UNAVCO Management Review

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Submitted by

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Submitted to

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UNAVCO provides community-based planning and management of activities benefiting geodesists in the solid Earth research community. Scientists are using the Global Positioning System (GPS) to investigate earthquake processes, mantle properties, active magmatic systems, plate boundary zone deformation, intraplate deformation, glacial isostatic adjustment, global geodesy and plate tectonics, global change, and polar processes (Fig. 1). GPS investigations are playing an increasingly important role in developing our understanding of plate motions and plate boundary zones. We are moving from an idealized model based primarily upon seismology and geology to rigorously-determined global models that simultaneously invert GPS observations for plate motions and boundary zone deformation. The latest models include 100’s of GPS projects, many supported by the UNAVCO Facility. Scientists are investigating plate boundary zones, the most tectonically and magmatically active regions of the planet, at an unprecedented level with EarthScope and other experiments around the globe. As GPS methods continue to improve, mm-level global reference frame determination is within reach, and challenging problems such as resolving continental-scale vertical deformation due to glacial isostatic adjustment can be addressed.

UNAVCO is a consortium of research institutions, and its mission is to support and promote Earth science by advancing high-precision techniques for the measurement and understanding of deformation. Hence, our primary members are geodesists who study crustal deformation. The primary tool supported by UNAVCO has been GPS. However, UNAVCO is moving toward including support for other techniques useful for studying deformation. Borehole strainmeters, Interferometric Synthetic Aperture Radar (InSAR), and Light Detection and Ranging (LIDAR) are expanding the spatial and temporal signals that can be investigated with geodetic techniques. At the same time, GPS is finding applications in a frequency range that used to be the sole provenance of seismology as GPS moves from one solution per day to one per second. UNAVCO is also expanding its role in education. These changes in UNAVCO are part of a conscious strategy to meet the future needs of the science community supported by UNAVCO. During the past year, UNAVCO developed a Strategic Plan to guide it through the next five years.

UNAVCO has staff and facilities in 6 locations (Fig. 2) with the majority of the staff located in Boulder, Colorado. The UNAVCO Facility in Boulder, Colorado is the primary operational arm of UNAVCO. The UNAVCO Facility exists to support research using GPS technology for Earth science research in crustal deformation. The Facility performs this task by providing state-of-the-art GPS equipment and field engineering support for projects; by installing, operating, and maintaining

Figure 1. Progression of refinements in geodetic understanding of crustal deformation. Clockwise from the top left: Simplified model derived from geology and seismology; global strain rate map using about 100 GPS investigations; EarthScope instrumentation of Pacific North America Plate boundary; and, isostatic rebound rates in North America.

Figure 2. Location of UNAVCO Offices.
continuous GPS networks globally; by undertaking new technology development and evaluating commercially available products for research applications; by distributing and archiving GPS data and data products; and by performing and promoting educational and outreach activities.

UNAVCO is constructing the EarthScope Plate Boundary Observatory (PBO), a geodetic observatory designed to study the three-dimensional strain field resulting from deformation across the active boundary zone between the Pacific and North American plates in the western United States. UNAVCO installs arrays of GPS receivers and strainmeters and provides data and processed results that will be used to deduce the strain field on timescales of seconds to decades, and UNAVCO supports imaging and geochronology investigations to examine the strain field over expanded spatial and temporal scales. Most of the UNAVCO employees working on construction of PBO are grouped in a division created expressly for this purpose. This structure allows UNAVCO to manage PBO construction with clear lines of responsibility and authority, essential for a project of this size; and it insures that ongoing activities of the UNAVCO Facility in support of the science community are not adversely impacted. UNAVCO has five regional offices established to construct PBO (Fig. 2).

II Support of Science Projects

The UNAVCO research community uses GPS for a wide array of science investigations exploring tectonic problems all over the globe. The UNAVCO Facility provides these scientists with project engineering, equipment and archiving support. The scope of projects ranges from individual NSF EAR and Office of Polar Programs (OPP) projects, to very large projects such as the NASA Global GPS Network (GGN), the NSF EAR Major Research Equipment Facility Construction (MREFC) EarthScope Project, and the collaborative NSF-EAR PBO Nucleus Project.

The UNAVCO Facility is organized into the Engineering, Equipment, and Data Groups. These three groups conduct their work collaboratively and with a strong sense of team effort and a spirit of cooperation with and support to the community. The Engineering Group provides comprehensive permanent and campaign project support including planning and budgets, installation, operations, training, technical support, field engineering, and maintenance as well as system testing and development. The Equipment Group maintains, tracks, and ships the UNAVCO pool receivers that are loaned to projects. It also assembles, tests, and repairs equipment including the new PBO permanent stations and campaign systems. The Data Group is responsible for data management including, data retrieval, storage and distribution. The Data Group is also responsible for insuring access to data and the long-term preservation of archived data through appropriate backup systems. The Facility also includes a small administrative staff that provides proj-

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Figure 3. Typical phases of a GPS project and the role of the UNAVCO Facility in supporting these projects. The focus of each of these efforts is to ensure the collection of GPS data of the highest quality in order to meet the science objectives of the project.
The implementation of a GPS project is a collaborative effort involving the Principal Investigators (PIs) and Facility staff and the various phases are depicted in a general fashion in Figure 3. The process and can involve:

1) Technical planning and budget development for proposals. PIs are encouraged to contact UNAVCO as early in the proposal development process as possible so that staff can help PIs develop technically feasible and fiscally efficient plans for acquiring their desired GPS measurements.

2) Pre-deployment planning, preparation and training. A detailed project implementation plan is developed that assures both that current technical, logistical, financial, safety and other best practices are considered and followed and that appropriate Facility resources for development and implementation are allocated. This is a highly interactive process with the PIs to ensure science goals are met and PI expertise is utilized.

3) GPS data collection and network operation and Maintenance. Staff are available to support the deployment phase of projects either by accompanying and supporting the PI in the field or by providing technical support and consultation remotely.

4) Data pre-processing. Data from campaign, semi-permanent, or permanent occupations are reformatted, verified for quality, and distributed to users.

5) Data processing and scientific analysis. Though UNAVCO helps facilitate PI collaborations and community support for data processing training, PIs independently process, analyze and interpret their own data. Questions can arise about problematic data, however, and Facility staff are often called upon for technical consultation.

6) Archiving of data and science products. All GPS data collected under NSF-EAR funded programs are required to be submitted to the UNAVCO archive for long-term storage and availability. The Facility archives both continuous data flow from permanent stations and campaign data collections. Access to various data sets is provided by online systems. GPS velocity and strain result archives are also supported.

### Engineering and Equipment Support

Increased availability of low power, high memory GPS receivers at relatively low cost have enabled projects to operate in longer-term, unattended occupation modes and in ever-greater numbers. As a result, demand for permanent station network support continues to increase and campaign deployments have involved larger numbers of receivers. The UNAVCO Facility is currently responsible for helping to monitor, maintain, and provide technical support to 550 GPS stations in support of 31 discrete projects under multiple sponsors. UNAVCO engineers train PIs and their students in support of individual projects and UNAVCO occasionally offers formal classroom training on GPS, strainmeters, and other topics of value to the science community.

**Individual NSF-EAR peer-reviewed research projects.** PI projects continue to be a key component of UNAVCO activities. Typically about 50 projects receive varying levels of support by the UNAVCO Facility over the course of a year. These include both campaign and permanent station projects at diverse locations around the world. Support spans a range of possibilities shown in Figure 3. The RETREAT Project in Northern Italy and Croatia is an example of a project that received a full complement of UNAVCO support. UNAVCO prepared and shipped portable campaign and semi-permanent GPS equipment to Italy, trained PI collaborators in the field, participated in the initial phase of the experiment, identified and resolved technical issues in the field, and submitted data to the archive. The Mauna Loa experiment involved rapid deployment of continuous stations in response to recent increased activity on the volcano. UNAVCO staff were involved in network design, installation, new IP-based telemetry, and data management. Utilizing Facility and PI resources, eleven systems were deployed only months after the project was funded and data were made available from UNAVCO immediately after installation. Other projects recently supported include volcano studies such as the Galapagos network, emergency earthquake response to the Parkfield 2004 earthquake, and tectonics studies in the Basin and Range, central U.S., Mexico, Alaska, eastern Mediterranean, Spain, and the south Pacific.

### NSF-EAR Earthscope/Plate Boundary Observatory Project and the PBO Nucleus Project.

Although the PBO division of UNAVCO has the primary responsibility to manage and implement the PBO Project, the UNAVCO Facility provides support for many aspects of this project including receiver testing, site reconnaissance, installations, systems design, equipment packaging and
testing, campaign support, and archiving. The Facility supports the EarthScope Portable Campaign GPS receiver pool, providing equipment support, PI support and training, field deployment, and data processing and archiving capabilities. The Facility also manages the collaborative NSF-EAR PBO Nucleus project that will transition 209 GPS stations from independent, region-specific operations to streamlined “PBO style” operations by September 2008.

The Facility is also providing engineering and project management support to the EarthScope/GeoEarthScope component. Funded PI research currently involves InSAR and future science projects could include airborne- and ground-based LiDAR and radiometric age dating. Increasingly, the UNAVCO research community is using InSAR and LiDAR to extend the spatial and temporal scales of deformation measurements. GPS provides complementary data or geodetic control for measurements. The UNAVCO Facility hosts a WinSAR archive and it supported a large-scale NSF EAR-funded airborne LiDAR experiment with GPS field engineering, training and equipment. UNAVCO sees an expanding role for this type of support in the future.

NASA Global GPS Network Support. The UNAVCO Facility is multi-agency funded with approximately 30% of its funding provided by NASA. The Facility, working in close cooperation with the Jet Propulsion Laboratory (JPL), provides daily monitoring, troubleshooting and maintenance of 76 globally distributed permanent GPS stations that comprise NASA’s Global GPS Network (GGN). Agencies and institutions around the world, including many International GPS Service (IGS) participants, use GGN data to produce highly accurate products that are essential for Earth science research, geodetic reference frame determination, global plate motions, precision timing, satellite orbit determination, navigation applications, multidisciplinary science applications, and education. Products include GPS satellite ephemerides, Earth rotation parameters, tracking station coordinates and velocities, GPS satellite and tracking station clock information, Zenith tropospheric path delay estimates and Global ionospheric maps.

In FY2004, primary responsibility for network monitoring and first-response troubleshooting was successfully transferred from JPL to the UNAVCO Facility under the coordination of the NASA Project Manager in the Engineering Group. Much of this work is coordinated with the remote stations operators and is effective due to the strong relationships established over the years by the Facility, JPL and NASA-funded PIs. This high level of corporate knowledge extends to the whole of the Facility and means that UNAVCO is capable of deploying nearly anywhere on the globe. The UNAVCO Facility also maintains an operational back-up capability to retrieve and provide station data to the various users in case of failure at JPL. Research and development is also an important part of the NASA project and current work is focused on developing a global capability to measure the new GPS L2C observable. Equipment has

Table 1. UNAVCO Receiver Pool. Table shows the quantities of receivers by funding source and type. The “Available Pool” receivers are not currently assigned to long-term projects.

<table>
<thead>
<tr>
<th>Make/Model</th>
<th>EAR</th>
<th>OPP</th>
<th>Total</th>
<th>Assigned to Long-term Projects</th>
<th>Available Pool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trimble NetRS</td>
<td>18</td>
<td>19</td>
<td>37</td>
<td>2-Salton Trough 2005</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6-Mauna Loa 2005</td>
<td></td>
</tr>
<tr>
<td>Trimble 5700/R7</td>
<td>30</td>
<td>41</td>
<td>71</td>
<td>10-Denali EQ Response</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2-Barrow, 1-Toolik Lake</td>
<td></td>
</tr>
<tr>
<td>Topcon GB-1000*</td>
<td>51</td>
<td>51</td>
<td>102</td>
<td></td>
<td>51</td>
</tr>
<tr>
<td>Trimble 4000**</td>
<td>24</td>
<td>8</td>
<td>34</td>
<td>3-SAGE-NZ, 6-MIT, 5-Antarctica, 2-U. Maine, 1-PBO Nucleus</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2-Baja, 2-Parts</td>
<td></td>
</tr>
<tr>
<td>Trimble 4700/4800**</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Ashtech MicroZ/Z-XII**</td>
<td>10</td>
<td>2</td>
<td>12</td>
<td>4-Nisqually EQ Response</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7-Testing, 1-U.Colo.</td>
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</tr>
<tr>
<td>Total</td>
<td>140</td>
<td>71</td>
<td>211</td>
<td>63</td>
<td>148</td>
</tr>
</tbody>
</table>

*For projects in the EarthScope PBO footprint, ** Occasional use, but unsupported and being phased out by attrition
been purchased and a test installation established at the UNAVCO field site near Marshall, CO. As new satellite systems such as Galileo become available, the GGN and IGS need to be at the forefront to ensure the infrastructure is there to use these new observables and that the effects on products such as reference frames and related science is minimized.

**NSF Office of Polar Programs Support.** UNAVCO provides year-round support for Antarctic and Arctic scientific applications of GPS to the NSF Office of Polar Programs (OPP). Support is provided to a wide range of disciplines, including glaciology, geophysics, geology, volcanology, and biology. The applications of GPS range from crustal deformation and ice dynamics surveys to mapping and geodetic information systems. Support includes pre-season planning, field support and training, data management and archiving, post-season follow-up, and development work for supporting new applications. Polar GPS equipment is shared with other Facility projects and the ongoing use of all types of GPS surveying—from kinematic to permanent stations—helps to keep Facility engineering staff up-to-date with the latest practices and procedures.

**Development and Testing.** The Facility is actively engaged in development and testing activities conducted in collaboration with community PIs and in coordination with a number of GPS and related vendors to address remote data communications, power systems, and receiver and antenna performance. Facility development and testing occurs in relationship to specific PI projects, but also benefits the broader GPS community as experiences and techniques are disseminated via the web, meetings, workshops and classes and direct engineer training. The UNAVCO development and testing process is effective because it builds upon years of interactions, shared goals and acknowledged expertise. Recent activities include testing of new Internet Protocol (IP)-based GPS receivers with VSAT (Very Small Aperture Terminal), CDMA (Code Division Multiple Access), and IP-based spread spectrum radios for GPS communications. The UNAVCO Facility is also supporting an experiment to evaluate receiver pseudorange biases, to test the temperature range performance of new GPS receivers, and to coordinate an effort to assess the effects of radomes on antenna calibration.

**UNAVCO Equipment Pool.** The UNAVCO-managed NSF shared pool of GPS systems continues to be a high-demand resource for the high precision GPS research community. The state-of-the-art and well maintained and equipped receivers 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. Receiver selection and systems integration is based on extensive Facility testing. Systems include ancillary equipment such as tripods, calibrated tripods, batteries, field enclosures, and solar panels. Equipment has been systematically upgraded through a separate Facility NSF EAR I&F grant, supplements associated with specific PI projects, regular NSF OPP purchases and the new NSF EAR PBO Campaign pool. There are currently 148 receiver systems available in the pool (Table 1). 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 nearly year-round use with non-PBO equipment usage ranging from 30 to 100%. The PBO pool acquisition is in progress and will number 100 campaign systems by FY2006.

**Community GPS Receiver Purchases and Pricing Program.** As a benefit to members, UNAVCO has negotiated special pricing with a number of vendors who supply GPS receivers and other equipment that is commonly used by the community and supported by the Facility. Discount pricing is provided both due to quantity discounts on pooled purchases, and because the UNAVCO Facility, rather than the manufacturer, handles repairs and other technical support issues from the end users. Under this program, UNAVCO members purchased approximately 240 GPS receivers in 2004 and 2005. Technicians at the Facility are factory trained and authorized to repair pool and community-owned receivers.

**Enhancement of Community Technical Knowledge and Capability.** By virtue of its involvement in many different projects in support of multiple research programs, the UNAVCO Facility is exposed to diverse GPS applications involving different aspects of technology. UNAVCO’s involvement in EarthScope/PBO and UNAVCO’s support of Polar Programs helps push GPS technology to new levels in order to address challenges faced in efficiently operating very large receiver networks and challenges faced in extreme environments. UNAVCO has a qualified engineering staff with relevant knowledge and experience with many of the technical and equipment issues that may arise in any typical project. Experience gained on any project is disseminated through Facility staff, who use this knowledge to more effectively support projects to which they may be assigned. The Facility’s equipment testing and communications laboratory forms a key venue for technical
interaction between staff members, various project personnel, equipment vendors and others in sharing and disseminating technical information in implementing and supporting community projects. Senior engineering staff typically have 10 to 15 years of experience in GPS engineering and new staff typically 5 years. On-the-job training is an important component of staff training and is critical to keeping staff knowledge at the highest levels. Examples of how the UNAVCO Facility has supported enhancements to the community’s technical knowledge and capability over the last year include: various communications system integration and testing; GPS receiver functional testing and interaction with equipment vendors to solve problems and improve functionality; antenna rotation testing to identify manufacturing defects; and various project training sessions.

Table 2. UNAVCO Archive Statistics.

<table>
<thead>
<tr>
<th></th>
<th>Permanent Stations Handled (per year)</th>
<th>Campaigns Processed (per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># Archived</td>
<td># Files</td>
</tr>
<tr>
<td>FY 2002</td>
<td>217</td>
<td>63,282</td>
</tr>
<tr>
<td>FY 2003</td>
<td>270</td>
<td>77,783</td>
</tr>
<tr>
<td>FY 2004</td>
<td>380</td>
<td>113,629</td>
</tr>
<tr>
<td>FY 2005*</td>
<td>681</td>
<td>224,948</td>
</tr>
<tr>
<td>Total</td>
<td>783 w/data</td>
<td>641,735</td>
</tr>
</tbody>
</table>

Data Management and Archiving

The UNAVCO Boulder Facility provides data management and archiving support for high precision campaign and permanent station GPS data collected by community investigators. The Facility Data Group maintains an extensive collection of computer and storage systems hardware and associated data management software, database tools and web access tools to manage this important task. Over the last two years the Data Group has developed a scalable system including significant hardware upgrades and software enhancements needed to handle a dramatic increase in data volume and the diversity and complexity of data collection methods (Figure 4 and Table 2). The addition of a large Enterprise-class Storage Area Network (SAN) RAID has greatly increased reliability and robustness of service by minimizing the impact of disk failures and increasing data throughput. A new automated tape system allows rapid generation of local and offsite (IRIS DMC) backup tapes helping to ensure longterm preservation of the data.

The Facility data management relies on databases, web forms, reports and map interfaces to manage critical station data through a subaward to the Scripps Orbit and Permanent Array Center Archive located at University of California, San Diego. Station metadata are verified using database cross-checks between equipment, operations and archive databases. Data are available to the user within minutes of the hour or UTC (Universal Time Coordinated) midnight depending if hourly or daily files are provided from the source. Data are publically available subject to the UNAVCO/NSF data policy. UNAVCO has a number of tools to facilitate data discovery and data access, and participates as a GPS Seamless Archive Center (GSAC). Staff provide support to PIs and other users via telephone and email and accommodate special data delivery or access requirements for raw or translated data. UNAVCO also supports archiving of GPS permanent station data through a subaward to the Scripps Orbit and Permanent Array Center Archive located at University of California, San Diego.

Facility staff also work with PIs to archive campaign data, a process that can require manual handling of storage media and scanning of paper logs and additional interactions with contributors. All campaign data are stored in the UNAVCO physical repository as well as online. In addition to GPS raw and RINEX primary data, the Facility maintains science product archives for derived products including GPS velocities such as the UNAVCO Global GPS Velocity Field (GPSVEL) and strain rates from the International Lithosphere Program (ILP) Global Strain Rate Map (GSRM) and other GPS-derived strain projects.

UNAVCO’s data management and archiving activities continue to evolve at a rapid rate as the community’s data needs grow driven in no small part by the large volume of data anticipated by PBO. Archive infrastructural improvements specifically implemented for EarthScope PBO, benefit the entire community. Technology improvements such as the storage and tape library are shared investments and automatic redundant offsite data collection and backup archives at IRIS will be extended to non-PBO data. The UNAVCO Facility is the primary long-term repository for all PBO generated GPS data and data products.

III Education and Outreach

In a December, 2002 Education and Outreach report, UNAVCO articulated its rationale for a strong E&O program, described the current activities at that time, and set forth future initiatives. Activities in 2002 included: field-based student training and collaboration with the GLOBE project; web-based resources including development of the Jules Verne Voyager map tool; support of the International Lithosphere Project (Global Strain Rate Map); and working with the broader community education and outreach initiatives such as EarthScope. These important activities were carried out by staff members who were primarily dedicated to the main activities within UNAVCO, namely facility equipment, engineering, data acquisition, and archiving.

Future initiatives listed in the 2002 report included adding an Education and Outreach Coordinator position and formalizing a student intern program. Both of these objectives have been accomplished. An Education and Outreach Coordinator was hired in June 2004. The following summary highlights the UNAVCO E&O program from June 2004 to the present, emphasizing the accomplishments of many people in the UNAVCO community.
The Standing Committee on Education and Outreach consists of UNAVCO community scientists and leaders and active participants in geoscience education. The committee’s first meeting in April 2005 resulted in a draft mission statement and set of goals, and a vision for the UNAVCO E&O program. This will be the basis for further strategic planning in this area during 2005; the process will include a broader communication with the UNAVCO community before a final plan is approved by the Board of Directors. Diversity is included in the mission statement and will promote the importance of diversity in UNAVCO’s work. Evaluation and the use of research based on best educational practice are embedded in the values of having an excellent, professionally assessed program. Resources for evaluation, planning and implementation are built into each project.

**Draft E&O Mission Statement, June 2005:** The mission of UNAVCO Education and Outreach Program is to promote a broader understanding of Earth science by making accessible the data, scientific methods, and results of the unique suite of scientific research in which UNAVCO’s community of scientists is engaged. We will foster collaboration between the scientific and educational communities and will increase the number and diversity of students to strengthen and sustain the next generation of earth scientists.

**Draft Statement of E&O Goals, June 2005**

- Increase the understanding and public appreciation of geodynamics and earth deformation processes and their relevance to society
- Broaden the use of UNAVCO data and products by a wide audience of educational and research users
- Increase the diversity and broader participation in geoscience education and research
- Build a sustainable community of UNAVCO scientists and educators engaged in education and outreach
- Collaborate with other organizations to provide systemic impact on geoscience education

**Programs**

**RESESS:** A three-year program of internship support for under-represented minorities in research programs at UNAVCO member institutions has been funded by the GEO Opportunities for Enhancing Diversity in the Geosciences. UNAVCO leads this collaboration that also includes SOARS (UCAR), IRIS, the University of Colorado, the USGS, Highline Community College, and Central Washington University. The program is called RESESS (Research Experience in Solid Earth Sciences for Students) and will officially begin in October 2005. UNAVCO’s present Cooperative Agreement includes money to support a UNAVCO intern. This internship will be incorporated into RESESS.

RESESS will operate in collaboration with UCAR’s highly successful SOARS project which promotes research, mentorships, and a learning community, all of which are recognized as important for successful retention of minority students in the sciences. As part of UNAVCO’s service to the community, we are developing a cadre of educators/researchers that are knowledgeable about the value of undergraduate research and about activities required to retain individuals from underrepresented populations.

**Jules Verne Voyager Mapping Tool:** This tool was developed by the Facility for use in providing quality assurance for campaign data, and it quickly evolved into an educational product. Community members participate in its continuing development and in providing an educational context for the Voyager. UNAVCO has recently formally evaluated its usefulness as an educational product and is working in collaboration with community members in both the improvement of the tool and the accompanying educational materials.
**Educational Modules:** The contribution of modern geodesy to the study of plate tectonics is not usually incorporated into curriculum at middle/high school level, general education in universities (introductory geoscience), nor in most upper level geoscience college and university programs. However, the direct measurement of crustal movement is important in our understanding of what a plate tectonic ‘theory’ is and how modern science is performed. UNAVCO is in the process of increasing education staff to work in the design of modules which incorporate the research which UNAVCO supports and distributing these modules to a broad audience. These will be accompanied by posters and workshops.

**Short Courses:** Strengthening the workforce and fostering new knowledge in geodesy can only be accomplished with new generations of scientists understanding the science and the tools. UNAVCO regularly holds classes training community members in the technology. Recent classes include an April 2004 class on GPS techniques, a March 2005 GAMIT workshop held at Ohio State University, and a July 2005 class on using strainmeter data. UNAVCO has invested in an upgrade in classroom space to facilitate more short courses for graduate students, post doctoral fellows, and practicing scientists.

**Outreach**

UNAVCO’s strategic plan for E&O also recognizes the ongoing importance of broadening the accessibility of its data and products. Booths at professional meetings has increased during 2005, and written materials with flexible format and content provide current information to our current users and increases UNAVCO’s visibility in the broader scientific community. The UNAVCO website has been redesigned for easier use, and plans are evolving for a more rapid, changing content from community research on the website.

**IV Community Interaction**

UNAVCO community Science Workshops provide an opportunity for the UNAVCO community to meet their colleagues and discuss the latest developments in their field. The format of the meetings is a mix of plenary science sessions, breakout sessions on more specialized subjects, poster sessions, and free time. Because of the focused nature, these meetings serve a unique role in the UNAVCO community and are very popular. The next workshop will occur in March 2006. Funding through UNAVCO for participant support allows investigators to attend these meetings and enables participation of students.

The most recent meeting was held jointly with the Incorporated Research Institutions for Seismology (IRIS) in Washington State. There were more than 300 attendants with an approximately even split between people with primary interests in seismology (IRIS) and primary interests in geodesy/deformation (UNAVCO). The meeting included plenary sessions on: The Sumatra Earthquake, Explosive Volcanism, Polar Geoscience, and, Next Generation Imaging. There were breakout sessions focused on: Stable North American Reference Frame (SNARF); Seismic Analysis Code; Cascadia Tremor and Slip; Field Experiments; EarthScope Plate Boundary Observatory Nucleus; Cascadia-Megathrust to Subduction; EarthScope USArray; EarthScope PBO; Broader Impacts; Nuclear Explosion Monitoring; Global Earth Observatory System of Systems (GEOSS); Digital Photography;
UNAVCO also organizes and conducts community workshops and working groups on special interest topics. UNAVCO facilitates the discussion that leads up to the genesis of the workshops. The proposal for funding is submitted through UNAVCO. UNAVCO handles all of the logistics for the workshops and working groups. Recent workshops/working groups supported by UNAVCO include:

**Long Valley** - UNAVCO sponsored a workshop addressing Long Valley science issues. The workshop was held at Mammoth Lakes, California on October 8th-12th, 2003. It included an interdisciplinary approach to volcano studies and brought together researchers from all of the relevant disciplines, including geologists, geophysicists and geochemists. The agenda included presentations and discussions to bring everyone up to speed on exactly what is known from each of the disciplines. The second part of the workshop focused on key questions that could potentially be resolved by new observations (including EarthScope), measurements not included within the EarthScope facilities program, laboratory experiments, or theoretical and numerical studies. The National Science Foundation and U.S. Geological Survey supported the workshop, which included over 65 participants from academia, government agencies, and the private sector, with participants from Italy, Japan, New Zealand, and Great Britain.

**Magmatic Systems** - An EarthScope Workshop on Active Magmatic Systems was held at Heathman Lodge in Vancouver, Washington, October 30th to November 3rd, 2002. The workshop included some 62 participants from over forty universities, research institutions, and research consortia, as well as representatives from the National Science Foundation, NASA, and the U.S. Geological Survey. A summary of the workshop and its recommendations was published in EOS (Hamburger, EOS, v. 84, n. 25, 24 June 2003, p. 235)

**SNARF** - UNAVCO is home to a working group to establish a standard reference frame for EarthScope PBO observations and results. The Stable North America Reference Frame (SNARF) working group is chartered “to establish a high-accuracy, standard reference frame, including velocity models, procedures and transformations, tied to a “stable North America” that would serve the scientific and geomatics communities by providing a consistent and stable reference with which scientific and geomatics results (e.g., positioning in tectonically active areas) can be produced and compared.”

**Polar** - An Antarctic Remote Geophysical Observatories Meeting was held at the UNAVCO building in Boulder, Colorado on the 19th and 20th of September 2004. There were about 20 participants. The meeting was convened in response to a request from NSF for a more coordinated approach to remote stations deployments. From both a science and science support perspective, NSF expressed an interest in pursuing future geodetic (and presumably seismological) research in a more coordinated way than has been done previously. The overall goal of the workshop was to provide NSF with a ‘community vision’ of future research needs. A second goal was to advance planning for remote station deployment as a long-term effort for the International Polar Year (IPY) or to support other antarctic research projects. The principal recommendation of the workshop was to put forward a community level proposal for remote GPS and seismic sites in the Antarctic interior. This proposal will address science rationale, technology development, field support, logistics, operations, and maintenance, and the role of facilities including IRIS and UNAVCO. This effort will also be integrated with broader IPY initiatives, and a proposal to NSF is anticipated in response to the August 2005 NSP/OPP call for IPY proposals. An expression of intent has also been lodged with the IPY committee and received official IPY endorsement.

**Communication with sponsors.** UNAVCO keeps funding agencies informed of all activities through annual and quarterly reports (See supplementary material). In addition, key UNAVCO staff often consult with NSF Program Managers by phone and email. Senior UNAVCO staff visit NSF and NASA Program Managers frequently. Recent visits, and the staff involved, include:

- 2004-07-14,15 Prescott, Eriksson, Meertens at NSF and NASA
- 2004-10-28,29 Lambert, Shedlock at UNAVCO Board Meeting
- 2004-11-04 Lambert at UNAVCO
- 2004-11-18 Prescott, Boler at NSF
- 2005-01-12 Prescott, Wilson, Jones at NSF
- 2005-02-08 Shedlock at NSF and NASA
- 2005-03-14 Shedlock, Whitcomb at EarthScope offices
- 2005-05-04 Prescott at NSF and NASA
- 2005-06-08,10 Lambert, Labrecque, Shedlock, Whitcomb, Zimmerman at UNAVCO/IRIS Meeting
- 2005-08-15 Shedlock visited UNAVCO
V Governance and Planning

Governance

UNAVCO was founded in 1984 as The University NAVSTAR Consortium under the auspices of the Cooperative Institute for Research in Environmental Sciences at the University of Colorado. In 1992, UNAVCO became a part of the University Corporation for Atmospheric Research (UCAR). In April 2001, UNAVCO was incorporated in Colorado as an independent, 501[c](3) non-profit. UNAVCO became an operational entity in 2002. During the first year of operation of the new, independent UNAVCO, the UNAVCO Facility continued to be part of UCAR. UNAVCO assumed responsibility for the management of the Facility under a Cooperative Agreement with NSF entitled Support of UNAVCO Community and Facility Activities signed in 2003. At about the same time UNAVCO and NSF signed another Cooperative Agreement giving UNAVCO responsibility for the EarthScope/PBO. Much of the management structure, the physical plant and many of the staff are new.

As of July 2005, UNAVCO had 48 members (U.S. universities) and 15 Associate Members (government institutions and foreign research organizations). UNAVCO holds an annual Members’ Meeting. The principal purpose of this meeting is to elect members of the Board of Directors and to inform members about UNAVCO activities. In the past, this meeting has been held in conjunction with the community Science Workshop discussed in the previous section. Future Members’ Meetings will be held during the December meeting of the American Geophysical Union (AGU). UNAVCO and the AGU Geodesy Section will co-sponsor a combined reception and meeting.

UNAVCO is governed by a seven member Board of Directors. Five Board positions are selected from among the Representatives of Member institutions and two positions are at-large. Board members serve two-year terms and can serve a maximum of two consecutive terms. The terms are staggered so that four positions are filled in even years and three in odd years. Under UNAVCO’s
Bylaws, the Board of Directors has overall responsibility for UNAVCO activities. The Board of Directors takes a very active role in overseeing UNAVCO. The Board meets weekly by teleconference, and convenes three times/year in person. There are five corporate officers: Chair and vice-Chair of the Board, Treasurer, Secretary and President. UNAVCO has three operational divisions, the Facility, the Plate Boundary Observatory, and Education and Outreach. These operational groups are supported by Finance, Contracts, Human Resources and Information Technology within UNAVCO headquarters. These structures are shown graphically in Figure 8.

UNAVCO activities are advised by a number of committees populated with members of the UNAVCO community. There is one standing committee for each of the three major activities of UNAVCO: the Facility, the Plate Boundary Observatory, and Education and Outreach. These standing committees are appointed by and report to the Board of Directors. There are two other Board Committees: The Membership Committee and the Audit and Finance Committee. Finally, the Members have a Members Nominating Committee that is responsible for recruiting individuals to run for the Board of Directors’ positions.

**Strategic Planning**

The UNAVCO Board of Directors and President comprise the primary long-range planning group. The UNAVCO Board takes advice from the Standing Committees for the UNAVCO Facility, Education & Outreach, and the Plate Boundary Observatory. These Standing Committees are charged with insuring that UNAVCO’s activities meet current and future objectives. UNAVCO has in place a strategic plan that provides broad guidelines for future activities at UNAVCO. The Strategic Plan identifies the following goals for the 2005-2009 time period:

**Goal 1. Provide effective support of investigations funded by NSF and NASA**

UNAVCO currently has five major commitments: Community and Facility Support from NSF/GEO/EAR/IF, Earthscope/PBO from NSF/MREFC, Existing Networks, Global GPS network support from NASA, and Arctic/Antarctic support from NSF/OPP. UNAVCO’s highest priority is the effective execution of current responsibilities under these projects. UNAVCO will: continue PBO construction, operation and maintenance; continue support of NSF-GEO-EAR investigators; continue support of the NASA Global GNSS/GPS Network; continue and enhance support of NSF-GEO-OPP investigators; assure that the data acquired for these projects are made available for current and future scientific use; and continue UNAVCO’s traditional role in instrument and technique development.

**Goal 2: Add new capabilities required to support geophysical research**

In the past UNAVCO has primarily supported GPS investigators. UNAVCO is responsible for installing strainmeters as part of the EarthScope PBO project. Also as part of the PBO project, UNAVCO is responsible for acquiring, archiving, and distributing LIDAR data. InSAR interferograms constitute a complementary data set to the GPS observations currently supported by UNAVCO. The interferograms provide detailed spatial coverage that cannot be achieved by GPS; GPS provides temporal sampling and precision that cannot be attained by InSAR. Together, the two techniques are powerful tools for observing and understanding deformation. In order to carry out the PBO project, several new activities are required: develop UNAVCO capability to support strainmeter investigations; develop UNAVCO capability to support LIDAR investigations; and investigate ways in which UNAVCO can support InSAR investigations.

**Goal 3: Expand and improve Education and Outreach (E&O)**

UNAVCO has carried out an effective Education and Outreach program through the efforts of a few key staff and community members. With the recent addition of a full-time Education and Outreach Coordinator, UNAVCO has an opportunity to build on the past Education and Outreach activities to reach a broader audience. Objectives are: increase the diversity of scientists applying geodetic techniques to solve earth science problems, thereby increasing the pool of potential geodynamic scientists; and increase the level of understanding of deformation processes among students, politicians, members of the public, and other scientists.

**Goal 4: Develop a stronger UNAVCO scientific community**

One of UNAVCO’s strengths has been community activities. The UNAVCO Annual Meeting has provided a forum for the community. UNAVCO has been a leader in testing and evaluating equipment and has facilitated group purchases of equipment. UNAVCO will seek to enhance the support it provides to the UNAVCO community by formalizing several activities that have been
conducted on an ad-hoc basis in the past: formalize a Visiting Scientist Program; formalize a Student Intern Program; formalize summer training courses; increase UNAVCO membership.

Goal 5: Develop long-term plans

Over a longer time frame UNAVCO is endeavoring to: explore options for follow-on programs to EarthScope in western North America; explore possibilities for a global PBO; and undertake broader working relationships with international scientific organizations to strengthen international collaboration.

Diversity

UNAVCO recognizes that neither the UNAVCO member community nor the UNAVCO staff adequately reflect the diversity of the population of the United States. This lack of diversity hurts our community. Members of underrepresented groups will not consider careers in our fields because of the absence of role models and the perception that geoscience is not a promising career choice. UNAVCO is attempting to address diversity issues on several fronts. The RESESS program discussed above is one approach. In addition, UNAVCO aggressively advertises all of its open positions in venues that reach a diverse audience. Openings are advertised on the “Historically Black Colleges and Universities” and “Society for Advancement of Chicanos and Native Americans in Science” web sites and in urban newspapers. UNAVCO has had moderate success in hiring women to technical positions. Women scientists and engineers occupy many senior and technical positions at UNAVCO (Education and Outreach Manager, Facility Data Group Manager, Facility Development and Testing Engineer, Facility Field Engineer, Facility Senior Data Programmer, PBO Regional Engineer, PBO Field Engineer, PBO Field Assistant, PBO Permitting Assistant). We have done less well at attracting members of underrepresented groups but it continues to be a high priority.

VI Management

Management Systems

UNAVCO, Inc. is subject to extensive NSF and OMB requirements related to financial management, cost charging, audits, government property, procurement, and subawards. UNAVCO corporate policies and procedures, training of personnel, internal audits of processes, and established controls insure compliance with the NSF and OMB requirements. In addition, PBO has a set of project-based controls (earned value system) that insure adherence to the specific project and EarthScope requirements.

UNAVCO has a complete set of written policies and procedures available on our internal website to all employees. These policies and procedures insure that UNAVCO meets all federal and state requirements as well as additional requirements placed on UNAVCO by NSF and OMB.

UNAVCO uses the project-based Microsoft Business Solutions Solomon Financial Management System. This software has been certified compliant with Generally Accepted Accounting Principles and US Government requirements, and the software provides Project Controller and Allocator modules to separately capture the detailed costs of projects by work breakdown structure and cost category. This commercial software package provides UNAVCO with a comprehensive accounting system that has been tailored to meet UNAVCO and NSF requirements. In addition, the system includes a web-based front-end that provides local and remote access by operational and financial staff. All backup documentation for transactions is scanned and available in image form through the web-based Solomon system.

UNAVCO is audited annually for compliance with NSF and OMB requirements. An external auditing firm is selected by the Audit and Finance Committee. This outside audit of UNAVCO’s finances is conducted in accordance with A-133 audit requirements for Non-Profit Corporations. The past three years the external audit has been conducted by JDS Professional Group, Inc. UNAVCO successfully passed A-133 Audits for 2002, 2003 and 2004 with no findings. The results of the A-133 Audit are reported to NSF through the central Federal Audit Clearinghouse. UNAVCO subawardees are required to certify annually that they comply with A-133 procedures. In 2005, UNAVCO’s financial management
system was also audited by the Defense Contract Audit Agency (DCAA), who approved the system, with no findings or recommendations.

The UNAVCO procurement policy describes how UNAVCO procures items in compliance with all mandated requirements. The procurement module within the Solomon Financial System is used to control and document the process from creation of the Purchase Order to receipt of purchased item. Internal controls require separation of personnel and departments responsible for the various steps of; 1) requesting a purchase, 2) approving a purchase, 3) creating a purchase order, 4) receiving the items, 5) preparing the check to vendor, 6) signing the check, and 7) mailing the check. Conflict of interest and sole source issues are properly addressed in the procurement policy and in actual implementation. Cost competition is strongly enforced and has resulted in significant savings for UNAVCO projects and indeed the overall UNAVCO community. For example, the 2003 cost competition for GPS receivers resulted in savings of more than $3.4M on UNAVCO receiver and antenna purchases. In addition, the community benefited from UNAVCO’s buying power with GPS hardware providers by being able to purchase over 240 receivers and antennas at an approximate cost savings of $10K per unit. The community buy options in the UNAVCO GPS vendor subcontracts, administered by UNAVCO, therefore resulted in an estimated savings to date for UNAVCO community members of over $2.4M, a savings to NSF programs over and above the direct savings on UNAVCO purchases for NSF programs.

UNAVCO must adhere to property management requirements established by the NSF awards, NSF Grant Policy Manual, and OMB Circular A-110. UNAVCO’s property management policy addresses all these requirements and UNAVCO has developed an equipment database (SQL [Structured Query Language] Server) to track and control all equipment. This database contains all the information fields required for government property. UNAVCO’s equipment department conducts a physical inventory every September, compares it with the UNAVCO equipment database, and submits a government property report by 15 October of every year. Internal checks and audits on the equipment and inventory system are conducted more frequently.

Other UNAVCO management policies and procedures control health and safety, participant support costs, subaward monitoring, employee related issues, etc. UNAVCO strives to keep its overhead staff and costs low to benefit the direct programs we manage. The total indirect cost rate (general and administrative) applied to projects to recover all headquarters expenses is 10.17% for calendar year 2005, 7.54% for 2006, and 8.14% for 2007.

**Plate Boundary Observatory**

While PBO is only one of the many science projects that UNAVCO supports, the level of effort required has dictated that this project be handled in a very different manner than UNAVCO’s other projects. UNAVCO has established a separate division to construct PBO. This structure has many advantages: UNAVCO can efficiently manage PBO construction with clear lines of authority and responsibility; the ongoing activities of UNAVCO in support of the science community are not adversely impacted; PBO can take advantage of Facility resources; the Facility and larger science community takes advantage of volume pricing driven by PBO quantity purchases.

**PBO Specific Controls**

In addition to being subject to the above controls that apply to all of UNAVCO activities, PBO has its own set of controls.

Budget and schedule progress on PBO is monitored using Earned Value Management (EVM). The principal tool for monitoring EVM is a Cost/Schedule Status Report System (CSSR). CSSR reports are prepared on a monthly basis for monitoring of progress. PBO is managed through a Work Breakdown Structure and a Project Execution Plan that spells out the cost, schedule and milestones for the project. Progress against the Project Execution Plan is also reported quarterly to NSF. All of these reports are part of an EarthScope-wide reporting and monitoring system and are submitted in integrated form for all of EarthScope. A formal Change Control process governs approval of all changes to EarthScope’s execution plan. The level of approval required depends on the budget and schedule impact of the change. For major changes, NSF approval is required. PBO has implemented a document and image control system to track and archive all documents related to the development of the PBO Facility. EarthScope and PBO have an extensive series of management meetings to coordinate activities. EarthScope-wide, there are two weekly teleconferences: The EarthScope Facility Executive Committee meets by telephone once a week, often with the
UNAVCO Funding

All UNAVCO activities and future plans are developed within the context of current and prospective funding. In Calendar Year 2005, UNAVCO Facility Funding (Fig. 9) comes from several sources. The core piece of the Facility funding is provided by a cooperative agreement with NSF that includes funding from NSF Instrumentation and Facilities and from NASA. Other significant sources come from a grant for PBO Nucleus (integrating existing GPS into PBO) and, beginning in 2006, from RESESS, a student intern program funded under NSF’s Opportunities for Enhancing Diversity in the Geosciences. Funding for PBO constitutes the largest single source of funding to UNAVCO.

VII Summary

Over the past 22 years, UNAVCO has built the trust and respect of scientists who have contributed to building UNAVCO for the purpose of supporting and promoting their research. UNAVCO strives to involve the community in decision making and in planning for the future of this scientific field. UNAVCO provides Tools (GPS, software, data archives) and People (science community, technical staff) that in combination are reshaping Ideas about the spatial and temporal evolution of the crust of the Earth.

Supplementary Information

The following supplementary material is available on the UNAVCO web site <http://www.unavco.org/pubs_reports/proposals/related-docs/2005-mngmt-review/2005-mngmt-review.html> and is available in hard copy form upon request.

- Strategic Plan
- Facility Annual Reports
- EarthScope Annual Reports
- Committee membership
- Facility, PBO, and E&O Standing Committee Lists and Charges
- Registrant List and Poster List from 2003, 2004, 2005 Workshops
- List of projects supported in past three years (included in annual reports)
- December 2002 Outreach Report