urged that those statements be highlighted in the executive summary.

Hudnut noted the use of borehole strainmeter data from the Chino Hills earthquake. He added that USGS expertise could be helpful in providing better interpretation of data from EarthScope's Plate Boundary Observatory (PBO) instruments, but meanwhile USGS is having trouble maintaining its own dilatometers. He stated that USGS processing complements PBO processing and to the extent there is overlap, the results are right in step. USGS maintains 90 GPS stations in Southern California to PBO standards, so a single data stream comes out the other end through PBO. However, PBO does not fund real-time or near-real-time processing using ultra-rapid and rapid orbits and does not see that as part of its mission. Although PBO recovers high-rate data, they do not process it. Jessica Murray-Moraleda heads up a USGS working group with individuals from both the earthquake and volcano groups.

Archuleta asked why there was a need to process the real-time data in both Menlo Park and Pasadena. Hudnut explained that there are two packages – GAMIT and GYPSY – with results that can agree but can go in different directions. NSF pays UNAVCO which contracts groups to do GAMIT and GYPSY processing, which is then merged by Tom Herring at MIT. USGS does the same: Pasadena uses GAMIT and Menlo Park uses GYPSY. This dual approach is also the case for real-time and high-rate processing:



Because there is inherent noise in the data that is not well understood, the dual-processing is a good check on the results. All the USGS geodesists have both research and operational responsibilities for routine processing. Historically, geodesy has been tightly commingled between research and operational functions, and the writing team found that trying to tweeze that apart in both the internal work and external support was tricky.

Hudnut stated that the writing team felt that GPS could be very useful for earthquake early warning using pairs of instruments along a fault – zipper array as fault rupture detector. In FY 2008, he received multi-hazard demonstration project funding for fault-crossing lifelines of special interest.

He noted that those GPS stations in southern California that most directly met USGS earthquake program needs are being operated by USGS while the rest of what had been the SCIGN network were being supported by NSF through UNAVCO and the PBO Nucleus project. Another recommendation was to maintain a basic field crew capability in Menlo Park for survey-mode GPS. He described the need to expand capabilities to make full use of imagery differencing such as repeat-pass LIDAR and InSAR, which can be used for damage analysis. A question is at what point should USGS earthquake program do this or others should given that NASA and others are heavily involved in InSAR in particular. NASA's proposed InSAR satellite received a high rating from the National Research Council's recent decadal survey of NASA missions with multiple scientific communities seeing the value of such a capability. Hudnut noted the challenge with recruiting and keeping young geodesy talent, having lost two to UNAVCO in the past several years. He emphasized the importance of open-source software. Hudnut expressed frustration that USGS was not currently in a position to authoritatively comment on data being analyzed from these new technologies.

Archuleta asked what must be done internally by USGS and what can be contracted out, noting the approach taken with the regional seismic networks. Zoback followed up, asking what specific expertise was needed internally and how many individuals. McCarthy added that with the seismic networks, USGS relies on university colleagues and asked about pursuing that model. Hudnut indicated that unlike with the seismic networks, the external geodetic network grantees do not see themselves as operators in the same way. Dieterich asked whether all the high-rate data being generated was being analyzed. Hudnut indicated that the original promise of EarthScope was for funding to enable research with the data being generated by the facility, but slower-than-expected budget increases at NSF meant that the resources are not there to look at all the data even if the academic networks saw themselves in a monitoring role. He argued that it was important for USGS's statutory responsibility under the Stafford Act to be looking at the data, especially in urban areas, which is not happening. USGS needs to have the capability to study data anomalies as quickly as possible.

Archuleta noted that SCEC twice asked for proposals on strain anomalies and had no takers; you do not want to have someone staring continuously at a blank wall. Hudnut stated that NASA and NSF are funding some science on transient detection. USGS could rely on algorithms developed by other people with other people's money, taking an operational role but even so would need more experienced people. McConnell asked how

could or should USGS take a leadership role in geodesy, asking about UNAVCO's mission compared to the USGS mission. Hudnut replied that UNAVCO is a non-profit organization funded almost entirely by NSF to make data accessible to the research community. USGS staff have been involved in UNAVCO leadership. The goal of UNAVCO is to process the data and make higher-level products available to researchers. Lerner-Lam added that UNAVCO has no operational responsibility for hazards but then raised the question what about NASA. Hudnut replied that NASA sees a role for itself in this arena and has money to spend. NASA has funded some of the real-time GPS development. USGS is working with NASA on alerts for volcanoes. Hudnut indicated that USGS would happily work with UNAVCO to split off the real-time data stream and have USGS use it for alerts.

***Action Item (SESAC): Consider the need for a recommendation to be made from SESAC regarding NASA.***

Dieterich asked whether the report represents a change in direction and whether anything was proposed to be eliminated. Hudnut replied that the writing team did not single anything specifically for cuts but instead focused on those activities that align well with the USGS mission, Stafford Act responsibilities, interagency agreements, and current capabilities. The program council has looked for what may be outside the fence.

Hudnut concluded with several final topics. He noted that USGS is the only entity doing survey-mode GPS on a regional scale. Although EarthScope funded a pool of GPS instruments through PBO, the funds have not been there to use them; this represents an opportunity if USGS could find the funds. Geodetic data are adding a new dimension to seismic hazard maps, but a key research area is how to invert GPS data into fault slip rates. Super-high-precision lidar data like the B4 project on the southern San Andreas Fault enables quantitative imaging of the deformation field from a surface-rupturing earthquake at a resolution that InSAR does not allow, potentially providing unprecedented understanding of the heterogeneity of slip on the fault.

There was general agreement that just a single white paper was needed rather than a separate review document. The white paper would benefit from external review, for example external researchers like Emily Brodsky and Roland Burgmann who use the USGS borehole strainmeter data.

***Action Item (USGS Staff): Applegate will relay the committee's comments to the writing team and propose an approach going forward.***

## **EXECUTIVE SESSION**

During a brief executive session, the committee discussed follow-on to the geodesy white paper.

The meeting adjourned for the day at 5:00 p.m.

Friday, August 1st

## Wenchuan Earthquake Report

Walter Mooney, who serves as the earthquake program's China coordinator, provided SESAC with an overview of the Wenchuan earthquake and the US response to it. He noted that such a well-recorded and observed continental earthquake represents a rare opportunity to improve our understanding of such large, damaging earthquakes globally and here in the United States.

An agreement with the China Earthquake Authority was negotiated at a meeting held in Beijing by a U.S. delegation led by Jack Hayes, NEHRP Director, for access to data and permission to visit the affected area. The committee was shown a video prepared by one of Walter's students who visited the epicentral area 10 days after the event. No laser mapping was allowed but other requests were granted.

An EERI/GEER team will be visiting the epicentral area beginning on August 2nd. There is field evidence for 4 meters of vertical displacement in what appears to be a thrust event that became strike-slip, apparently reflecting motion on more than one fault. Like an eastern US earthquake, the shaking was felt over a broad area to the east with two pulses of slip corresponding to heavy damage in Wenchuan and Beichuan. Inversions will be redone once field geology evidence and geodetic measurements have been obtained.

Mooney listed topics for immediate cooperation including fault mapping, remote sensing, engineering seismology, strong ground motion, landslides, liquefaction hypocenters, focal mechanisms, aftershock probabilities, and deep drilling of the fault. He reported that Emily Brodsky has been to Beijing to talk with the geological survey about drilling. USGS's Angela Jayko is going over at the end of September to do fault mapping. Ed Harp and Randy Jipson from the USGS Geologic Hazards Team are going to look at landslides. USGS is working with China to set up a single site with links to all 70 strong-motion sensors. The NEIC did an excellent job with reporting on the event and disseminating information.

According to Mooney, the Longmenshan system that ruptured is accumulating very little geodetic slip, which underscores that infrequent earthquakes can represent a very significant hazard. Shaking lasted for 500 seconds at a distance of 1,500 kilometers. Buildings in the region were designed to withstand forces up to 0.15g, but the quake generated 0.5g. All the monitoring stations located on the hanging wall were destroyed, but the footwall stations indicate 0.7m horizontal movement. Damage was light in Chengdu, the nearest major city on the Sichuan plain.

Mooney reported that the Chinese had 300 broadband stations (Refteks) deployed in the region that will have generated a tremendous trove of data. Papers have already been published examining the Coulomb stress change, two with USGS co-authors. One of these (Toda et al. in *Geophysical Research Letters*) concludes that certain areas have a 40-68% chance of rupture in the next decade. The journal *Science* reported that Zinlingpu Dam (100-150m deep), which was completed two years ago directly above the epicenter, may have triggered the earthquake.

Mooney emphasized that people in China were hungry for information. The CEA has apologized for not predicting the quake for which no precursor signals were seen. With the US and China having signed the agreement at a high level, it is up to the individual investigators to negotiate specific research activities.

### **Episodic Tremor & Slip Workshop Summary**

David Shelly, a Mendenhall postdoctoral fellow at Menlo Park, reported on a workshop took place on Vancouver Island in February 2008 with 50 participants. SESAC had requested a summary as part of the agenda because of their 2007 report recommendation that the USGS earthquake program become more engaged on the issue of episodic tremor and slip. According to Shelly, the focus of the workshop was on earthquake hazards and educational opportunities. Slow slip events are modeled to occur in a transitional zone downdip of the stick-slip locked section of the subduction interface. Observations of triggered tremor (from teleseisms) and slow slip are turning up in many areas: Southern Japan, Pacific Northwest, Hawaii, California's San Andreas Fault, Alaska, the Central US (maybe), and Central America.

In order to assess earthquake hazards, it is necessary to constrain rupture dimensions, rupture heterogeneity, repeat time, and wave propagation. A key question to address is what connection exists between slow slip, tremor and earthquakes. We can calculate the coulomb stress change on the up-dip locked portion of subduction zones, which is very small (0.1 bar) but over the week-long timeframe it does add up. In 2004, Mazzotti and Adams estimated the conditional probability for a major megathrust earthquake on the Cascadia subduction zone is 1 in 4,000 during a two-week slow-slip event compared to a probability of 1 in 200,000 in between -- a 50-fold increase. The workshop consensus was that this may be an over-estimation and that these simple stress-transfer probability gains are not significant.

McConnell, who also attended the workshop, noted that the workshop was geared to having not just the scientists but also emergency managers and decisionmakers, so extensive discussion took place about how to advise from a public warning stance but also how to take advantage of a tremendous educational opportunity.

Dieterich noted that this workshop grew out of a NEPEC meeting held last year in Portland, Oregon, which concluded that further examination was warranted. Looking at Cascadia as a whole, these tremor events have occurred hundreds to thousands of times since the last megathrust event. There may be interesting and valuable forecasting information, but it is not yet actionable.

In response to a question from Zoback whether there was a sense among workshop participants that fire departments and police should be notified and used as an educational opportunity, McConnell indicated that emergency managers wanted more understanding from the scientific community, recommending that people be informed that a tremor event is going on, but at the same time being clear that it people were not being asked to be on alert. Rathje noted that there was a risk of people becoming complacent.

McConnell added that it was noted at the workshop that people could come to think that there was an earthquake “season”.

Dieterich noted that NEPEC did call for USGS to get more involved in this problem and emphasized that there is a lot of preparation that should be going on. Zoback added that while we do not want to alarm people, at the same time you do not want to be in a position of not informing the emergency response people that there might be such an increased probability. Engagement on the scientific and monitoring level, notification of disaster response, and education of public at large are all important.

McConnell stated that this was the first workshop to bring together scientists and decisionmakers from many different areas on this topic, which raised the question of what exactly to educate people on. She noted that we still face the question of what would be done if there was a magnitude-5 or 6 earthquake on the locked section of the subduction zone during one of these events. In such a situation, it would be imperative to speak with one voice.

Nishenko asked if there was a sense of how these tremor events fits into the larger Cascadia earthquake cycle, in particular whether they accelerate toward the next rupture. He further noted that scientifically, this phenomenon represents an opportunity to produce higher-resolution maps of strain accumulation adjacent to locked zones. There is direct evidence relating the boundaries between earthquake ruptures and slow-slip ruptures from southwest Japan and Alaska. In Hawaii, slow slip on the south flank of Kilauea appear to correlate with triggered seismicity.

Shelly indicated that the workshop concluded there was a need to look at as many places as possible in order to narrow down which parameters are important. An example is the shallow aseismic creep on the San Juan Bautista section of the San Andreas Fault.

There is evidence that slow slip and earthquake processes behave fundamentally differently. For earthquakes, longer duration corresponds to higher moment rate whereas with slow slip, that is not the case. Numerical modeling suggests that low effective stress is necessary to make slow-slip work, which probably means high pore pressures. Petrologic modeling indicates tremor occurs close to the basalt-eclogite transition with accompanying water release, so there is a fluid source in this region. Tidal triggering of tremor suggests faults must be right at the edge of failure and quite weak so low effective stress.

Shelly laid out the workshop’s findings with regard to implications for policy and response:

- Current estimates of the size of and uncertainty in probability changes at present make public hazard warnings premature.
- Application to hazard will likely be through improved definition of the locked zone.

- Planning across state/national/international boundaries for various realistic scenarios is needed.
- The repeating nature of tremor and slip provides a reminder to update scenarios and communications between the research community and emergency managers periodically to reach out to the public.
- Episodic tremor and slip events represent a tremendous educational opportunity, including juicy blog material.
- Action items from the workshop included setting up an EarthScope website on episodic tremor and slip. In a sign of the times, a Facebook group has been established with 25 members so far.
- Scientists and emergency managers need to coordinate how to respond to extraordinary tremor slip or earthquake activity; USGS has posted a Mendenhall opportunity to look into this issue.
- Proposals are being made to hold an American Geophysical Union Chapman conference, produce a special volume of the Journal of Geophysical Research, publish a workshop report in EOS, and write a workshop report.

In discussion, Mooney asked why this phenomenon was not seen sooner. Rogers noted that instruments have been capable for 25 years, but the signal looked like noise; it is necessary to look at multiple stations over time to see migration along strike. In many cases, the individual station signal does not look different from a wind signal. Zoback noted that the workshop report prepared for EOS calls for more dense geodetic stations and grouping seismometers for beaming of seismic energy to determine seismic source direction and asked how would one come up with blueprint for Cascadia monitoring and the potential for array seismology. Rogers replied that there is now a lack of density in Oregon since the EarthScope Transportable Array stations have moved on after their 18-month deployment. The University of Washington has laid out arrays during the recent events, and strainmeters are proving very useful.

Zoback added that PBO has many strainmeters that were purchased but do not plan to install due to increased costs. These are sitting on the shelf. He added that beam steering was used at a small temporary array at Parkfield to show migration. Rogers stated that USGS should be asking how dense the network needs to be, both geodetic and seismic.

***Action Item (SESAC): The committee plans to include in its annual report a call for USGS to develop an effective monitoring and research plan for greatly enhancing the understanding of episodic tremor and slip events.***

## **ANSS Steering Committee Report**

Ralph Archuleta reported on the June meeting of the ANSS National Steering Committee, which was established as a subcommittee on SESAC. Ralph noted that ANSS Coordinator Bill Leith could not make the report because he was in Paris (no expressions of sympathy were recorded). In Archuleta's view, what is most disheartening about ANSS is that this year has seen the smallest number of instruments yet installed

since ANSS was initiated. Overall implementation is only at 10% of what was planned and authorized. The only reason that any installations took place was that of the \$2 million increase received by the earthquake program for the multi-hazards initiative, \$800K went to ANSS instrumentation on the Southern San Andreas Fault. Otherwise, annual operational costs have gone up, squeezing out development of the network.

On a positive note, a number of states are adopting Transportable Array stations before they move, and ANSS is picking up the long-term costs. The New Madrid bicentennial represents an opportunity for not only education and outreach but also to raise awareness for station adoption by showing the practical value. Another opportunity in the east is with nuclear power plants through the U.S. Nuclear Regulatory Commission.

ANSS is supposed to put 3,000 instruments in structures; 11 structures have been instrumented so far. USGS does not have good expertise in structural monitoring, only one structural engineer; otherwise, it is relying on contractors. And with those structures, such as the UCLA Factor Building, there is a challenge due to the volume of data being produced. The new USGS/California Geological Survey National Center for Engineering Strong Motion Data has been developed to archive waveform data. The engineering community has been a strong support group for ANSS, and it is important that they are well served. The USGS National Strong Motion Project (NSMP), which was developed to acquire strong-motion recordings, has not yet been fully incorporated into ANSS. Engineers are looking for a set of easily searchable standard products, for example acceleration integrated to velocity and displacement. There should not be a separate group to handle these data as if they need asbestos gloves.

The biggest issue within seismic monitoring is dollars, but it is also critical to take advantage of the tremendous investment represented by EarthScope's USArray component. There is a good strategy on which instruments to adopt. The real weakness is going to be in NSMP: ANSS needs to take more responsibility for structural monitoring rather than separate collection arm.

Lerner-Lam asked if it was anticipated that NSMP was going to move in the direction of better archiving. Archuleta replied that the plan is for all free-field data to flow through the regional networks; buildings would require a separate entity. One wants the data to be as accessible as possible by earthquake or any other sorting mechanism. Parrish noted that some regional networks do not funnel data to the National Center for Engineering Strong Motion Data or do not provide the accompanying metadata. Rathje asked if thought had been given to site conditions, and Archuleta replied that this was an important part of the metadata and that efforts were needed to collect more. Applegate noted the effort going on in southern California by Alan Yong.

Rogers asked whether the NSMP group should change its focus to which Archuleta replied that they should focus on instrumenting structures, ensuring that data flow into ANSS and knowing how to process the data generated by specific earthquakes.

## **Executive Session**

Following a short break, the committee convened for a final executive session. Topics discussed by the committee included NSMP, the Advisory Committee on Earthquake Hazard Reduction, global risk modeling, and future committee membership. McConnell and Lerner-Lam will rotate off after the next meeting.

The committee agreed to hold its next meeting in January or February 2009 in the Pacific Northwest, possibly Portland.

The meeting adjourned at noon.