

**Progress Report**  
**The San Diego Foundation Science & Technology Blasker Grants Program**  
**Spring 2006**

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**Organization Name:** Scripps Institution of Oceanography Visualization Center

**Project Name:** Interpretation and Dissemination of Coastal, Seismic and Geological Characteristics of the San Diego Region Using Interactive 3D Visualization Techniques.

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**Completed by:** Atul Nayak

## **Part I: Project Narrative**

### **1. Progress to date**

During the first 6 months of this project we worked on projects to solve problems in seismology, the application of computer graphics to specific projects in ocean sciences and the design of a new type of display system. Details follow:

#### **I. Study of two significant seismic events in southern California.**

##### **Magnitude 5.2 earthquake on June 12, 2005 near Anza, CA.**

Dr. Debi Kilb examined two unusual events that followed the magnitude 5.2 earthquake near the town of Anza, California, on June 12, 2005. Although the main shock fault was only several kilometers long, aftershocks stretched for at least 50 km along the San Jacinto Fault zone. There was a magnitude 4.9 earthquake 4 days later and 72 km away, near the town of Yucaipa. We tested the hypotheses that the extended Anza aftershocks were triggered by aseismic slip that followed the main shock and that the close space-time proximity of the Anza and Yucaipa earthquakes was a coincidence.

Kilb measured the density of the Anza aftershocks as a function of distance,  $r$ , from the main shock fault. If a broad region of aseismic slip triggered these earthquakes we expected a near constant density, whereas if the earthquakes are typical aftershocks we expected the density to decay as  $r^{-1.4}$  (Felzer and Brodsky, 2005). We observed the latter. Stochastic models of the Anza aftershock sequence based on normal aftershock production, local faulting geometry, and excellent local catalog completeness also look very similar to the observed sequence. This suggests that the apparently long spatial extent of the Anza sequence resulted merely from the dense Anza seismic network that provides the unique ability to record very small aftershocks. To test whether the Anza main shock triggered the Yucaipa earthquake we extrapolated local aftershock decay relationships in time and space to estimate the probability of the main shock triggering a magnitude 4.9 earthquake near Yucaipa after 4 days. We compared this to the probability of the Yucaipa earthquake occurring randomly. We found that there is a 21% chance that the Anza main shock triggered the Yucaipa earthquake.

We conclude that the extended Anza aftershock sequence is not out of the norm, and instead it results from the improved seismic recording capabilities in southern California. Work on creating visualizations to support these findings is in progress.

##### **Investigation of the time lag and magnitude differential between the main shock and first aftershocks of the 31 October 2001 Anza earthquake.**

The magnitude of the main shock of the earthquake on 31 October 2001 measured  $M_L=5.1$ . The largest aftershock was of magnitude  $M_L$  2.8 i.e. significantly smaller than the main shock magnitude. This large magnitude differential is due to a combination of factors that includes complexity of the San Jacinto fault system and the lack of large earthquakes in the Anza region in the last 20 years. Seismic stations within a 70 km radius of the main event recorded 8 aftershocks in

the initial sequence of aftershocks compared to seismic stations outside that radius. This indicates that the lack of large aftershocks in the initial part of the Anza 2001 aftershock sequences is not a limitation of the detection capabilities and is a confirmed true phenomenon.

Significant updates were made to the text, diagrams and visualizations for the research paper titled '*Aftershock Detection Thresholds as a Function of Time: Results From the ANZA Seismic Network Following the 31 October 2001 Anza, California,  $M_L$  5.1 Earthquake*'. We also created an on-line supplement that contains visualizations that help us discern specifics about the 2001 aftershock sequence.

## **II. Design and development of a mobile multiple display system.**

We collaborated with researchers at the California Institute of Telecommunications and Information Technology (Calit2) and the Center for Earth Observations and Applications (CEOA) to design and deploy the 'Mobile Interactive Imaging Multi-display Environment' (MiniMe) system. The MiniMe comprises of a cluster of Apple Mac Mini computers and a grid of 15 Dell 24" monitors. Atul Nayak, the principal architect of this system collaborated with Greg Dawe, Calit2 to design the mounting solution to make the system portable. Nayak and Dane Samilo worked on porting various software suites (SAGE and COVISE) to the Mac OS X platform for use on the MiniMe and related cluster computing tasks. We continue to develop tools required for scientists to use this unique display system.

## **III. 3D visualizations of the Huntington Beach experiment.**

We collaborated with researchers working on the SCOOS (Southern California Coastal Ocean Observing System) project to create high quality 3D interactive scenes and high definition renderings of the sensors used for in-situ observations in the San Pedro bay. This work was carried out using a visualization software tool called 'Fledermaus' and the Autodesk Maya modeling and animation suite. Using these tools, we incorporated various heterogeneous datasets into a single visualization – for example, we combined USGS aerial photography, high-resolution bathymetry and 3D models of sensors. We used the OptIPuter Visualization cluster (10 dual processors PC Linux cluster) to distribute the rendering of the high definition movies across multiple CPUs. This has enabled us to define a reusable automated rendering pipeline.

## **IV. High-resolution Sub-bottom and Bathymetric Surveys in San Diego Bay.**

The Unified Port of San Diego (UPSD) and researchers at SIO carried out a collaborative investigation to collect sub-bottom seismic-reflection and multibeam bathymetry data in San Diego bay. Surveys were carried out using SIO's state-of-the-art shallow-water technology to study the fundamental processes shaping San Diego bay. We are working with graduate student Danny Brothers to create interactive 3D visualizations using aerial photography, chirp and multibeam data.

## **V. High-resolution survey offshore La Jolla.**

A high-resolution CHIRP survey reveals shore-parallel variations in the Holocene sediment thickness offshore La Jolla, California. We are working with graduate student Leah Hogarth to create interactive 3D visualizations using this data.

## 2. Unexpected results so far.

None.

## 3. Publications and dissemination of results.

We have developed a webpage that contains information specific to our projects that include abstracts, images, data links, QuickTime movies, and interactive visualizations

<http://www.siovizcenter.ucsd.edu/sandiego>

Im T., Nayak A., Keen C., Samilo D., Matthews J. (2006), High resolution renderings and interactive visualization of the 2006 Huntington Beach experiment, *Eos Trans. AGU 87(52), Fall Meet. Suppl., Abstract IN31A-1318.*

Nayak A., Dawe G., Samilo D., Keen C., Matthews J., Patel A., Im T., Orcutt J., Defanti T. (2006), Design of a High Resolution Scalable Cluster Based Tile Display for Earth Sciences Visualization, *Eos Trans. AGU 87(52), Fall Meet. Suppl., Abstract IN31A-1309.*

## 4. Development of project participants.

This project is the first opportunity for the PI Atul Nayak to lead and manage a project and conduct innovative research in the fields of display technology and scientific visualization. Nayak has been able to apply existing tools and develop new technology for earth sciences data visualization. The project enabled co-PI Dr. Debi Kilb to investigate seismic events and test hypothesis, especially regarding the ability of the ANZA sensor network to record earthquakes of low magnitudes. This project has also provided funds for undergraduate student Dane Samilo's internship salary and has trained him in cross-disciplinary research. Further, the visualization technology developed under this project has led to the career development of other staff (Thomas Im, Programmer Analyst), graduate students (Danny Brothers, Leah Hogarth) and undergraduate students (Anand Patel, Paulo Ang) by providing them with new tools for the interpretation of their datasets.

## 5. Additional funding obtained.

CEOA provided funds for the hardware and software required to construct the MiniMe system. We also leveraged technology and hardware developed by NSF-funded projects e.g. the storage system developed by OptIPuter.

## 6. What did funding from The San Diego Foundation allow you to achieve that would not have been possible without such support?

This funding has made possible research in the areas of computer science and earth sciences. We were able to test hypothesis in seismology and develop new visualizations and a display system that is expected to define the next generation of tools that scientists will use to conduct their research.

## **Part II: Project Budget**

### **1. Expenditure report**

A total of \$15240.32 of the project budget has been utilized in the period August 2006 – December 2006. These include salaries for Atul Nayak, Debi Kilb, Dane Samilo and Laura Cravens-Wertz (Project Administrative Assistant) and costs for telecommunications and supplies. At the time of writing this report, the expenses for the month of December 2006 were not available due to the UCSD shutdown for the holidays. The expenses for December 2006 will include salary and travel for Atul Nayak and one undergraduate student to the American Geophysical Union Fall Meeting. A detailed breakdown of the expenses is attached and if requested, we will submit an updated expenditure report in February 2007 that will include the expenses for December 2006.

We will continue to support project personnel with the remainder of the funds for the next 6 months of the project duration.

### **2. How will the activities of this project be sustained in the future?**

We will utilize the remainder of the project budget to complete this project.