Annual Report for Period: 03/2006 - 02/2007 **Submitted on:** 02/09/2007
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: Walker, Rebecca
Worked for more than 160 Hours: Yes
Contribution to Project:
Ms. Walker was hired in September 2005 as Education Specialist and receives 100% FTE support from the grant. Her responsibilities include development of educational modules for

undergraduate general education and middle school Earth science classrooms, conducting professional development workshops for educators, and general outreach related to project activities.

Ms. Walker left UNAVCO in August 2006 and was replaced by Shelley Olds.

Name: Olds, Shelley

Worked for more than 160 Hours: Yes

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 who's salaries are supported by project funds, as well as financial oversight through other institutional employess.

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 Managemement 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 resrouces 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 responisibily 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 comprehesive, is not complete. List of publications and findings that have used data from the Nucleus network are continually solicted from community members, but there are many new users of whom we are not yet aware.

Training and Development:

Outreach Activities:

Project status

For 2006, we initially anticipated focusing the majority of our efforts on the college audience, but we have had unexpected opportunities to target the middle/high school audience. With respect to the middle/high school audience, we are primarily targeting pre-existing teacher networks. The project has met all goals set for 2006 and formal evaluation is taking place.

Materials developed:
I. Two lesson-plans or curricular æmodulesÆ have been developed for the middle/high school Earth Science classroom:
1) Visualizing Relationships Between Earthquakes, Volcanoes, and Plate Boundaries in the Western United States. This is constructed for pencil and paper with or without a computer-based activity. http://www.unavco.org/edu_outreach/docs/voyager_activity.pdf
Learning outcomes:
ò Using the western United States as an example, observe the locations of earthquakes, volcanoes, and plate boundaries.
ò Understand that there is a spatial relationship between earthquakes, volcanoes, and lithospheric plate boundaries.
2) The case of the mystery earthquakes, including episodic tremor and slip. Both a teacherÆs guide and student activities were developed by Master Teacher-in-Residence, Roger Groom, with Becca Walker, UNAVCO Education Specialist. This has been tested in GroomÆs classroom during the fall or 2006.
Other materials were developed to support these activities:
Using GPS to study plate tectonics (with Dr. Jessica Murray, USGS)
http://www.unavco.org/edu_outreach/docs/gps_tev.pdf

These materials were tested in several workshops for middle and high school Earth Science Teachers (total of 90):
1. Yuma Arizona, January: 30 teachers
2. Pacific Northwest (Teachers on the Leading Edge project): 12
3. SACNAS, October: 18 teachers
4. AGU, December: 30 teachers

II. One module for introductory geology at the college level was developed (general education requirements) and was tested in one workshop (total of 11 faculty). 13 interviews were conducted for input prior to making this module.
1) Using GPS data to study crustal deformation, earthquakes, and volcanism: A short course for faculty, Geological Society of America 2006. The module was developed by Dr. Andy Newman, Georgia Tech, and modified by UNAVCO education specialist, Shelley Olds.

Formal evaluation of PBO Nucleus E&O work
An evaluation plan was developed during 2006. Dr. Sandra Laursen from the University of Colorado is helping the UNAVCO staff obtain data to measure the success of the PBO Nucleus education goals. She will conduct interviews later in the project when educators has used these materials in their classrooms.

Published abstracts
1) Plate Boundary Observatory Nucleus Education and Outreach: Bringing GPS and Data-rich Activities Into College and Secondary Earth Science Classrooms, Becca Walker and Susan Eriksson, Spring AGU, 2006
2) Providing access to Plate Boundary Observatory (PBO) data for secondary and college audiences through workshops, classroom resources, and the web, Eriksson, Susan, WALKER, Becca, JACKSON, Mike, and GROOM, Roger, Geological Society of America Annual Meeting, 2006

Journal Publications

F. Blume, W. Prescott, G. Anderson, S. Eriksson, N. Feldl, "PBO Nucleus Project Status: Integration of 209 Existing GPS Stations into the Plate Boundary
Observatory", Eos Trans. AGU, p. G43B-1002, vol. 87(52), (2006). Abstract

W. L. Chang, R. B. Smith, R. Harris, "Elastic and viscoelastic strain loading models of the Wasatch fault, Utah, from GPS measurements and comparisons with geological observations", Eos Trans. AGU, p. G53A-0875, vol. 86(52), (2005). Abstract

W. L. Chang, R. B. Smith, C. M. Puskas, J. M. Farrell, "Source modeling and tectono-volcanic implications of the 2004-2006 rapid deformation at Yellowstone caldera", Eos Trans. AGU, p. G43C-08, vol. 87(52), (2006). Abstract

C. M. Puskas, R. B. Smith, L. Flesch, W. L. Chang, "Role of the Yellowstone hotspot in western US deformation and lithospheric stress", 2005 Annual Meeting, Geol. Soc. Am., Salt Lake City, UT, October 16?19, p. , vol. , (2005). Abstract

R. B. Smith, M. Jordan, C. Puskas, G. Waite, J. Farrell, "Geodynamic models of the Yellowstone hotspot constrained by seismic and GPS imaging and volcano-tectonic data", 2005 Annual Meeting, Geol. Soc. Am., Salt Lake City, UT, October 16?19, p. , vol. , (2005). Abstract

R. B. Smith, W. Chang, C. Puskas, J. Farrell, "Tectonic and magmatic stress interaction of the Yellowstone volcanic system", Eos Trans. AGU, p. V14B-07, vol. 86(52), (2005). Abstract

J. L. Davis, B. P. Wernicke, S. Bisnath, N. A. Niemi, P. Elosegui, "Subcontinental-scale crustal velocity changes along the Pacific-North America plate boundary", Nature, p. 1131, vol. 441, (2006). Published

J. L. Davis, M. E. Tamisiea, E. M. Hill, "Assimilation of GRACE and GPS data into models for glacial isostatic adjustment (GIA)", AGU Joint Assembly, May 2006, p. , vol. , (2006). Presentation

J. L. Davis, S. Bisnath, E. Malikowski, B. Wernicke, K. Mahan, "Transient deformation at Yucca Mountain", Yucca Mountain Project, DOE, June 2006, p. , vol. , (2006). Presentation

J. L. Davis, "Non-Secular Signal Detection and Character in GNSS Data", 2006 UNAVCO Science Workshop, March 2006, p. , vol. , (2006). Paper presentation

J. L. Davis, B. P. Wernicke, S. Bisnath, N. A. Niemi, P. Elosegui, "Subcontinental-Scale Crustal Velocity Changes Along the Pacific-North America Transform Plate Boundary From BARGEN GPS Data", AGU Fall Meeting, December 2006, p. , vol. , (2006). Presentation

K. Johnson, R. Bürgmann, K. Larson, "Frictional afterslip following the 2004 Parkfield, California earthquake", BSSA, p. S231, vol. 96 (4b), (2006). Published

A. Bilich, K. M. Larson, "Mapping the GPS Multipath Environment using SNR Data", Eos Trans. AGU, p. G11A-0003, vol. 87(52), (2006). Abstract

N. E. King, A. Yong, J. Langbein, "Comparison of Historic and GPS-Derived Strain Rates in Southern California", SCEC Annual Meeting, p. , vol. , (2006). Presentation

N. E. King, D. Argus, J. Langbein, D. C. Agnew, G. Bawden, R. S. Dollar, Z. Liu, D. Galloway, E. Reichard, A. Yong, F. H. Webb, Y. Bock, K. Stark, D. Barseghian, "Space geodetic observation of expansion of the San Gabriel valley, California, aquifer system, during heavy rainfall in winter 2004-2005", J. Geophys. Res., p. , vol. , ( ). Accepted

N. E. King, A. Yong, J. Langbein, "Comparison of Southern California Shear Strain Rates from Triangulation, Trilateration, and GPS", AGU Fall Meeting, p. , vol. , (2006). Abstract

F. Rolandone, D. Dreger, M. Murray, R. Bürgmann, "Coseismic slip distribution of the 2003 Mw 6.6 San Simeon earthquake, California, determined from GPS measurements and seismic waveform data", Geophys. Res. Lett., p. L16315, vol. 33, (2006). Published

A. Kim, D. Dreger, M. H. Murray, "Kinematic source model of the 2004 Parkfield earthquake", EOS Trans. AGU, p. S43A-1041, vol. 86(52), (2005). Abstract

T. A. Herring, R. King, S. McClusky, M. Murray, M. Santillan, T. Melbourne, G. Anderson, "Plate Boundary Observatory GPS data analysis", EOS Trans. AGU, p. G21B-1264, vol. 86(52), (2005). Abstract

T. A. Herring, R. King, S. McClusky, M. Murray, M. Santillan, T. Melbourne, G. Anderson, "Plate Boundary Observatory (PBO) measurements of the North America plate boundary", EOS Trans. AGU, p. G53B-0903, vol. 87(52), (2006). Abstract

M. Bevis, K. Hudnut, R. Sanchez, C. Toth, D. Grejner-Brzezinska, E. Kendrick, D. Caccamise, D. Raleigh, H. Zhou, S. Shan, W. Shindle, A. Yong, J. Harvey, A. Borsa, F. Ayoub, R. Shrestha, B. Carter, M. Sartori, D. Phillips, F. Coloma, "The B4 Project: Scanning the San Andreas and San Jacinto Fault Zones", EOS Trans. AGU, p. H34B-01, vol. 86(52), (2005). Abstract

J. R. Murray, J. Langbein, "Slip on the San Andreas fault at Parkfield, California over two earthquake cycles and the implications for seismic hazard", BSSA, p. S283, vol. 96, (2006). Published

J. Murray, J. Langbein, R. Jachens, R. Simpson, "The spatio-temporal evolution of afterslip following the 2004 Parkfield, California earthquake", Eos Trans. AGU, p. S32A-04, vol. 87(52), (2006). Abstract

A. M. Freed, R. Bürgmann, E. Calais, J. Freymueller, S. Hreinsdóttir, "Implications of Deformation Following the 2002 Denali, Alaska Earthquake for Postseismic Relaxation Processes and Lithospheric Rheology", J. Geophys. Res., p. 10102, vol. 111, (2006). Published

T. B. Williams, H. M. Kelsey, J. T. Freymueller, "Contemporary GPS-derived strain in northwestern California: termination of the San Andreas fault system and convergence with the Sierra Nevada block contribute to southern Cascadia forearc contraction", Tectonophysics, p. 171, vol. 413, (2006). Published

S. Hreinsdóttir, J. T. Freymueller, R. Bürgmann, J. Mitchell, "Coseismic Deformation of the 2002 Denali Fault Earthquake: Insights from GPS measurements", J. Geophys. Res., p. B03308, vol. 111, (2005). Published

Y. Ohta, J. T. Freymueller, S. Hreinsdóttir, H. Suito, "A Large Slow Slip Event and the depth of the seismogenic zone in the south central Alaska subduction zone", Earth Planet. Sci. Lett., p. 108, vol. 247, (2006). Published

A. Freed, R. Bürgmann, E. Calais, J. Freymueller, "Stress-dependent power-law flow in the upper mantle following the 2002 Denali, Alaska, earthquake", Earth Plan. Sci. Lett., p. , vol. , (2006). Submitted

J. Langbein, J. R. Murray, H.A. Snyder, J. Svarc, B. Coyle, "Postseismic Deformation and Fault-slip From the 2004 M6 Parkfield, California Earthquake Using 2 Years of GPS and Creepmeter Data", Eos Trans. AGU, p. S23C-0170, vol. 87(52), (2006). Abstract

J. Langbein, J. R. Murray, H.A. Snyder, "Coseismic and initial postseismic deformation from the 2004, Parkfield, California, Earthquake observed by GPS, EDM, creepmeters, and borehole strainmeters", BSSA, p. 304, vol. 96, (2006). Published

W. L. Chang, R. B. Smith, "Contemporary deformation of the Wasatch Fault, Utah, from GPS measurements with implications for inter-seismic fault behavior and earthquake hazard: observations and kinematic analysis", J. Geophys. Res., p. , vol. 111, (2006). Accepted

W. L. Chang, R. B. Smith, "Lithospheric rheology from postseismic deformation of an M=7.5 normal-faulting earthquake with implications for continental kinematics", J. Geophys. Res., p. , vol. , (2006). Submitted

C. M. Puskas, R. B. Smith, C. M. Meertens, W. L. Chang, "Crustal deformation of the Yellowstone-Snake River Plain volcano-tectonic system: Campaign and continuous GPS observations, 1987-2004", J. Geophys. Res., p. , vol. , (2006). Accepted

D.W. Vasco, C. M. Puskas, R. B. Smith, C.M. Meertens, "Crustal deformation and source models of the Yellowstone volcanic field from geodetic data", Geophys. Res. Letters, p. , vol. , (2006). Submitted

Books or Other One-time Publications

Web/Internet Site

URL(s):
http://www.unavco.org/exnet/exnet.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
Unobligated funds: $ 0.00

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 2 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 from 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 second 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 primary data archive for the entire network, and data from all stations is continually analyzed by the PBO Data Analysis Centers. Approximately 77% 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 from original network operators to UNAVCO/PBO are proceeding apace, and Education and Outreach activities related to the project are flourishing. PBO Nucleus project personnel have continued to make important contributions to the testing and development of the hardware and procedures used by both the PBO and Nucleus projects.

Fig. 1. CAST, near Price, UT. Upgraded 5/24/06

Fig. 2. SELD, Seldovia, AK. Upgraded 5/20/06

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 95% of possible data were returned by the stations to during year 2, and 99% 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. Project Engineer Nicole Feldl, hired in June 2005, is 100% supported by the project and is involved in all aspects of the project on a day-to-day basis; Project Engineer Eleanor Boyce hired in October 2006 . Education and Outreach activities are the responsibility of Education Specialist Shelley (100% support), hired in September 2006, to replace Rebecca Walker who left UNAVCO in August. She is supervised by UNAVCO E & O Coordinator Dr. Susan Eriksson, who contributes 25% FTE to the project at no charge.

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 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, Ms. Feldl 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. QCY2, King City, CA, installed 5/26/06.

Figure 4. RUBY, NV, upgraded 11/17/06.

3. Project Operations

As of January 31 2007, 160 of the 210 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.

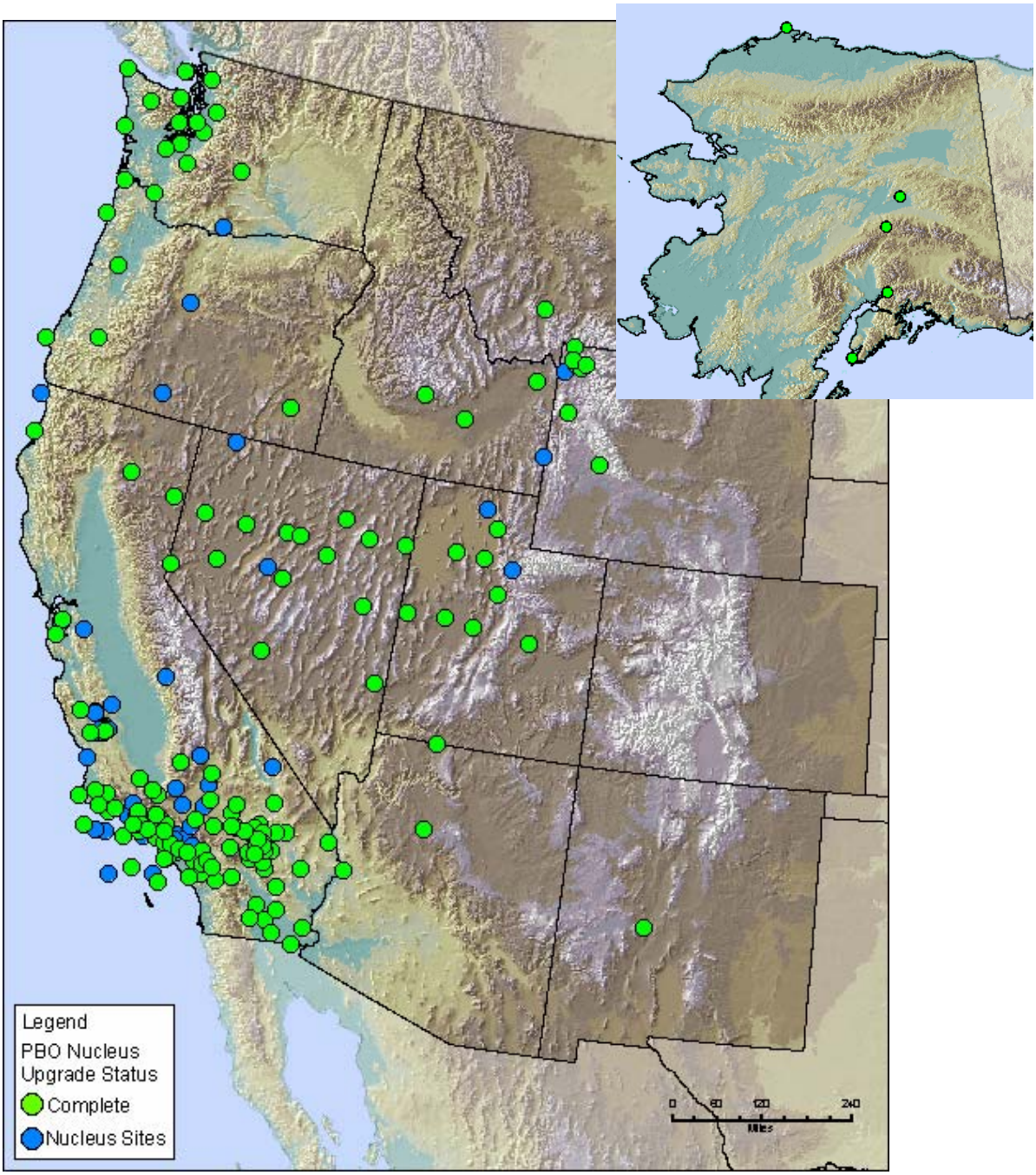


Figure 5. PBO Nucleus Network status, 2/1/2007. 160 upgrades have been completed, 49 remain.

The distribution of upgraded GPS stations throughout the six original existing networks is shown in Table 1. Hardware problems continued to plague 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 are being replaced preemptively. 100% of the 160 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, 2006**
AKDA (Alaska)	Univ. of Alaska	5	5	1
BARD (N. Ca.)	Univ. of California, Berkeley	10	4	1
BARGEN (Basin and Range, S. Ca.)	California Inst. of Technology	26	23	11
EBRY (Rocky Mtn., Basin and Range)	Univ. of Utah	16	13	6
PANGA (Pac. NW, N. Ca, Basin and Range)	Central Washington Univ.	27	22	15
SCIGN (S. Ca.), Parkfield (N. Ca.)	Univ. of Southern California	124	92	65
SuomiNet (Rocky Mtn.)	New Mexico Tech	1	1	1
Total:		**209**	**160**	**100**

Table 1. Distribution of upgraded stations in PBO Nucleus network.

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 Austin, Baker, and Fallon, NV central Oregon, and Southern California that are shared between Nucleus and PBO stations, and the installation of a new deep-drilled braced monument at QCYN2 near King City, CA to replace the aging QCYN monument (Figure 3, above). New permits were obtained for the construction of Nucleus-operated VSAT data relays at Ruby Valley, NV and Shoshone, CA, the former having been completed in November

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 to be as cost-effective as possible, minimizing recurring costs for operating the network for the indefinite future. As Figure 5 shows we have made good use of radio communications and cost-sharing arrangements, as 43% of the stations will be cost free in the planned final configuration of the 209 station network. We have minimized the use of expensive satellite systems and duplication of cellular service where line of sight between Nucleus and/or PBO stations exists. Figure 7 shows the planned distribution of power types for the final network.

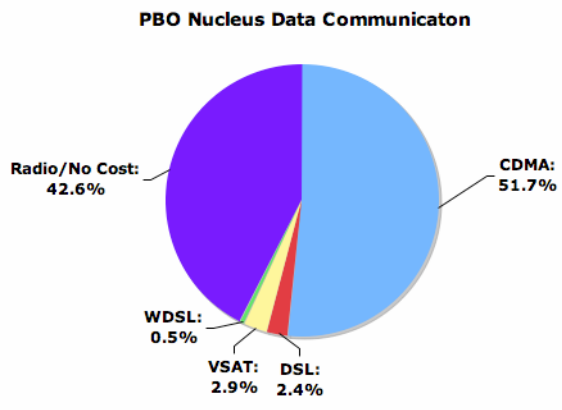


Figure 6. Summary of communication styles.

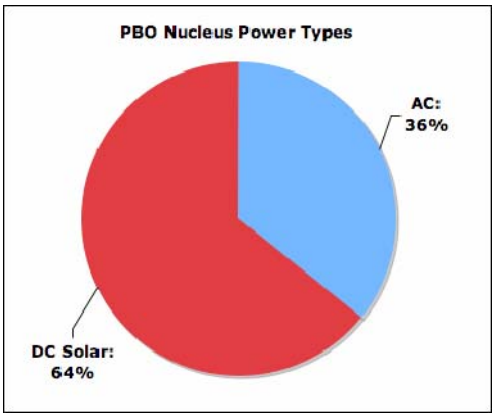


Figure 7. Summary of station power types.

4. Changes to the PBO Nucleus Station List

The year began with 210 stations in the network, with SC01 in New Mexico having been added since the proposal was submitted. We added this station not with the intent of increasing the scope of the project but in anticipation of other stations needing to be removed, and to have a roster of 209 stations at the completion of the project for inclusion in the Operations and Maintenance phase of PBO. This year saw the removal of four stations from the Nucleus roster and the addition of three new ones.

SUTB in the central valley of northern California and part of the BARD network, was removed when the permit-holder refused to allow any changes to ownership or hardware configuration of the station; UC Berkeley will continue the operation of the station with internal funding and make the data publicly available, so no replacement is necessary. This removal restored the number of stations in Nucleus to 209.

ECCO in the L.A. Basin was removed at the request of the landowner, El Camino Community College, who needed this valuable piece of real estate for the construction of new student housing. In its place we added LASC to Nucleus, a SCIGN station that had

been designated for USGS operation. Located only 3 miles to the northeast, LASC assures similar geographic coverage.

Two other stations, NEWP at Newport Airport on the Oregon Coast, and JNPR near Long Valley, CA, were deemed unworthy of upgrades and continued operation due to aging monuments. These opportunities were presented to PBO and will be replaced by P367 and P632 respectively in early 2007.

To replace these stations we added PCOL near Tacoma, WA and CPXX on the eastern flank of Mt. Ranier. Both of these stations are strategically located in the Cascadia subduction zone and fill geographic gaps in previous PBO and Nucleus coverage of the ETS area. 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. On 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.

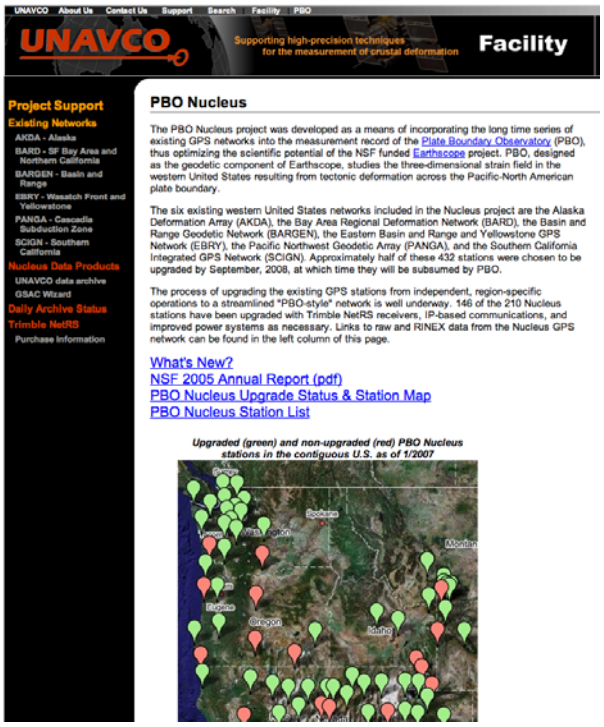
6. Station Permit Transfers

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 having been completed, and the remainder being actively addressed. The process is being coordinated by the PBO Nucleus project manager, PBO Permitting office and various network coordinators or their designees.

6. Education and Outreach

Shelley Olds joined UNAVCO in October as Education Specialist for the PBO Nucleus Project, replacing Rebecca Walker who left us in August. Major accomplishments during the project period included four workshops for middle- and high school teachers held in different locations in the western U.S., and the housing of Teacher-in-Residence Roger Groom of Portalnd, OR at the UNAVCO Facility for two weeks this summer. Further details are discussed in the Outreach Activities section of this report.

7. Project Information Dissemination



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).

Figure 8. The PBO Nucleus Project web page