

Annual Report for Period:03/2007 - 02/2008

Submitted on: 01/28/2008

Principal Investigator: Meertens, Charles M.

Award ID: 0453975

Organization: UNAVCO, Inc.

Title:

PBO Nucleus: Support for an Integrated Existing Geodetic Network in the Western U.S.

Project Participants

Senior Personnel

Name: Prescott, William

Worked for more than 160 Hours: No

Contribution to Project:

Name: Blume, Frederick

Worked for more than 160 Hours: Yes

Contribution to Project:

Dr. Blume is the project manager and receives 20% FTE support from this grant.

Name: Meertens, Charles

Worked for more than 160 Hours: No

Contribution to Project:

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Name: Feldl, Nicole

Worked for more than 160 Hours: Yes

Contribution to Project:

Ms. Feldl was hired in June 2005 as Project Engineer and receives 100% FTE support from the grant. She is involved in all aspects of the project, including performing station upgrades and maintenance in the field, configuration and testing of equipment, monitoring of data flow, and project documentation.

Name: Boyce, Eleanor

Worked for more than 160 Hours: Yes

Contribution to Project:

Ms. Boyce was hired in October 2006 as Project Engineer and receives 50% FTE support from the grant. She is involved in all aspects of the project, including performing station upgrades and maintenance in the field, configuration and testing of equipment, monitoring of data flow, and project documentation.

Other Participant

Name: Olds, Shelley

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Bohnenstiehl, Kyle

Worked for more than 160 Hours: No

Contribution to Project:

Oversaw process of transferring existing GPS site permits from original network operators to UNAVCO and procuring new permits where needed.

Name: Lewman, Rand

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Jarvis, Chelsea

Worked for more than 160 Hours: No

Contribution to Project:

Research Experience for Undergraduates

Organizational Partners

University of Utah

This institution is a subawardee of this grant. In addition to salaried staff and field expenses partially supported by project funds, the University provides vehicles, office space, and computer and communication hardware used for data flow and network operations.

Central Washington University

This institution is a subawardee of this grant. In addition to salaried staff and field expenses partially supported by project funds, the University provides vehicles, office space, internet support, and computer and communication hardware used for data flow and network operations.

University of Southern California

This institution is a subawardee of this grant. The University provides staff whose salaries are supported by project funds, as well as financial oversight through other institutional employees.

California Institute of Technology

This institution is a subawardee of this grant. In addition to salaried staff and field expenses partially supported by project funds, the University provides vehicles, office space, and computer and communication hardware used for data flow and network operations.

University of California-Berkeley

This institution is a subawardee of this grant. In addition to salaried staff and field expenses partially supported by project funds, the University provides vehicles, office space, and computer and communication hardware used for data flow and network operations.

University of California-San Diego Scripps Inst of Oceanography

This institution is a subawardee of this grant. In addition to salaried staff and field expenses partially supported by project funds, the University provides vehicles, office space, and computer and communication hardware used for data flow and network operations.

United States Geological Survey

The USGS provides office space, vehicle support, computers, and organizational staff to the project. PBO Nucleus stations in Parkfield are primarily maintained by USGS staff using USGS resources, with hardware support provided by Nucleus.

USGS staff in southern California regularly perform maintenance on PBO Nucleus stations, and Nucleus staff (employed by USC) do so on USGS-operated stations. The USGS provides a dedicated vehicle to the Nucleus project as well as office space and supplies to Nucleus project staff in Pasadena.

The USGS Golden office provides the project access to their NSN satellite network which allows access and control of GPS stations at remote locations free of charge. USGS staff have worked extensively on development of a secure network in order to satisfy USGS and UNAVCO IT policy requirements.

Harvard Smithsonian Ctr for Astrophysics

The University provides computer and communication hardware used for data flow and network operations.

University of Alaska Geophysical Institute

University provides staff, vehicles, office space, and computer and communication hardware used for data flow and network operations, and station maintenance.

Other Collaborators or Contacts

Plate Boundary Observatory, UNAVCO Inc.: In addition to staff and activities of the PBO Permitting and Data Management and Information Technology (DMIT) groups that are funded directly by this grant, staff and resources from PBO Boulder and regional offices have been extensively involved in PBO Nucleus project activities. PBO staff have performed maintenance on Nucleus stations, provided vehicles and other resources to Nucleus staff, and been involved in the design and implementation of communication networks that are shared between Nucleus and PBO GPS stations.

UNAVCO Facility, UNAVCO Inc.: Staff from the UNAVCO Facilities Engineering and Data Management and Archive (DMAG) groups have provided extensive support to the PBO Nucleus project under core funding from NSF I&F. DMAG staff has primary responsibility for archiving data from non-upgraded GPS stations, and Engineering group staff have assisted with data flow and field maintenance activities.

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

Findings:

Research findings resulting from PBO Nucleus activities are publications and discoveries that are presented by users of raw data produced by this project. The 'Publications and Products' section of this report, shows the variety and importance of the applications of PBO Nucleus data by the geodetic community, and while comprehensive, is not complete. List of publications and findings that have used data from the Nucleus network are continually solicited from community members, but there are many new users of whom we are not yet aware.

Training and Development:

Outreach Activities:

Please see the Education and Outreach section of the main project activities document

Journal Publications

- F. Blume, C. Meertens, G. Anderson, S. Eriksson, E. Boyce, "PBO Nucleus Project Status: Integration of 209 Existing GPS Stations into the Plate Boundary", *Eos Trans. AGU*, p. G33A-910, vol. 88(52), (2007). Abstract,
- Walls, C; F. Blume, C. Meertens; E. Arnitz; S. Lawrence; S. Miller; W. Bradley; M. Jackson; K. Feaux, "Integration of the Plate Boundary Observatory and Existing GPS Networks in Southern California: A Multi Use Geodetic Network", *Eos Trans. AGU*, p. G13B-1223, vol. 88(52), (2004). Abstract,
- Jackson, M.; G. Anderson; F. Blume; C. Walls; B. Coyle; K. Feaux; B. Friesen; D. Phillips; K. Hafner; W. Johnson; D. Mencin; B. Pauk; T. Dittmann, "An EarthScope Plate Boundary Observatory Progress Report", *Eos Trans. AGU*, p. G13B-1222, vol. 88(52), (2007). Abstract,
- Langbein, J., "Noise in GPS Displacement measurements from Southern California and Southern Nevada", *J. Geophysical Research*, p. , vol. , (2008). Accepted,
- Bennett, R. A., Hreinsdottir, S., Velasco, M. S., and Fay, N. P., "GPS constraints on vertical crustal motion in the northern Basin and Range", *Geophysical Research Letters*, p. L22319, vol. 34, (2007). Published, 10.1029/2007GL031515
- Schmidt, D. A., "Observations of the Recent Slow Slip Events in Cascadia Captured by the PBO Strainmeters", *Seism. Res. Letters*, p. 267, vol. 78 (2), (2007). Published,
- Gao, H., and D. A. Schmidt, "The Slip History of the 2004 Slow Slip Event on the Northern Cascadia Subduction Zone", *Eos Trans. AGU*, p. T41A-1540, vol. 87(52), (2006). Published,
- Schmidt, D. A., "The 2005 Cascadia ETS Event Inferred From PBO Tensor Strainmeters and GPS", *Eos Trans. AGU*, p. T41A-1545, vol. 87(52), (2006). Published,
- Burgmann, R; Hilley, G; Ferretti, A; Novali, F, "Resolving vertical tectonics in the San Francisco Bay Area from permanent scatterer InSAR and GPS analysis", *GEOLOGY*, p. 221, vol. 34, (2006). Published, 10.1130/G22064.
- Johansen, I. A., E. J. Fielding, F. Rolandone, and R. Bürgmann, "Coseismic and postseismic slip of the 2004 Parkfield earthquake from space-geodetic data", *Bull. Seism. Soc. Am.*, p. 269, vol. 96, (2006). Published,
- Johnson, KM; Burgmann, R; Larson, K, "Frictional properties on the San Andreas fault near Parkfield, California, inferred from models of afterslip following the 2004 earthquake", *BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA*, p. S321, vol. 96, (2006). Published, 10.1785/012005080
- Freed, AM; Ali, ST; Burgmann, R, "Evolution of stress in Southern California for the past 200 years from coseismic, postseismic and interseismic stress changes", *GEOPHYSICAL JOURNAL INTERNATIONAL*, p. 1164, vol. 169, (2007). Published, 10.1111/j.1365-246X.2007.03391.
- Johnson, K., G. Hilley, and R. Bürgmann, "Influence of lithosphere viscosity structure on estimates of fault slip rate in the Mojave region of the San Andreas fault system", *Journal of Geophysical Research*, p. , vol. 112, (2007). Published, 10.1029/2006JB004842
- Freed, AM; Burgmann, R; Herring, T, "Far-reaching transient motions after Mojave earthquakes require broad mantle flow beneath a strong crust", *GEOPHYSICAL RESEARCH LETTERS*, p. , vol. 34, (2007). Published, 10.1029/2007GL03095
- Funning, G., R. Bürgmann, A. Ferretti, F. Novali, and A. Fumagalli, "Creep on the Rodgers Creek fault from PS-InSAR measurements", *Geophys. Res. Lett.*, p. , vol. 34, (2007). Published, 10.1029/2007GL030836
- Puskas, CM; Smith, RB; Meertens, CM; Chang, WL, "Crustal deformation of the Yellowstone-Snake River Plain volcano-tectonic system: Campaign and continuous GPS observations, 1987-2004", *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*, p. , vol. 112, (2007). Published, 10.1029/2006JB00432

- Vasco, D.W., C. W. Wicks, C. M. Puskas, R. B. Smith, W. Thatcher, and C.M. Meertens, "Crustal deformation and source models of the Yellowstone volcanic field from geodetic data", *J. Geophys. Res.*, p. B03401, vol. 112, (2007). Published, 10.1029/2006JB004325
- Chang, WL; Smith, RB; Wicks, C; Farrell, JM; Puskas, CM, "Accelerated uplift and magmatic intrusion of the Yellowstone caldera, 2004 to 2006", *SCIENCE*, p. 952, vol. 318, (2007). Published, 10.1126/science.114684
- Puskas, C., R. B. Smith, and R. McCaffrey, "Intraplate deformation and block rotations of the western U.S. Interior", *Earth and Planetary Science Letters*, p. , vol. , (2007). Submitted,
- Chang, W. L., and R. B. Smith, "Rheological properties of extensional lithosphere from postseismic relaxation of the 1959 M=7.5 Hebgen Lake Montana earthquake", *J. Geophys. Res.*, p. , vol. , (2007). Submitted,
- Smith, R. B., C. Puskas, and K. Settles, "Effects of the Yellowstone hotspot and its mantle plume on the western U.S. interior", *Geol Soc. Amer. Abstracts with Programs*, p. 107-9, vol. 39(6), (2007). Published,
- Puskas, C. RB Smith, K. Settles, and F. Pollitz, "Geodynamics of the western U.S. interior", *Geol Soc. Amer. Abstracts with Programs*, p. 74-9, INV, vol. 39(6), (2007). Published,
- Smith R.B., J. Farrell, M. Jordan, C. Puskas and G.P. Waite, "Crustal structure and tectono-magmatic processes of the Yellowstone-Snake River Plain system from gravity-density measurements and strength models employing seismic constraint", *Eos Trans. AGU*, p. V51F-02,, vol. 88(52), (2007). Published,
- Chang, W., R B. Smith, C. Wicks, J. Farrell, and C. Puskas, "Source Modeling and Seismic-Volcano Implications of the 2004-2007 Accelerated Deformation at Yellowstone Caldera?", *Eos Trans. AGU*, p. V51F-01,, vol. 88(52), (2007). Published,
- Settles, K.R., Smith R.B., Puskas C., Lowry, and D. Blackwell, "TI: Seismic and GPS constraints on the dynamics and kinematics of the Yellowstone volcanic field", *Eos Trans. AGU*, p. V51F-05, vol. 88(52), (2007). Published,
- Farrell, J M, C. M. Puskas, W. Chang, R. B. Smith, H. Heasler and J. Lowenstern, "A Prototype Hydrothermal Monitoring System, Norris Geyser Basin, Yellowstone National Park, Wyoming", *Eos Trans. AGU*, p. V53B-1326, vol. 88(52), (2007). Published,
- Puskas, C.M. R. B. Smith, L M. Flesch and K. Settles, "Effects of the Yellowstone Hotspot on Western U.S. Stress and Deformation", *Eos Trans. AGU*, p. V51F-04, vol. 88(52), (2007). Published,
- Hill, D. and R. B. Smith, "Effects of the Yellowstone Hotspot on Western U.S. Stress and Deformation", *Eos Trans. AGU*, p. V51F-08,, vol. 88(52), (2007). Published,
- Taira T. and R. B. Smith, "Seismic Source Evaluation of Possible Magmatic Related Earthquakes in the Yellowstone Volcanic System", *Eos Trans. AGU*, p. V51F-07, vol. 88(52), (2007). Published,
- Olds, Shelley and Eriksson, Susan, "Bringing GPS data and data-rich activities into college and secondary Earth science classrooms", *Geol Soc. Amer. Abstracts with Programs*, p. 155, 56-1, vol. 39(6), (2007). Published,
- Olds, Shelley and Eriksson, Susan, "Fostering Inquiry and Scientific Investigation in Students by Using GPS Data to Explore Plate Tectonics and Volcanic Deformation", *Eos Trans. AGU*, p. ED51B-042, vol. 88(52), (2007). Published,
- Chang, W., and R.B. Smith, "Accelerated uplift of the Yellowstone caldera", *National EarthScope Science Meeting, Monterey, Calif.*, p. , vol. , (2007). Published,
- Smith, R. B., "The Yellowstone Hotspot", *GeoSwath 2007 EarthScope Science Meeting, Boise, Id.*, p. Keynote A, vol. , (2007). Published,

Books or Other One-time Publications

Web/Internet Site

URL(s):

http://facility.unavco.org/project_support/es/nucleus/nucleus.html

Description:

The "PBO Nucleus Web Center" is continuously updated to provide comprehensive, up-to-date information relating to the project. Station status, data access, publication lists, and other important information is available here.

Other Specific Products

Contributions

Contributions within Discipline:

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Activities and Findings: Any Training and Development

Any Book

Any Product

Contributions: To Any within Discipline

Contributions: To Any Other Disciplines

Contributions: To Any Human Resource Development

Contributions: To Any Resources for Research and Education

Contributions: To Any Beyond Science and Engineering

PBO Nucleus: Support for an Integrated Existing Geodetic Network in the Western U.S. - Year 3 Project Activities

1. Overview

The PBO Nucleus project is designed to operate, maintain, upgrade and integrate 209 existing GPS stations and 1 long-baseline laser strainmeter into the Plate Boundary Observatory (PBO). Originally designed and constructed as six independent networks: the Alaska Deformation Array (AKDA), the Bay Area Deformation Array (BARD), the Basin and Range Geodetic Network (BARGEN), the Eastern Basin and Range and Yellowstone Network (EBRY), the Pacific Northwest Geodetic Array (PANGA), and the Southern California Integrated Geodetic Network (SCIGN), these stations form the Nucleus around which the PBO is based and built. It will increase the number of stations in the completed PBO and extend the time series back to the early 1990's when the first of the Nucleus stations were constructed.

During the third year of the project excellent progress has been made in transitioning the network from independent, region-specific operations to a centralized unified network. The UNAVCO Facility continues to be the primary data archive for the entire network, and data from all stations is continually analyzed by the PBO Data Analysis Centers. Approximately 93% of the network has had its hardware upgraded to PBO standards and its data flow transferred to the PBO Data Management and Information Technology (DMIT) group. Transfers of site permits and metadata from original network operators to UNAVCO/PBO are currently our primary focus, and Education and Outreach activities related to the project are flourishing. New Earned Value Management (EVM) tracking techniques have been applied to all aspects of the project to ensure that all tasks will be completed to coincide with the beginning of the O&M phase of PBO at the end of year 4 of Nucleus on September 30, 2008.



Fig. 1. PKRD, near Los Angeles. Upgraded 9/22/07



Fig. 2. PTSG, Crescent City, CA. Upgraded 8/5/07

Most importantly, the network has been maintained in excellent health with a large volume of high-quality data having been made available to the scientific community. Over 96% of possible data were returned by the stations during year 3, and 98% of stations in the network are currently healthy and producing data. These data are being used by the community to produce a lot of exciting and important results, which are described in the Products and Publications section of this report.

2. Project Personnel

The PBO Nucleus project is managed by co-P.I. Dr. Frederick Blume (20% support), with oversight from P.I. Dr. Charles Meertens, who derives no support from the project, and as of 1/1/2008, Dr. M. Meghan Miller has become the P.I. as the new President of UNAVCO.. Field Engineer Eleanor Boyce, hired in October, 2006, is 100% supported by the project and is involved in all aspects of the project on a day-to-day basis; Project Engineer Nicole Feldl left UNAVCO in July of this year to pursue a Ph.D. at the University of Washington . Education and Outreach activities are the responsibility of Education Specialist Shelley Olds(100% support), hired in September 2006. She is supervised by UNAVCO E & O Coordinator Dr. Susan Eriksson.

Many other UNAVCO personnel are supported directly or otherwise by funding from the Nucleus project. The PBO DMIT group is funded on a per-station basis to monitor data flow, archive and analyze data from Nucleus stations. A 10% FTE from the PBO permitting group is supported to advise network operators and assist with the transfer of site permits to UNAVCO/PBO. Members of the UNAVCO Facility's Data Management and Archive Group (DMAGU) are supported through the PBO DMIT funding and NSF core funding to oversee data flow for non-upgraded stations and archiving for all stations. Additionally, many UNAVCO Facility and PBO employees from Boulder and regional offices have assisted with Nucleus project operations when practical at no cost; Nucleus personnel, when available, have assisted with PBO station installation and maintenance, and Facility supported projects as well.

Critical non-UNAVCO personnel are supported by the PBO Nucleus projects through 6 sub-awards. Dr. Blume and Ms. Boyce coordinate the operations, maintenance and permitting activities of network coordinators, technicians, and specialists at the University of Utah, U.C. Berkeley, U.C. San Diego, Central Washington University, Caltech, and the University of Southern California. Personnel at these institutions are responsible for station maintenance until an upgrade is performed, as well as many of the upgrades themselves.



Figure 3. FORE, Heber City, UT, installed 4/26/07.



Figure 4. HUNT, Parkfield, CA, upgraded 8/21/07.

3. Project Operations

As of January 1 2008, 195 of the 209 GPS stations in the PBO nucleus network have been upgraded to PBO standards, as defined by having Trimble NetRS receivers, choke ring antennas, and IP-based data communications. Upgrades have been performed primarily by Nucleus-supported personnel from UNAVCO and the sub-awardees; many have been done with assistance from PBO and UNAVCO Facility employees as well as contributions from various other institutions. The prioritization of upgrades as a function of station health, location, IP comm. availability and cost, and synergy with other projects has proven to be very effective. Figure 5 shows the current status of the network, with completed upgrades highlighted; the level of completed upgrades is currently several months ahead of schedule.

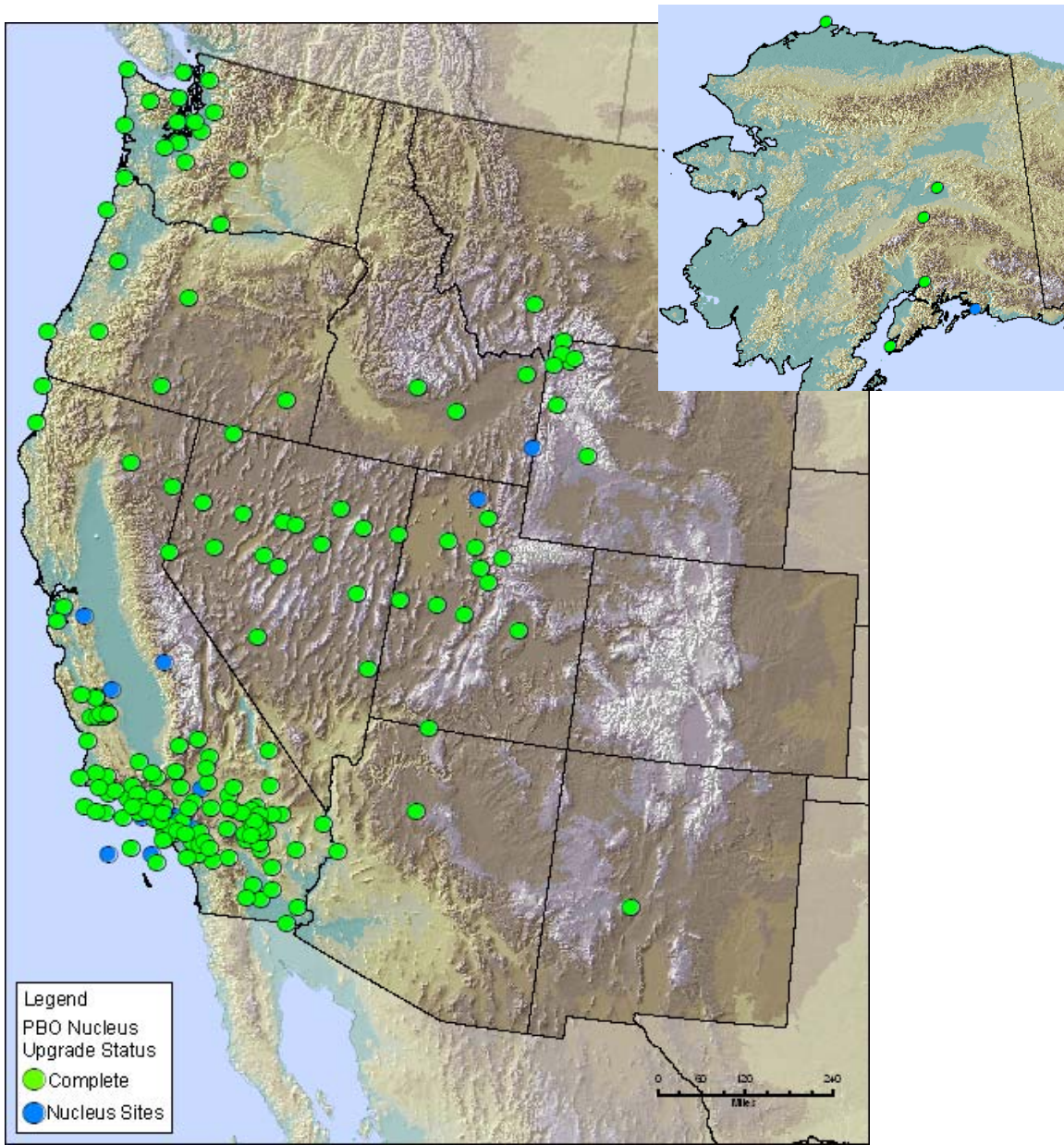


Figure 5. PBO Nucleus Network status, 1/1/2008. 195 upgrades have been completed, 14 remain.

The distribution of upgraded GPS stations throughout the six original existing networks is shown in Table 1. Hardware problems continued to be an issue with the Trimble NetRS receivers during the past year, as compact flash card defects which were at first thought to be limited to a single batch were found to have applied to all cards in the first generation NetRS. Nucleus project personnel made significant contributions in diagnosing and solving the issue and all applicable receivers in the field have been replaced preemptively. 99% of the 195 upgraded stations are healthy. Overall station health is presently at 99% (206 of 209).

Existing Network (PBO Regions)	Original Operating Institution	# Stations in Nucleus	Upgrades Complete	Upgrades since January 1, 2007
AKDA (Alaska)	Univ. of Alaska	6	5	0
BARD (N. Ca.)	Univ. of California, Berkeley	10	6	2
BARGEN (Basin and Range, S. Ca.)	California Inst. of Technology	26	26	6
EBRY (Rocky Mtn., Basin and Range)	Univ. of Utah	18	16	4
PANGA (Pac. NW, N. Ca, Basin and Range)	Central Washington Univ.	26	26	6
SCIGN (S. Ca.), Parkfield (N. Ca.)	Univ. of Southern California	122	115	32
SuomiNet (Rocky Mtn.)	New Mexico Tech	1	1	0
<u>Total:</u>		<u>209</u>	<u>195</u>	<u>50</u>

Table 1. Distribution of upgraded stations in PBO Nucleus network, January 2008.

The first installation of a new GPS station done entirely by Nucleus staff was done this year at FORE near Heber City, UT to replace the old HEBE monument (Figure 3, above). The old station was moved at the request of the landowner to make room for the 10th hole of a new golf course.

Synergy with PBO and other projects has been a cost-effective method of maximizing productivity, with PBO, Facility, Nucleus, and subawardee personnel having combined forces several times on a variety of projects. Highlights include the design and construction of communication networks in the Mojave and in southeastern Oregon that are shared between Nucleus and PBO stations. Nucleus personnel participated in the reconnaissance and installation of new PBO stations in many regions.

An important part of the successful operation of the Nucleus network is the continued maintenance of stations in their original configurations prior to upgrades, and a great deal of resources and expertise have been devoted to this effort. Remote troubleshooting is routinely done by UNAVCO and network operators to monitor and maintain station health while minimizing travel expenses, and several site visits have been made to repair stations where upgrades are not currently practical.

The purchase of new hardware that replaces existing equipment has created a pool of surplus equipment that has been used to support other projects, as well as to maintain other Nucleus stations prior to upgrade. Working receivers removed from Nucleus stations are being used in new permanent stations constructed by the University of Utah along the Wasatch front, and surplus Zephyr antennas have been installed at the 25 stations of the EarthScope-funded Rio Grande Rift project of the Universities of Colorado and New Mexico, allowing for permanent installations there.

We have planned the upgraded communication schemes and new GPS station permits to be as cost-effective as possible, minimizing recurring costs for operating the network for the indefinite future.

4. Changes to the PBO Nucleus Station List

This year saw the removal of four stations from the Nucleus roster and the addition of four new ones. In order to meet the stated goal of integrating 209 stations into the PBO O&M network, a qualifying new station must be added whenever one must be removed for operational or permitting reasons or by landowner request.

KELS in southern Washington state and IVCO in the Imperial Valley of southern California removed at the request of their landowners to make room for new development. In both instances Nucleus and PBO staff cooperated to site and permit new PBO installations adjacent to the old ones and to overlap station operations for a good data tie. P744 is now operating in Imperial and P446 in Kelso.

SNI1 on San Nicolas Island off the southern California coast was removed from Nucleus due to the restrictive nature of the Naval Reserve permit and access to the island for non-US government personnel. The station will continue to be operated and maintained by the USGS indefinitely.

To replace these stations we added HWUT and LMUT, both former EBRY stations in the Wasatch, and EYAC near Cordova, AK. These stations fill important geographical gaps and address critical scientific targets of interest to the EarthScope Scientific community.

Finally, as mentioned above, FORE was constructed by Nucleus personnel as an SDBM near Heber City, UT to replace HEBE. A two-month tie was run between the two stations before HEBE was removed in June.

All of these changes were approved by the appropriate PBO Siting Committees. The list of supported Nucleus stations and status is continuously updated and available on line at:

<http://pboweb.unavco.org/dmsdocs/Root%20Folder/PBO%20Operations/Reports/Nucleus/NucleusStatus.xls>

5. Data Management

The continuous acquisition and distribution of high-quality geodetic data to the research community is the top priority of the PBO Nucleus project. In spite of the continuing problems with compact flash memory failures in NetRS receivers, Nucleus attained a 96% rate of data return for the network during the first ten months of the project. It is anticipated that similar or higher return rates will be maintained through the duration of the project.

At the time of upgrades Nucleus stations are renamed to comply with PBO's 16 character ID standards using a convention that was developed in order to preserve the original identities that have been in use by community data users. The transitions in data flow and responsibility have been seamless and invisible to the end users while greatly increasing efficiency and monitoring capabilities on the operational end. During this transition process meta-data are routinely verified and corrections to historic and present data made as necessary, resulting in a more reliable data set.

Data from all 209 PBO Nucleus stations have been analyzed by the PBO Data Analysis Centers since their inception, both during testing and operation phases. At the outset this data comprised 60% of the volume analyzed, although the percentage naturally decreases as more new PBO stations come on line. The AC director routinely communicates with Nucleus project personnel when data quality or meta-data issues arise. Level 2 data products are generated for all Nucleus stations.

Many PBO Nucleus stations have historically produced other data streams, such as high-rate real time GPS and meteorological data. Users from the geodetic and atmospheric research, surveying, and other communities rely on these data for ongoing operations, and care has been taken to preserve these capabilities while ensuring compliance with the PBO/EarthScope Data Management Plan (http://pboweb.unavco.org/dmsdocs/Root%20Folder/Data%20Management/Planning/Data%20Management%20Plan/pbo_dataplan.pdf). These auxiliary functions are provided as a courtesy only and are not supported by the Nucleus proposal.

6. Station Permit Transfers

When the PBO Nucleus network is fully integrated into PBO in October 2008 it is important that station permits as well as the hardware and data conform to PBO standards. Station permits negotiated by the original networks must be transferred to UNAVCO/PBO and renegotiated where possible to minimize recurring payments and extend the terms through 2017. This process is proceeding smoothly, with over 50% of the network's permits having been transferred, and the remainder being actively addressed. Over 70% of permitting activities, based on EVM tracking, have been completed and are on schedule (see below). The process is being coordinated by the PBO Nucleus project manager, PBO Permitting office and various network coordinators or their designees. The permitting situation for many of the stations has turned out to be much more complex than originally anticipated as many were installed by verbal agreement between parties that have long since moved on from their original organizations. In all cases, though, a written permit will be procured for every Nucleus station integrated into the O&M phase of PBO, even if it means the removal of key stations from the network.

7. Earned Value Management

EVM techniques were applied to the PBO Nucleus project in the middle of year 3 at the request of PBO management to ensure that all tasks were completed to coincide with the beginning of the O&M phase of PBO at the end of year 4 of Nucleus on September 30, 2008. In July of 2007 a schedule for permitting activities and metadata transfer for the remainder of the project were developed and added to station upgrades and procurement to produce an EVM schedule. Earned Value for the 209 station

equivalents of the Nucleus network are as follows: Station Upgrades 50%, Hardware Procurement, 5%, Metadata transfer to the PBO Operational Database (POD), 5%, and Permitting Activities 40%. The latter category is further broken down to landowner contact 10%, Submission of a Permit application 10%, and the receipt of a completed site permit 20%. By this metric the project is currently 5% ahead of schedule in all aspects, and on track for a successful completion. Progress is depicted graphically in Figure 9 below.

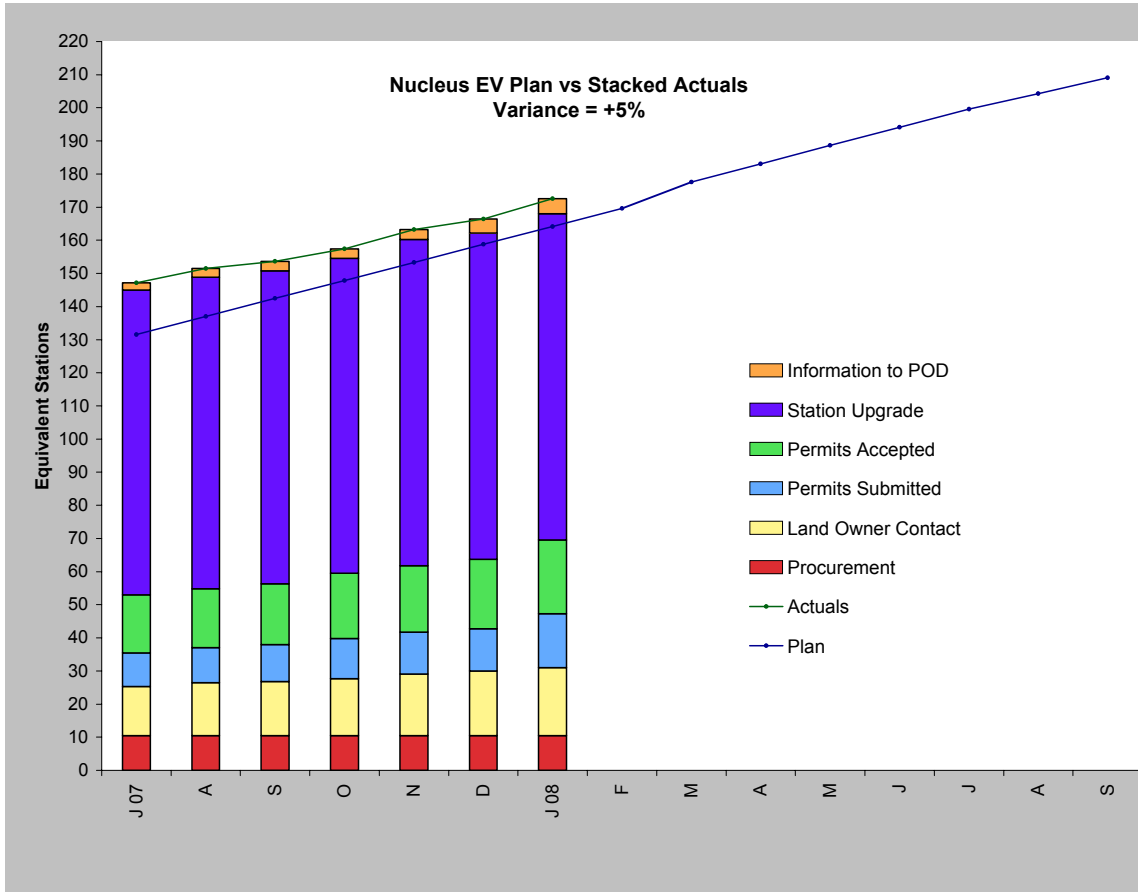


Figure 9. EVM tracking of PBO Nucleus since July, 2007.

8. Project Information Dissemination

The screenshot shows the PBO Nucleus web page. At the top, there is a navigation bar with links: Home, About Us, Contact Us, Support, Search, Facility, PBO, and Education & Outreach. Below this is a header with the UNAVCO logo and the text "Supporting high-precision techniques for the measurement of crustal deformation" and "Facility".

Project Support

Existing Networks

- AKDA - Alaska
- BARD - SF Bay Area and Northern California
- BARGEN - Basin and Range
- EBRY - Wasatch Front and Yellowstone
- PANGA - Cascadia Subduction Zone
- SCIGN - Southern California

Nucleus Data Products

- UNAVCO data archive
- GSAC Wizard

Daily Archive Status

Trimble NetRS

Purchase Information

PBO Nucleus

The PBO Nucleus project was developed as a means of incorporating the long time series of existing GPS networks into the measurement record of the [Plate Boundary Observatory \(PBO\)](#), thus optimizing the scientific potential of the NSF funded [Earthscope](#) project. PBO, designed as the geodetic component of Earthscope, studies the three-dimensional strain field in the western United States resulting from tectonic deformation across the Pacific-North American plate boundary.

The six existing western United States networks included in the Nucleus project are the Alaska Deformation Array (AKDA), the Bay Area Regional Deformation Network (BARD), the Basin and Range Geodetic Network (BARGEN), the Eastern Basin and Range and Yellowstone GPS Network (EBRY), the Pacific Northwest Geodetic Array (PANGA), and the Southern California Integrated GPS Network (SCIGN). Approximately half of these 432 stations were chosen to be upgraded by September, 2008, at which time they will be subsumed by PBO.

The process of upgrading the existing GPS stations from independent, region-specific operations to a streamlined "PBO-style" network is well underway. 184 of the 210 Nucleus stations have been upgraded with Trimble NetRS receivers, IP-based communications, and improved power systems as necessary. Links to raw and RINEX data from the Nucleus GPS network can be found in the left column of this page.

[NSF 2006 Annual Report \(pdf\)](#)
[PBO Nucleus Upgrade Status & Station Map](#)
[PBO Nucleus Station List](#)

Upgraded (green) and non-upgraded (red) PBO Nucleus stations in the contiguous U.S. as of June 27, 2007

Click map for real-time station status

Figure 10. The PBO Nucleus Project web page

The PBO Nucleus Web Center (<http://www.unavco.org/exnet/exnet.html>) is continuously updated with information about project operations and network status as well as other important information. This page also contains links to data archives and data products, interactive mapping tools, and affiliated projects. PBO Nucleus project updates are also posted on the EarthScope web page (<http://www.earthscope.org>), and up-to-date network status is also available on the PBO Google Earth database and status files on the PBO Home page. (<http://pboweb.unavco.org>).

9. Education and Outreach

Community Educators Reached/Engaged

As part of the PBO Nucleus program, education and outreach personnel engaged teachers, university faculty, community members, and other education professionals through workshops, short courses, and conference sessions throughout the year. See table below for details.

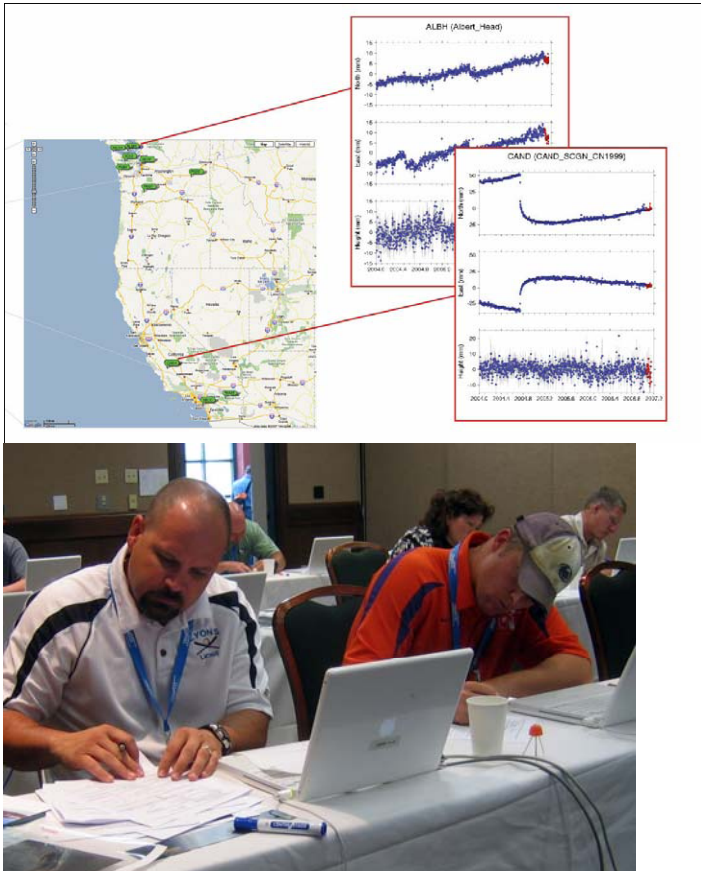


Figure 11: Sample PBO GPS time series viewing tools used at workshops and short courses. Teachers calculating plate movement through GPS data.

Event	Type	Secondary-Ed Faculty	University Faculty	Scientists/Community Members	Other education professionals
CESE	Poster	10	10	5	10
EarthScope-Using EarthScope Data in the Classroom (for teachers)	4-hr Wkshp	15	2	5	2
EarthScope-Bringing EarthScope Research into the Undergraduate Classroom	2-hr session	17	10	100	
NSTA – Short Course	4-hr Short Course	37		1	
NSTA - Workshop	1-hr Wkshp	2			
Technology in Education Conference	3-hr Wkshp	15			5
NAGT: Teaching Geophysics in the 21 st Century	4-hr session		15		0
NABGGT	Poster				30
GSA Short Course	4-hr Short Course	7	6	1	1
GSA Poster session	Poster		20		5
NSTA Area Conference – Denver, CO	1 hour workshop	15			
CAST (Conference for the Advancement of Science Teaching) - Austin, TX	4 hr short course	5			
AGU Poster Session	Poster	6	20	7	11
Totals		131	83	119	64

Evaluation

As part of the E&O program funded through the PBO Nucleus project, UNAVCO Education and Outreach distributed a brief web-based questionnaire to our former workshop and short course participants. This questionnaire focuses on the courses they teach and the usefulness of the UNAVCO E&O materials in their teaching. This will help us prepare our future professional development workshops and provide a measure of how well the E&O is doing in its mission.

The questionnaire was distributed to approximately 115 former participants in late November 2007 (Figure 12). By the end of December, 27 responses have been submitted, with 20 volunteering to be interviewed by our independent evaluator. Our goal is to have twenty-five respondents volunteering to be interviewed.

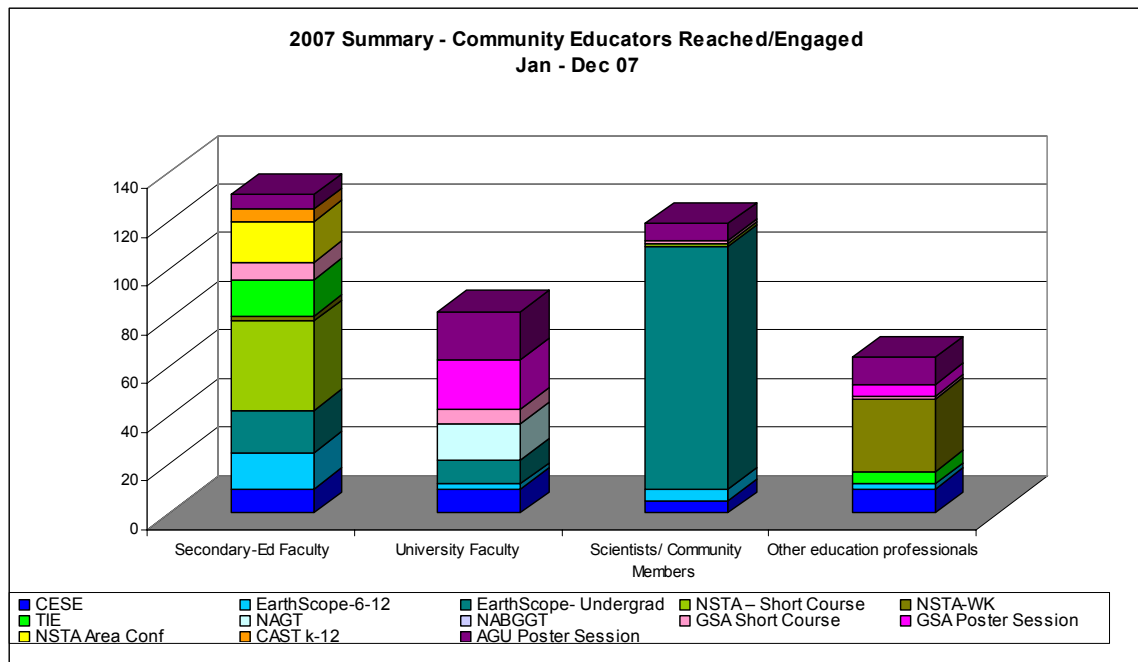


Figure 12. Types of courses and educators receiving evaluation questionnaire

Learning Materials Development

The *Data for Educators* page on the UNAVCO Education and Outreach website is part of a growing number of tools and products to access the data and scientific discoveries of the UNAVCO community for a variety of educational audiences. Other outreach improvements for the UNAVCO website included the addition of rotating science and community highlights to provide information about the research progress of the UNAVCO membership. Web statistics are being tracked to study the users and target web pages of our website.



Figure 13. New E&O webpages on the UNAVCO website.

To date the curricular materials introduce learners to high-precision GPS data, how to obtain the data in numerical or graphic format, how to interpret the data and make predictions based on this data. As a package these materials contribute toward creating a learning module for Earth Science secondary classrooms, undergraduate general education courses, and geophysics majors.

The curricular materials in the following list are designed to provide workshop participants and their students with experience with GPS data from a variety of deformation processes such as tectonic plate motion, plate motion near a subduction zone (ETS), rebound after an earthquake, deformation due to volcanic activity and are targeted to both secondary and lower undergraduate faculty:

- How does GPS Work?
- Locating Position Using GPS
- Visualizing Relationships Between Earthquakes, Volcanoes, and Plate Boundaries in the Western U.S. Using EarthScope Jr.
- Draft: Introducing GPS and Time Series Plots
- Using GPS to Visualize the Influence of a Subducting Plate
- Draft: Episodic Tremor and Slip: The Case of the Mystery Earthquakes
- Draft: The Science of Prediction: Monitoring Volcanic Activity
- Draft: Where AM I?: the Evolving Technology of Navigation
- Draft: Will It Blow?: Monitoring Yellowstone's Volcanic Activity
- Using GPS Time Series Plots to Determine Plate Motion in California
- In progress: EET Chapter: Exploring Subduction in the Cascadia Region Using EarthScope GPS and Seismic Data.

Many of these materials have been field tested in workshops geared toward secondary educators or faculty of undergraduate students. Feedback on these materials has been collected from each workshop and appropriate revisions are being made. Materials marked as draft are still in progress and need to undergo scientific and pedagogical review.

Master Teacher-in-Residence

Denise Thompson teaches science at Orting High School in Orting, WA. She spent a week at the UNAVCO Boulder office working with the Education & Outreach team to develop high-school level educational materials. During her week at UNAVCO she developed the following materials, currently undergoing scientific and pedagogic review and revision:

The Science of Prediction: Monitoring Volcanic Activity

This lecture with powerpoint slides for high school students presents the signs of volcanic activity: eruption history, volcanic gases, heat and hydrothermal activity, earthquakes, ground deformation and describes the technology used to monitor volcanoes. Students learn about how scientists monitor volcanic activity and how such monitoring detected the impending eruption of Mt. St. Helens in 1980.

Where AM I?: the Evolving Technology of Navigation

Students construct a timeline using WebQuest illustrating how navigation technology has changed over time and describe how improving technology has impacted science.

Will It Blow?: Monitoring Yellowstone's Volcanic Activity

Guided by a worksheet and using an Excel Data Set , students interpret historical lava flow and hydrothermal activity data and real-time earthquake and GPS ground deformation monitoring data for Yellowstone National Park to determine the suitability of a fictitious scenario. Students are asked to construct a presentation or written report to submit to the developer based on the National Science Standards format.

Web Statistics

Figure 14 reflects the number of individual E& O web pages viewed Apr 2005 -Nov 2007. Figure 26 reflects total times all E&O pages were viewed Apr 2005-Nov 2007. Note the spike of activity in Oct 2007 was when the GSA Short Course was presented

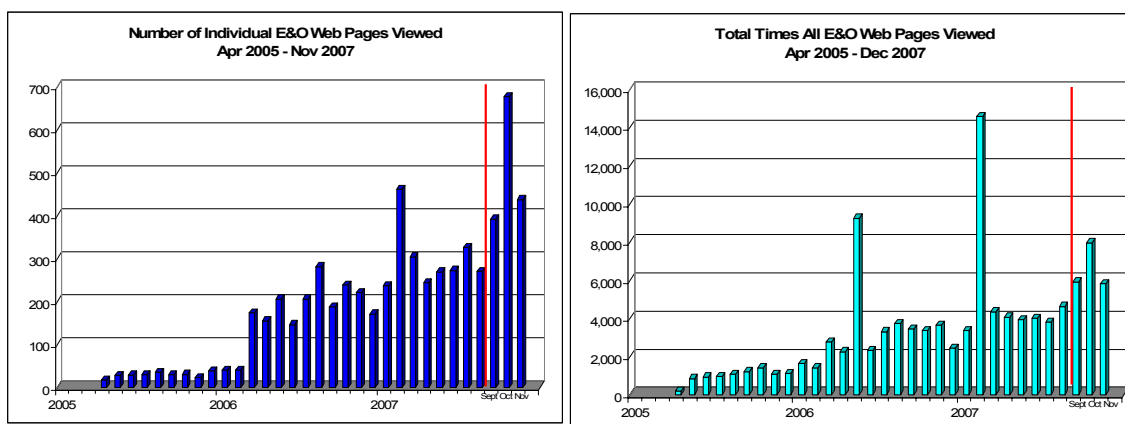


Figure 14.