UNAVCO Final Report

Acquisition of New GPS Equipment for the UNAVCO Community Pool in Support of Current and Emerging Solid-Earth Science Research Applications

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Activities and Findings

UNAVCO was funded to purchase portable GPS equipment for the UNAVCO Community receiver pool through this three year award (spanning 2003-2006). UNAVCO pool equipment has been and continues to be extensively used by the research community to conduct a wide range of geophysical and geologic investigations around the globe. The receivers purchased through this grant have the latest technology and enhanced capabilities. As anticipated in proposal, there has been an evolution in both GPS receiver technology and applications and demands upon the pool continue to grow. A number of projects utilized UNAVCO pool receivers in more traditional campaign measurements lasting a few days to weeks at a site. However, increasingly receivers are being requested for long, multi-year ("semi-permanent") occupations in order to capture transient motions such as associated with post-seismic deformation or slow earthquakes also called Episodic Tremor and Slip events. This type of longer-term observation strategy is made possible due to the increased memory, smaller physical size, and lower power requirements of new GPS receiver systems. Over the course of this award, UNAVCO purchased systems to meet both campaign and semi-permanent GPS needs. In addition to the receivers purchased under this award, aggressive upgrades have also been made by UNAVCO for NSF/Office of Polar Programs (OPP) and EarthScope/Plate Boundary Observatory (PBO) to meet specific needs of those programs. The combined UNAVCO receiver pool now numbers nearly 350 systems.

The demand for the new receivers grew beyond the rate of 10 receivers/year originally anticipated in the 2002 proposal. In the first year 10 Trimble 5700 campaign receivers were purchased. In year two, 11 Trimble R7s (the replacement for the 5700) and 10 Trimble NetRS semi-permanent system were purchased. One of the systems included a real-time kinematic option. In the final year, 24 NetRS receivers were acquired and outfitted. The ability to purchase of 25 more receivers than the originally budgeted number of 30 receivers was made possible by the availability of new lower-cost products (Trimble R7 and NetRS receivers, Figure 1) and aggressive discounts for UNAVCO Facility and Community negotiated by UNAVCO as a part of the large number of receivers purchased for the EarthScope/PBO 870 station permanent network.

The new receivers acquired under this EAR Instruments and Facilities award were essential to replace aging systems of the UNAVCO pool and to support new scientific requirements and equipment demands of the UNAVCO community. This award has proved critical to maintaining a current and viable GPS receiver pool for continued support to meet NSF-EAR project demands. In this report we will discuss the equipment purchased, associated UNAVCO Facility engineering support of the equipment and user training, and some of the scientific applications conducted by the research community that utilized this valuable shared equipment resource over the last three years.
GPS systems purchased for the UNAVCO Community pool as part of this grant. (right) Semi-permanent system, (center) Trimble campaign system (5700 and R7 receivers), and (left) real-time kinematic GPS system in use in the field. These new receivers represent state-of-the-art technology including low power, light weight, and high memory. The R7 and NetRS also have capability to track the new L2C GPS range observable. The NetRS, while designed for permanent reference station applications, has excellent capabilities for semi-permanent application including a built in LINUX computer and Ethernet connectivity, and 1Gb of internal memory. Thanks to PBO pricing, they also could be purchased at almost half the cost of the R7 receiver when bought with the Zephyr antenna rather than choke ring. To make the NetRS systems better suited for pool use and multi-project deployments, UNAVCO-designed a package which has the receiver in a single robust shipping case that is pre-wired with a power regulator and sealed connections for the GPS antenna, solar panels, and external or internal battery banks. This design facilitates minimizes the equipment handling, increases reliability in the field and reduces shipping costs.

GPS Receiver Pool and Usage

Prior to this award, the combined UNAVCO pool (EAR, OPP) consisted of only 88 receivers. By the end of the award the pool grew to 348 receivers (EAR, OPP and PBO). As shown in Table 1, many of these receivers are on long term loan to Principle Investigators (PIs) for a range of science investigations requiring semi-permanent occupations. The longer time period of measurement can be needed to observe time-dependent signals such as Episodic Tremor and Slip, volcanic deformation or post-seismic creep or in cases where higher precision is needed than can typically be obtained from traditional 2 or 3 day campaign surveys. Of the 348 receivers in the pool, approximately 60 of the older design receivers, such as the Trimble 4000, are being used on long term projects not needing latest technology, or are being retired due to attrition and lack of spare parts. We also note that the 100 EarthScope PBO receivers have tight restrictions on use and can currently only be deployed within the PBO footprint in North America. The 55 receivers purchased in this EAR I&F award are the workhorse for general UNAVCO use around the globe. Given below are examples from some of the science projects where this equipment has been deployed and utilization statistics.
The UNAVCO-managed NSF shared pool of GPS systems continues to be a very popular resource for the high precision GPS research Community. The state-of-the-art, well maintained and well equipped receivers and antennas (micro-center and chokering) in the UNAVCO pool offer the best geodetic data quality, are rugged for traditional campaign field surveys, and feature low power/large memory for semi-permanent applications. Systems include ancillary equipment such as tripods, calibrated tribrach, batteries, field enclosures, and solar panels. Equipment has been systematically upgraded through this Facility NSF EAR I&F grant, supplements associated with specific PI projects, regular NSF OPP-funded purchases, and the new NSF EAR PBO campaign pool. The increase to 348 receivers also has come with increase logistical challenges, some of which we manage with sophisticated databases (Fig. 2).

By maintaining a standardized pool of receivers provided by multiple sponsors, UNAVCO achieves economy of scale both in procurement discounts and technical support efficiency. Supporting multiple agencies with different field seasons keeps the equipment pool in use nearly year-round (see Figure 3). As demand catches up with new receiver supplies, the pool (non-PBO) utilization reaches 85 to 100%. We note that the entire pool is available for broader community use when not in use by sponsoring program-funded projects.

<table>
<thead>
<tr>
<th>Make/Model</th>
<th>EAR</th>
<th>OPP</th>
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<tr>
<td>Trimble NetRS</td>
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<td>19</td>
<td>84</td>
</tr>
<tr>
<td>Trimble 5700/R7</td>
<td>32</td>
<td>62</td>
<td>94</td>
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<tr>
<td>Trimble 4000 series**</td>
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<tr>
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<td>3</td>
<td>6</td>
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<tr>
<td>Ashtech MicroZ**</td>
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<tr>
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<tr>
<td><strong>Total</strong></td>
<td>254</td>
<td>94</td>
<td>348</td>
</tr>
</tbody>
</table>

*For projects in the EarthScope PBO footprint only, ** Occasional use, but unsupported and being phased out by attrition.

**Table 1. UNAVCO Current (2006) Receiver Pool.** Table shows the quantities of receivers by funding source and type. 34 Trimble NetRS, 10 5700 and 11 R7 receivers were purchased under this award.
Figure 3. UNAVCO Facility Receiver Pool. Shown are total number of available EAR and OPP receivers and the utilization of these receivers throughout the years.

Because of this high level of utilization, the Facility earlier in the year had to turn down several requests for 5700s, and had to fill them with 4000s or postpone the field dates. As community members begin using the newer technology, they do not want to go back to the older technology since this can significantly increase field costs. For example the older 4000 receivers require almost twice as much power (therefore batteries), two shipping cases and have only 20 megabytes of memory as opposed to 1 to 2 gigabytes for the R7. Low memory means more frequent need to download the receiver. With new systems, the receiver can be run for well over a year without downloading.

As UNAVCO pool acquired its new generation of state-of-the-art receivers, we introduced the community to the newer technology through a general training course “Surveying with UNAVCO Equipment” that was held in April 2004 (Figure 3a). During this first class, fifteen scientists, graduate students, and program managers came to UNAVCO to attend the course. The purpose of this course covered GPS field surveys from beginning to end, and consisted of presentations by UNAVCO staff regarding GPS
and office work essentials, along with hands on fieldwork. Over the last few years UNAVCO has conducted a number of campaign equipment training classes for students and investigators in Boulder, CO; Socorro, NM; Barrow, AK; Fairbanks, AK; and Greenland. UNAVCO also provides in-the-field, phone and email support, and web support for users to ensure that highest precision survey results are obtained with this equipment.

Real-time Kinematic (RTK) systems offer high precision surveying when used with a base station. An example is the Barrow Arctic Science Consortium (BASC) facility in Alaska. UNAVCO coordinated an annual site visit to the (Figure 3b) with the arrival of the research team from University of Texas, El Paso, (UTEP) to both upgrade the DGPS base receiver and train the UTEP team on the system. The base was upgraded from a Trimble 5700 to a Trimble NetRS, which offers remote reprogramming and downloading of the base, and frees the previous 5700 base to be used as a second rover. Alternatively, this second roving 5700 can be set up as an RTK base away from the BASC facility. This will benefit groups wanting real-time, cm-level, results up to 10 km from the BASC facility.

Figure 3. UNAVCO conducts classes for students and investigators at its Facility in Boulder and in the field. (a) Field practice in the UNAVCO course “Surveying with UNAVCO Equipment”. (b) Field training at the BASC in Barrow, AK.

Science Highlights

As summarized in Figure 4, the 55 new GPS receiver systems (10 Trimble 5700, 11 Trimble R7 and 34 NetRS receivers) purchased under this award were used for a number of projects around the world including static and kinematic campaigns, long term observations, earthquake emergency response, and polar studies. Details of the projects are included below. A more comprehensive report of the past use of the UNAVCO Facility receiver pool, and scientific applications can be found in the UNAVCO Facility annual reports http://www.unavco.org/facility/aboutus/publications/publications.html).
Airborne Laser Swath Mapping (ALSM) Survey of the southern San Andreas and San Jacinto faults, the “B4” Project (NSF-EAR Michael Bevis PI)

An ultra high resolution topographic dataset covering major fault systems in Southern California was produced using Airborne Laser Swath Mapping (ALSM), airborne photogrammetry and GPS. The survey area included nearly 1000 km of the San Andreas and San Jacinto faults, from Parkfield in the north to the Salton Sea in the south (Figure 5). Typical airborne LIDAR surveys provide vertical surface point accuracies of ~15 cm but this survey should provide significantly improved measurements with accuracies approaching 5 cm in the vertical and sub-meter in the horizontal. This enhanced resolution was achieved by conducting multiple aircraft overflights combined with densely spaced, high-precision geo-referencing surveys that included ground based GPS receivers spaced every 10 km along the flight lines. The primary survey took place in May 2005, and a secondary survey was completed in mid August 2005. The data produced by these surveys are collectively referred to as the B4 dataset. Similar surveys will be conducted following the next major earthquake on these fault systems.

This was the first scientific ALSM survey to be conducted at this scale. Numerous institutions participated in this project, including the Ohio State University, the National Center for Airborne Laser Swath Mapping (NCALM), the U.S. Geological Survey, and UNAVCO. UNAVCO provided 17 GPS systems from the UNAVCO Pool (Trimble R7 receivers, choke ring antennas and tripods) as well as engineering and data archiving support.
Figure 5. Sample ALSM image from the B4 project. The remarkable resolution of the results (left) even captured one the field vehicles and tripod such as the ground control point shown at the right.

**Joshua Tree Survey, 2006** (Community, Rick Bennett, PI) Twelve pool receivers were used to conduct a survey in Joshua Tree National Park. The network was established in 2005 to better understand the details of the crustal strain rate field between the southernmost San Andreas fault zone (SAFZ) and the eastern California shear zone (ECSZ). Figure at right.

**Antarctica 2004/05/06 Field seasons** (NSF-Office of Polar Programs, OPP) Receivers were provided for Antarctic field project support. Up to 75 receivers are sent down to the ice each season for a wide range of studies. Receivers are shared between Polar and EAR programs to make optimal use of equipment year round. UNAVCO OPP work is extensively reported in separate annual reports to NSF and are made available on the UNAVCO website. (right - South Pole). http://www.unavco.org/pubs_reports/reports/reports.html

**Bhutan** (NSF-EAR, Roger Bilham PI) *GPS Constraints on Inter-Plate and Intra-Plate Deformation of the Indian Subcontinent.* Two NetRS receivers were provided for installation at the continuous GPS stations in Bhutan. After the successful installations, the PI purchased identical instruments to replace those borrowed.
**GULFNET/Hurricane Katrina Rapid Deployment 2005** (Community, Roy Dokka (LSU), Giovanni Sella (NGS), Richard Capone (LSU). The UNAVCO Facility and PBO responded to a rapid response request by PIs Giovanni Sella and Roy Dokka to re-establish the Grand Isle, LA continuous GULFNET station which was damaged by Hurricane Katrina. GULFNET is a multiagency supported continuous GPS network that is used for scientific research and navigation. Drs. Dokka and Sella, who coordinate GULFNET, are active UNAVCO community researchers interested in causes and impacts of Gulf Coast subsidence. Data from the Grand Isle station, in addition to supporting subsidence studies, will be used to control aerial photogrammetric surveys being conducted to assess damage caused by Katrina. The UNAVCO Facility provided a GPS receiver, VSAT terminal and related equipment to establish satellite Internet dataflow during this time of enhanced need. Engineer Warren Gallaher and LSU staff members Anthony Cavell, and Richard Capone traveled to the station located at the Grand Isle Coast Guard Station where emergency power was available but Internet communications were severed. Grand Isle and other GULFNET data are available through the NGS, LSU and UNAVCO archives (figures below).

![Grand Isle Coast Guard Station](image1.png) ![GPS Receiver Installation](image2.png) ![Satellite Internet Terminal](image3.png)

**Denali Earthquake Response** (NSF-EAR, Jeff Freymueller PI) *Equipment Support: Mechanisms of Postseismic Deformation Following the 2002 Denali fault Earthquake.* One receiver was provided for the effort to complete the upgrade of post-Denali permanent sites.

**Baltoro Glacier, Pakistan**, Surface Velocity (John F. Shroder). UNAVCO GPS receivers were used to monitor the motions of the Baltoro Glacier, Pakistan. Measurements were made from the glacier terminus to K2 base camp over a horizontal distance of ~40 km. Repeated measurements of survey stake locations will enable determination of the glacier surface velocity. In addition, distinctive land features will be accurately located with the GPS system to enable their use as ground control points in the georectification of satellite imagery (figure at right).

![Baltoro Glacier](image4.png)

**DIVE** (NASA-SENH, Meghan Miller PI) A NetRS receiver was provided on a short term loan for installation at the sea-level monitoring site at the Scripps pier until a permanent receiver is purchased by the project.
Greece/Aegean (NSF-EAR-Geophysics, Robert Reilinger PI) Present Day Kinematics and Dynamics of the Eastern Mediterranean. Three receivers were provided for the resurvey GPS survey sites in central Greece, Peloponnesus, Crete, and Rhodes.

Highbourne Cay Bahamas (NSF-EAR-Biocomplexity, R. Pamela Reid PI) Biocomplexity of Marine Stromatolites: Biogeochemical Cycling, Microbial Population Dynamics, and Mineral Formation in a Three Billion Year Old Ecosystem. Two receivers were provided to geolocate important features and geological structures associated with biological-geological interactions in the stromatolite ecosystem over spatial scales ranging from single cell (µm) to kilometers and temporal scales ranging from minutes to seasonal and multi-annual.

Mauna Loa (NSF-EAR-Geophysics, Benjamin Brooks PI) Capturing Mauna Loa’s Current Reawakening - Integrated Geodetic and Numerical Investigations of Magmatic and Volcanotectonic Processes. Six of the pool NetRS receivers will be installed as part of a 12 station volcano deformation network with wireless Ethernet communications (figure at right).

Parkfield Emergency Response (NSF-EAR, Basil Tikoff PI) Comparing Deformation Rates in Wrench Borderlands from Geodetic and Geologic Data to Evaluate the Permanent and Recoverable Components. Two receivers were provided to measure ground surface displacements following the M 6.0 Parkfield earthquake of September 28, 2004.

RETREAT 2005, 2006 (NSF-EAR-Cont. Dynamics, Rick Bennett PI) Retreating trench, Extension and Accretion tectonics (RETREAT). Fourteen receivers were provided for GPS measurements with the aim of measuring crustal deformation associated with active geodynamic processes in the northern Apennines region of northern Italy (figure at right).

Salton Trough (Community, Rick Bennett PI) Two receivers were provided to upgrade two continuous GPS stations in northern Mexico to complement PBO south of the US border. The receivers are provided on temporary loan and will be replaced by the PI.

San Simeon Earthquake Response (NSF-EAR-Tectonics, Basil Tikoff PI) Comparing Deformation Rates in Wrench Borderlands from Geodetic and Geologic Data to Evaluate the Permanent and Recoverable Components. Five receivers were provided for the re-occupation of 20 GPS sites in central California to establish co-seismic offsets.
Indiana University Sierra Nevada field class 2006 (Community, Michael Hamburger) RTK GPS systems were provided for an intro-level field class for Indiana University undergraduate students for demonstration purposes (mapping Hilton Creek fault scarp).

Figure 6. Students learning GPS field techniques (using UNAVCO pool receivers) and regional geology in the context of natural history and environmental issues (from Prof. Michael Hamburger, Indiana University) in the “Volcanoes of the Eastern Sierra Nevada: Geology and Natural Heritage of the Long Valley Caldera” class. The class is unique in that it is designed for non-science majors. For more information see: http://www.unavco.org/edu_outreach/edu_outreach.html.

Peace-Athabasca Delta (Community, Laurence Smith) Over the summers of 2006 and 2007, we will be conducting field campaigns in the Peace-Athabasca Delta (PAD) of northern Alberta. The PAD is among the world’s largest freshwater deltas and is recognized as a UNESCO world heritage site as well as a RAMSAR convention wetland. We aim to address three fundamental questions on the hydrology of the Delta in particular and, more generally, of low-relief boreal wetlands: (1) Can inundate area in a floodplain lake attached to a river channel is used (alone, or in combination with other data) as a proxy for river stage or discharge in that channel? (2) Given an influx or efflux of water, how do changes in water surface height propagate through a large northern wetland? (3) How can techniques for understanding water movement in one boreal wetland be transferred to similar systems through the use of remote sensing?

Ha’apai Earthquake response (NSF-EAR, Michael Bevis) 8 Campaign GPS systems were provided to mount a geophysical and geological measurement campaign in the immediate aftermath of the M 7.9 Ha’apai earthquake of 3 May 2006 in order to clarify the mechanism of this event, and, more importantly, to observe subsequent developments, especially the aftershock development and postseismic deformation. The US effort which will involve OSU (Bevis), UTA (Taylor) and Washington University (Wiens) will be coordinated with efforts being mounted by
scientists from Australia and New Zealand. We will (i) set up some quasi-continuous GPS stations within the Ha’apai group, (ii) perform survey GPS measurements at a larger number of stations, (iii) set up some broadband seismometers, and (iv) perform a geomorphological analysis of vertical motions based on coastline displacements.

Coral Reef Ecosystems of Koh Tao (Community, Henrietta Laustsen)
Project goal is to identify possible stresses to the coral reef ecosystem of Koh Tao by comparing island development strategies to abiotic and biotic conditions over time. Project will address GPS mapping of the island, local coral reefs, and study sites. Environmental conditions observed will include marine, estuarian, and terrestrial areas. Biodiversity surveys will focus on mammals, fish, corals and other indicator invertebrate species.

Chhota Shigri Glacier (Community, Michael Bishop)
The research will utilize ASTER data as input into physical models to estimate glacier distribution, ice volumes and mass balance. This data will be ground-truthed at the Chhota Shigri Glacier in the Himachal Pradesh, India, in June 2006. The fieldwork will use differential GPS to monitor short-term ice motion patterns on this benchmark glacier.

Big Sky 2006 (NSF-EAR-HYDROLOGY Brian McGlynn)
GPS equipment and GPS processing support was provided to this project to study the human alteration of the patterns of land use/land cover (LULC) on the earth’s surface is one of the most profound impacts on the functioning of natural ecosystems. Understanding the consequences of LULC change is a critical issue at multiple scales. The intellectual merit of the proposed activity We will develop methods to quantify the impacts of geographic location and spatial distribution of LULC and LULC change over multiple scales and relate these metrics to measures of stream water quality, N uptake and retention. This approach will link the fields of watershed hydrology, Terrain analysis, and remote sensing.

SIGMA (Community, Ben Brooks) Provided Ethernet radio modems for the installation of a continuous GPS station on the summit of Mt. Aconcagua, Argentina. Aconcagua is the highest peak in the southern hemisphere and this project called SIGMA (Sistema Investigaciones GPS Mauna Aconcagua) is a joint project between multiple institutions in Argentina, the University of Hawaii, University of Memphis, and Ohio State University. The station is in the middle of ongoing GPS work in the CAP network. With the communications equipment requested here, the data will be downloaded remotely and made publicly available.

Associated UNAVCO Facility Engineering Support
The fifty-five receivers purchased under this award to date are part of the UNAVCO Facility equipment pool, a key component of UNAVCO’s campaign support effort. In addition to the maintenance, shipping and deployment of the receiver pool, the Facility provides training, fabrication and design of enclosures and equipment for long-term
occupations (sometimes called semi-permanent installations, where direct communications links are not possible), field engineering support, data processing when appropriate, discounted purchasing, and on-going receiver and antenna testing and evaluation to ensure the community is aware of and is using state-of-the-art receivers. A variety of these services were used in the investigations described above.

Many institutions and PIs using GPS have neither the technical ability nor the desire to maintain equipment for the occasional field or teaching applications, and they look to the UNAVCO Facility for access to equipment and associated technical support. Overall, the community continues to come to UNAVCO for hardware and software technical support, equipment recommendations, discounted equipment purchasing, and assistance with data processing and archiving. This support is provided by telephone, email, and web-based documentation, and is often required on very short notice due to project logistics and field urgency.

For the projects that do require assistance from a field engineer, the support requested is often of a high-level nature including survey design to achieve science objectives, power/communications engineering for semi-permanent applications, and post-project data processing support. Engineer supported projects are often conducted by PIs who are relatively inexperienced with GPS and view GPS geodesy as merely a convenient tool to further their scientific research. Knowledgeable technical support for campaign projects remains a critical UNAVCO support function, covering a range of GPS surveying methodologies including campaign measurements; kinematic, rapid static, and real time kinematic (RTK) applications; and semi-permanent applications.

Low power and high memory receivers in the UNAVCO pool now provide the community with the ability to utilize semi-permanent stations for sub-centimeter application, where continuous data are desired but there is no need to retrieve the data in real-time. Pool receivers may be set out for over a year before requiring data download. Examples of applications where this is important include measuring post-earthquake response and volcano monitoring.

**Benefits to the GPS Community.** To maximize access to UNAVCO support and to provide effective information dissemination, the UNAVCO Facility Web page features a single comprehensive support request form and supporting documentation to complement training and equipment received from UNAVCO. Equipment testing and maintenance procedures are also made available on-line as a resource for GPS users maintaining their own equipment or in need of emergency field repair instructions. The following campaign services are available, and support is tailored to the individual investigator's requirements and experience level:

*Equipment Loan* - A centralized pool of GPS receivers and ancillary equipment (also purchased with this equipment grant) such as tripods, tripods, batteries, and solar panels is available for community use (figure 7). By maintaining a standardized pool of receivers provided by multiple sponsors, UNAVCO achieves economy of scale both in procurement discounts and technical support efficiency. Supporting multiple agencies
with different field seasons keeps the equipment pool in year-round use. Equipment loans can be requested directly from the on-line support request form at www.unavco.net/support.asp. (See also Figure 2 above).

**Training** - Training by a field engineer on GPS surveying, equipment operation, data management, and data processing is available by request. Training is typically provided for one science group at a time, since the course material is often adjusted to an individual group's needs. In addition, a general audience course “Surveying with UNAVCO Equipment” was held at the Facility in April 2004. Training courses may be held at the Facility, the investigator's institution, or in the field immediately prior to project commencement. The UNAVCO training course outline is available on-line at www.unavco.org/facility/project_support/campaign/training_outline.html.

**Field engineering** - Investigators may request expert in-field GPS technical support for all or part of their project. Field engineers are available to assist with training, survey design, in-field support, and data processing. This support is especially useful for new investigators using GPS in the field for the first time, and for seasoned GPS researchers with large-scale campaigns where professional assistance with project management and logistics is required. Field engineering support can be requested using the on-line support request form at www.unavco.net/support.asp.

**Data processing** - New GPS users with relatively small, short-baseline campaign projects may receive Trimble software survey data processing support from UNAVCO. This service extends the utility of the UNAVCO pool to non-GPS scientists who simply use GPS as a surveying tool, and would otherwise not have the expertise to use this community resource. UNAVCO also sponsors GAMIT/GLOBK training classes for new investigators with advanced GPS data processing needs, and makes Trimble data
processing software available on loan. Several data processing resources are available online at [www.unavco.org/facility/project_support/campaign/training/processing.html](http://www.unavco.org/facility/project_support/campaign/training/processing.html).

*Discount receiver purchasing* - UNAVCO negotiates community pricing on GPS equipment from the major manufacturers. Discount pricing is provided both due to quantity discounts on pooled purchases (such as the ones purchased by the Facility for this grant and for EarthScope/PBO), and also because the UNAVCO Facility, rather than the manufacturer, handles the technical support issues from the end users. Over 480 receivers were purchased under the UNAVCO pricing by FY2006 by the Facility and community members.

*GPS Receiver Technology Advancements* - GPS technology for geodetic applications has improved dramatically through two generations of new equipment since the Trimble 4000 SSI receiver was introduced in 1995. Current generation GPS receivers have several improved features such as improved data quality, reduced power consumption, smaller size, and increased memory that make them desirable to the GPS research community. Several also feature Ethernet communication protocols, which allow data retrieval options using state-of-the-art communications hardware. UNAVCO also has the leverage to negotiate for the community’s unique requirements, such as custom firmware in the NetRS and new Topcon GB1000 used for PBO campaign applications. Custom firmware features include providing data in the UNAVCO developed non-proprietary BINEX format, and providing default settings suited for research applications rather than land surveying. Considerable effort goes into integrating and testing GPS and communication hardware with the goal of providing standard solutions for the community. The results of these tests are published on the UNAVCO website. [http://facility.unavco.org/science_tech/dev_test/testing/testing.html](http://facility.unavco.org/science_tech/dev_test/testing/testing.html)

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