INTRODUCTION
This document provides a guide to the strategies and accomplishments of UNAVCO Management and Governance to ensure the efficient and effective management of the Facility on behalf of the community and sponsors. We have used the Management Review Objectives and the questions posed by NSF to structure our response. Because of the number of topics, the response relies heavily on supporting documents, specifically the companion document UNAVCO: Enabling next generation geodesy for innovation, discovery, and learning, referred to simply as the Management Overview. Additional reference documents are listed therein and are included with the provided electronic archive. Space constraints compel us to provide very high-level responses here. Deeper interest can be addressed with more detailed information later in the review process.

UNAVCO’s legacy competencies support implementation of Global Positioning System (GPS) observational capabilities to characterize Earth deformation. GPS is now just one constellation among several Global Navigation Satellite Systems (GNSS); UNAVCO continues to primarily support GPS with lesser activities in other GNSS (specifically GLONASS). Thus, in this report, we will commonly refer to GPS alone or GPS/GNSS in combination for the relevant activities.

Table 1. UNAVCO Community Toolbox

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
</tr>
<tr>
<td>InSAR</td>
<td>Interferometric Synthetic Aperture Radar</td>
</tr>
<tr>
<td>LiDAR</td>
<td>Light Detection and Ranging</td>
</tr>
<tr>
<td>TLS</td>
<td>Terrestrial Laser Scanner</td>
</tr>
<tr>
<td>ALSM</td>
<td>Airborne LiDAR Swath Mapping</td>
</tr>
<tr>
<td>Strainmeter</td>
<td>Termite and Seismometer</td>
</tr>
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</table>

Building on GPS as a core competency, UNAVCO has developed a much wider range of geodetic capabilities over the last eight years (Table 1). UNAVCO provides services to support geodetic imaging (InSAR and LiDAR), strainmeters, and other borehole geophysical observations, as well as project planning and management, and a variety of services and programs in support of broad impact.

Figure 1. 2009-2013 Strategic Plan: Positioning UNAVCO—Advancing Science through Geodesy.

UNAVCO RESPONSE TO REVIEW OBJECTIVES
Review Objective #1:
Assess the quality, effectiveness and efficiency of UNAVCO, Inc. management and leadership in meeting the Facility goals and responsibilities as set forth in the Cooperative Agreement Award Specific Programmatic Terms and Conditions and detailed in proposal EAR-0735156.

CATEGORY 1: OVERALL MISSION
1.1 FACILITY PLANNING FOR THE CORE MISSION OF TRANSFORMATIVE SCIENCE FACILITIES SUPPORT

UNAVCO relies on a formal process of strategic plan implementation to ensure effective management and leadership in meeting Facility goals on an annual basis (Section 2 Management Overview). The community- and sponsor-vetted plan provides a structure within which the board and management set priority for annual activities: through Action Planning managers at all levels and the work of the board at its January Annual Meeting. By formal tracking of the prioritized actions, staff time and governance effort is allocated to advance the plan.
The resulting facility services and activities are detailed Management Overview Section 4. These include community-responsive support to the solid Earth and Polar academic research communities including advanced instrumentation, facilities, and cyberinfrastructure. Principal activities of the UNAVCO Facility include provision of specialized geodetic field instrumentation through community equipment pools, engineering services, co-operation of the NASA global GNSS infrastructure, data and archiving services, and education and outreach support to Principal Investigator EAR, OPP, and Community projects. With Facility support, UNAVCO Community investigators study earthquake processes, mantle properties, active magmatic systems, global plate tectonics, plate boundary zone deformation, intraplate deformation, hydrology, glacial isostatic adjustment, global geodesy, global change, and Polar processes.

1.2 Facility Management for Broad Impact

In addition to the suite of services in support of academic research in geodesy, UNAVCO provides program, planning, and infrastructure for broad impact of investigator and community activities. The central role played by Education and Outreach in workforce development and public outreach is one aspect of this (see 3.1 herein; 4.3 Management Overview). Beyond the human resource focus of broad impact, geodetic infrastructure also offers great collateral benefit to society.

Geodesy, surveying and navigation are closely related and each field benefits from advances in the others. The Global Positioning System was originally developed by the U.S. Department of Defense as a real-time positioning and navigation system. Systematic investments in both geodetic science and applications expanded its benefit to science and civic sectors.

Such broad use attests to the power of this technology and seeds natural collaborations among disparate communities of users. Science applications were the early impetus for precision, accuracy, and geophysically meaningful global reference frames. Civic applications were the early drivers of requirements for low latency and high sampling rates. Large numbers of commercial users have made rapidly evolving capabilities affordable across the spectrum of users; further, science applications are sufficiently numerous to allow tailored instrument specifications affordable.

So, beyond the applications of the UNAVCO academic research community, federal agencies (NGS and USGS), civic (county and state level) and commerce (utilities, private surveyors) make use of UNAVCO software, data, data products, and engineering design and implementation. In some cases these applications directly align with UNAVCO’s core values of open data and high-precision geodesy standards; direct partnerships or coordination result. In other cases, the public investment in UNAVCO benefits others in the absence of a formal collaboration.

UNAVCO standard and high-rate GPS data are routinely requested by other stakeholders, as is LiDAR imagery. In addition civic agencies and commercial survey companies take advantage of the NSF investment in high rate, real time GPS data from permanent GPS stations. At surveyor forums, the free and open access to UNAVCO data sets is regarded as transformative to civic and commercial applications. Many UNAVCO data holdings are downloaded by other archives; for example, the California Spatial Reference Center through the SOPAC archive and the National Geodetic Survey provide secondary archives that serve NSF supported and UNAVCO acquired GPS data to the private sector. UNAVCO also provides software support to the public through programs such as TEQC, a GPS translate, edit, and quality control program. Applications for early warning of natural hazards (earthquakes, tsunamis) that rely on geodetic data streams are in the early stages of concept development.

Category 2: Administrative matters

1.3 Budgeting for an Effective and Efficient Management Structure

Management includes both the human resources and administrative structures and policies that ensure effective and efficient support to UNAVCO. Managers work at a variety of levels in the organization, both within the large programs as well as in central management by Program Support Services.
Facility Management is directly funded through the Cooperative Agreement (CA) and includes support for the Director of the Facility Program and the Project Managers. The initial core budget for Facility management activities was developed in consultation with the UNAVCO Board of Directors and the Facility Advisory Committee (FAC) and sponsors and was evaluated through peer review of the proposal. Subsequent detailed annual budgets are determined with direct interactions between management and the four primary sponsors that fund the CA. Specific program activities are guided by strategic planning, review from the advisory committees, board action, and sponsor guidance. Demands for new activities may result in supplements to the CA (e.g. Terrestrial Laser Scanning) and additional proposals (e.g. the Enhanced Polar Support proposal).

Consistent with the terms and conditions of the CA (Appendix VII Management Overview), the Facility Program Director consults with community investigators for project planning and budgets; maintaining and deploying a pool of portable geodetic research equipment; field engineering support and training; operations and maintenance of a globally distributed GPS network; development and testing; data management and archiving; project management; and overall support of Facility operations including establishing, maintaining, and reviewing staff needed to fulfill project goals. Technical managers accomplish project planning and management, fieldwork, IT, and other operational tasks identified in the CA proposal and modified in annual budget requests. Efficient and responsive management is ensured through a structure that provides focused support of sponsor programs (e.g. NSF EAR, OPP, and NASA) and well as cross-cutting technical activities (e.g. TLS, D&T and Data Center). The Facility continually strives to increase management efficiency through training and evaluation, and has eliminated a full time management position.

Centralized management and administrative activities are funded through UNAVCO’s indirect G&A costs. The Board and the Audit & Finance Committee play an oversight role in review and approval of budget (6.1.2 Management Overview). Model business practices ensure efficient, effective and compliant resource management. A reorganization of UNAVCO Program Support has optimized these services and their costs, as appropriate to changes in overall resourcing at PBO completion.

UNAVCO has been aggressive in managing to a low indirect cost rate, one that reflects a sensitive balance between administrative efficiencies and sufficient support to meet program need and compliance requirements. During the peak of PBO construction in 2007, UNAVCO’s base upon which the indirect is calculated (Modified Total Direct Costs, or MTDC) was twice the anticipated base for 2009. Using a combination of budget cuts and efficiencies [see 1.6], attracting new work that bolsters the MTDC, and more sensitive forecasting and management of the indirect rate, the awards have been protected from the threat of a doubled rate. We are currently managing to a G&A rate near 16%.

1.4 Governance by Design: Inclusive, Engaged, Responsive, and Effective

The governance structure, bylaws, policies and committee charters are tailored to ensure meaningful community representation, roles and responsibilities in UNAVCO governance. In 2010, UNAVCO filled over 50 committee positions; with broad participation of its growing membership that includes 91 institutional Members (Figure 2). Under the current award period, the UNAVCO Board has undertaken several specific initiatives to ensure the inclusiveness, engagement, and effectiveness of community governance.

![Figure 2. UNAVCO Membership by year. UNAVCO’s 91 Members and 70 Associate Members reflect a growing and engaged global community with shared purpose (see 3.1 Management Overview for diversity metrics and membership criteria).](image-url)
The 2008 strategic planning committee included 20 participants; 16 of these were drawn from the U.S. academic research community, and 4 were senior managers (Section 2 Management Overview). Over the last three years, the board and president have worked together on policies and procedures for proactively staffing and charging governance committees – including extension of committee terms to three years for better continuity of staffing; major revision of committee charters to optimize and clarify committee charges and member roles, development or revision of supporting policies like the open meeting policy, governance conflicts of interest; commissioning of a bylaws review committee. The board engages in routine professional development using a new board member orientation, and formal training following a two-year cycle of non-profit governance topics. These are salient examples among the body of work undertaken since 2008 to strengthen governance.

1.5 Managing Pooled Technology Resources

Effective and efficient management of pooled technology resources has been the heart of UNAVCO and its predecessor activities since 1984, when the prohibitive expense of GPS receivers first motivated the US academic research community to pool them. UNAVCO’s recent acquisition and management of pooled TLS instruments for broad applications mirrors this early history across the Earth and Polar sciences. A large community of investigators has access to a powerful yet expensive technology at its developmental stages. While the technology and functionality are rapidly evolving and pricing is simultaneously decreasing, the NSF investment is managed for high level expansion of science applications, instrument utilization, and efficiency not possible with individual university ownership.

UNAVCO provides researchers with a well-maintained and managed pool of state-of-the-art geodetic equipment for loan to individual NSF-funded PI projects. This includes campaign, semi-permanent, and permanent GPS systems and Terrestrial Laser Scanning (TLS) instruments. UNAVCO and its Members have acquired 2,600 GPS systems under negotiated specifications and pricing (4 Management Overview), with large data storage capacity, low power, and small physical size allowing investigators to deploy large numbers of instruments and for long periods. UNAVCO repairs ~150 systems each year. In spite of increased demand, Facility manages a state-of-the-art pool to minimum wait time with a variety of data communications innovations.

Through funding augmentations, UNAVCO has added 4.5 EAR TLS instruments to the single Polar TLS acquired in 2008. UNAVCO acquired and commissioned the 2010 TLS pool, and deployed it at high capacity while continuing to optimize management processes.

1.6 Managing UNAVCO Human Resources

Three formal planning mechanisms support continuous review and improvement of position responsibilities: (1) proposal development and budget justification, (2) personnel processes and policy, and (3) formal alignment of UNAVCO staffing with strategic purpose.

As for any proposal, development of the cooperative agreement begins with governance-informed definition of the statement of work, and the staffing and resource needs to support it. Each staff position and increment of FTE is reviewed and optimized to the proposed work and resource constraints, through evaluation of community and sponsor needs. The proposal and subsequent annual budgets detail the responsibilities, capabilities and the FTE allocation by task for each person working on the project. Indirect costs support the required administrative support. For the current CA for instance, based on the guidance of UNAVCO’s governance and careful planning with the sponsors, the Development and Testing program was established with core funding. Similarly, if activities like TLS are supplemented during the course of the award, planning follows this same process. In the end, each funded FTE increment is tightly coupled to specific tasks and outcomes.

UNAVCO Human Resources oversees the personnel processes that define and annually review position descriptions, hiring strategy and policy, and performance. UNAVCO works closely with the Mountain States Employers Council to augment the capacity and resources of its small HR
staff; for instance MSEC is currently undertaking a compensation study for UNAVCO, and supporting a senior manager team development process to enhance the effectiveness and cohesion of UNAVCO leadership. All UNAVCO managers undertake formal programs for training and professional development.

Lastly, the UNAVCO president and senior management team are accountable for review of the alignment between the community-driven strategic plan and the existing staff positions and management structure. Such review occurs positions are vacant, or more comprehensively to proactively manage staff efficacy. The completion of the strategic plan in 2008 motivated a 2009 reorganization of headquarters staff into Program Support Services (responsible for all business services) and the Executive Office (governance support and the president), resulting in significant efficiencies.

**CATEGORY 3: ASSESSMENT & IMPROVEMENT**

**1.7 SELF-ASSESSMENT AND END-USER EVALUATION**

UNAVCO uses a variety of formal means to seek end-user feedback for self-assessment. Usability surveys query each supported PI for evaluation and suggestions for service improvement. The surveys use Likert scale questions as well as narrative evaluation. The results inform program management and optimization. In addition, community member assessment is included in the annual 360° performance evaluation of directors and the president. Lastly, senior management conducts periodic self-assessment surveys that rely on feedback from middle level staff who are the front line in meeting investigator needs.

**Usability Surveys for GPS equipment and engineering support.** Over the past three years 245 Usability Surveys have been sent to supported investigators with and 51 results were received (Table 2). OPP/EAR Project Managers review these responses and implement changes to improve service.

Some of the positive responses included: “Professional staff, extremely well trained + top quality equipment, verified before each campaign + flexibility and adaptability. It would cost me a lot of money to get my own staff and equipment at that same level.”

“The effectiveness was very impressive (the equipment was in Iceland only few days after the earthquake - the facility reacted very fast and shipped off the GPS receivers within 24 hours of me contacting the facility). And the quality and understanding of needs was of very high standards.”

**Table 2. GPS Usability summary**

<table>
<thead>
<tr>
<th>GPS Usability Survey Question (n=51)</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment provided met needs &amp; expectations</td>
<td>4.6/5.0</td>
</tr>
<tr>
<td>Effectiveness of administrative support</td>
<td>4.7/5.0</td>
</tr>
<tr>
<td>Cost effectiveness of UNAVCO support</td>
<td>4.8/5.0</td>
</tr>
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</table>

**Constructive Criticism and UNAVCO response:** “We had a serious problem with the equipment shipment to Ethiopia and it appears that the shipping agent on the US side was not doing his job. In the end the [UNAVCO] FE had to spend a lot of time and effort trying to locate the shipment and have it sent to the right destination. I would suggest using a different shipping in the future, but I heard that UNAVCO has already made that decision...!”

Response: UNAVCO implemented a shipping tracking system and replaced its previous shipping agent. Tracking is now routinely updated and distributed by UNAVCO; without reliance on the shipping agent.

**Usability Surveys for TLS.** TLS Support is a recent development at UNAVCO. In 2010, the TLS pool grew from 1 to 5.5 instruments (one is formally shared with a university MRI partner). Early user feedback to date consistently rates project planning and data acquisition support as excellent, while noting the need for improvement in data processing support – a need that will be addressed through the INTERFACE collaboration. Both the positive feedback and constructive critique inform improvements to management.

**Data Center Usability Surveys.** Project managers also formally solicit feedback from investigators who submit data for archiving, with generally positive feedback. One respon-
dent requested monthly e-mailed reports of volume of data archived for the month. The data center established a dynamically generated web page that allows the investigator to track the same information for his network at any time.

Most data are accessed anonymously. For users accessing data from the archive using the request mechanism, accounting for a tiny but important class of data access, survey forms are used to gather feedback. Most feedback comes from the web user feedback form for the Data Archive Interface users. This mechanism allows us to track bug reports, enhancement requests, and questions about how to use the interface. Over the past 18 months we received 34 user feedback requests including 13 enhancement requests, 16 bug or data problem reports, and 5 questions on how to use the DAIv2. In response to questions received, we created web video tutorials and a glossary accessible from within the Help tab within the application. Bug reports are investigated and the reporter is given a workaround if possible while the problem is fixed. Enhancement requests are entered into a queue of possible enhancements that will guide future planning.

1.8 Improvements to GPS Data Delivery for a Broadening Science Community

UNAVCO strives to continuously improve upon the quality, timeliness and cost-effectiveness of GPS data collection by a broadening science community. One measure of the community is the diversity of science interests represented at the 2010 UNAVCO Science Workshop (Table 3).

<table>
<thead>
<tr>
<th>UNAVCO Science Workshop 2010:</th>
<th>129 participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 countries</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. 2010 Science Workshop Interests

Quality & metrics. Many factors ultimately affect the quality of GPS/GNSS data ranging from receiver tracking performance to continuity of data supplied to the end user. UNAVCO has used its deep understanding of the fundamental data observables and excellent relationship with vendors to develop and support the TEQC 9,463 translation, editing and quality checking program that is widely used around the world to assess the quality of receiver data (Table 4). TEQC is used to generate data completeness, signal-to-noise, multipath and other QC parameters that are easily accessed through the archive Data Access Interface (DAI). Receiver, antenna, and communications systems continually evolve and UNAVCO’s Development and Testing team has been involved in the ongoing evaluation of GPS hardware and receiver firmware releases to ensure that field observations will be of high quality. Effects of hydrologic signals, equipment failures, radio frequency interference and multipath on data and position quality are all the subject of active investigations by UNAVCO staff and will help the community understand sources of noise and other influences on affecting data quality.

The widespread proliferation of continuous GPS networks has rapidly advanced the critical evaluation of data and position quality allowing for the identification of longer-term systematic errors. The large number of state-of-the-art permanent GPS stations is due both to NSF-EAR investment in EarthScope-PBO (1,100 CGPS) and other network, as well as the low UNAVCO price structure (resulting in acquisition of an additional 1500 receivers on other projects). These discounts have also allowed the UNAVCO Facility and UNAVCO Members to continuously modernize the pool of GNSS hardware.

<table>
<thead>
<tr>
<th>Year</th>
<th>TEQC Downloads</th>
</tr>
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<tbody>
<tr>
<td>2007</td>
<td>5,801</td>
</tr>
<tr>
<td>2008</td>
<td>7,942</td>
</tr>
<tr>
<td>2009</td>
<td>8,623</td>
</tr>
<tr>
<td>2010</td>
<td>9,463</td>
</tr>
</tbody>
</table>

Timeliness & metrics. UNAVCO has continued to improve upon the timeliness of data delivery with a suite of communication and download strategies while refining data handling
procedures and access tools, as attested to by the dramatic increase in connected, continuously operating GPS stations. At UNAVCO, Inc. inception in 2003, only 270 stations provided automated daily and hourly downloads. By the end of 2007, over 1,200 stations provided hourly, daily and real-time data. Today – at the end of 2010 – there are 25 half-hourly, 200 hourly, 1,400 daily and 250 real-time streaming stations serving a range of science and hazards science requirements; some are used for surveying applications as a collateral benefit. UNAVCO proactively built the capability to handle data load in a scalable and continuously improving data management system (Figure 3).

Figure 3. Daily File Recovery. The scalable data management system proactively accommodated the rapid increase in PBO stations over the last 6 years (excludes Nucleus). (right) Most PBO stations have latencies of less than two hours; with steady improvement towards <1 hour as refinements in data handling take hold.

Latency requirements correspond to the download interval. For example, daily downloads are needed within a day to allow for streamlined, automated daily processing in typical geodetic applications (Figure 3, 4). Shorter data intervals are needed with lesser latency as for meteorological applications at 60 or 30 minutes (or less). 2-second or better latency is the goal for real-time high rate (1Hz) data for special science applications, surveying, and navigation (Figure 5).

Cost effectiveness & metrics. The number of data files ultimately archived and delivered to the user community by the UNAVCO Data Center is a key long-term measure of the productivity of the UNAVCO Facility and its investigator community. Comparison of the data volume archived and managed to the FTE supporting archive activity measures this effectiveness (Figure 6). The total FTE working on the GNSS archiving tasks grew by a factor of 1.5 from 4.4 in 2004 to 6.5 in 2010. During that same time period, the number of files archived each year grew.

Figure 4. Daily File Data Latency. Most PBO daily files are archived with latency less than two hours; a comparison of 2008 and 2010 shows steady improvement (towards <1 hour) as refinements in data handling take hold.

Figure 5. Streaming Data Latency. To achieve lower latency with real-time data requires improved communications. UNAVCO communications upgrades for Cascadia PBO stations demonstrate improvement from 3 to 0.6 seconds by replacement of VSAT to 3G Cellular.
by a factor of 4.6 (from 160 thousand to 730 thousand). The number of files delivered grew by a factor of 28.7 (from 1.3 million to 36.5 million files). This efficiency has been achieved through the development and implementation of a scalable data management and archiving system that undergoes continual assessment and enhancement.

Figure 6. Archive Efficiency. Comparison of archive effort (FTE) with data throughput (archived and delivered to the user community), using a baseline of 2004 shows increased efficiency and robust scalability.

**Category 4: Compliance**

### 1.9 Fiscal Monitoring

UNAVCO keeps NSF and Program Officers apprised of financial performance relative to the all grants and contracts through two fundamental tools. First is the annual budget request, a refinement of the original five-year proposal budget that is submitted annually, which outlines the planned scope and spending for the coming year. Performance relative to that annual plan is reported at the end of the fiscal year with any significant variances explained. During the performance period, when questions of spending priorities or conflicts arise, UNAVCO collaborates with the program officer and develops mutually agreeable plans. The second reporting mechanism is the formal reporting of annual audited financial statements and quarterly FFR submissions. FFR reports show that grant funds are being expended with timelines and in the amounts agreed upon on a grant-by-grant basis.

This accountability is supported by a project accounting system that is interfaced with the financial accounting for UNAVCO. Under current procedures, all UNAVCO expenditures have documented rationale for necessity of expenditure. Increasing expenditure thresholds require increasing level of documentation, justification, cost analysis, and approval to ensure due diligence. Project managers have access to a variety of detailed and summary reports that allow them to review all transactions charged to the award for accuracy and completeness.

A documented process to monitor all terms and conditions of UNAVCO awards is under development. The process is in development and expected to be completely operational in 2011. This will further support historically strong financial compliance and ensure all terms and conditions receive the same level of oversight and scrutiny.

### 1.10 Informing the Sponsor

Using a variety of formal and informal methods, UNAVCO communicates closely with its sponsors. Because of the number of sponsors that support the community and facility CA, robust communication is essential. In particular, quarterly and annual reporting of a well-defined and standardized set of performance metrics for the CA is in place. This formal reporting is supplemented with weekly and commonly daily interactions between the sponsor and UNAVCO staff – the Director, President, and other project managers as appropriate.

For each sponsor that contributes core funding to the community, Facility, and PBO cooperative agreements (EAR – I&F, NSF OPP Arctic and Antarctic, NASA, and EAR – EarthScope), there is a point of accountability within the UNAVCO management structure. This supports a deeper dimension of communication and coordination than is possible through the formal reporting mechanisms. Beyond informing the sponsor, this also supports collaborative planning and problem solving around the technical and resource challenges presented by investigator needs and project requirements, or in the formative stages of proposal development.

Other forms of communication include the detailed budgets and justifications in the CA proposal and annual plan with budget request, that are typically developed in close consultation the individual sponsors. To help provide transpar-
ency into this complex funding profile, the Facility developed a Work Breakdown Structure and corresponding set of performance metrics that were vetted by the Facility Advisory Committee. This WBS is implemented into the UNAVCO Microsoft Dynamics accounting system. Facility performance metrics are presented in detail in the semi-annual and annual reports that are submitted to NSF via Fastlane, are openly available on the UNAVCO website, and are routinely reviewed by the FAC and the Board to advise governance. UNAVCO also provides an annual expenditure report that compares actual expenditures by cost category to budgeted amounts approved in the previous year's Annual Plan and Budget. UNAVCO has met in timely fashion all of its reporting requirements. As per the terms and conditions of the CA, in some cases specific additional sponsor engagement is necessitated. For example before a new station is added to the Facility O&M list a form is completed with justification and potential impact to Facility resources and loaded into the Facility Project Management Database. An email is automatically sent to the EAR cognizant program officer for his approval and his response logged into the system before action is taken.

**CATEGORY 5: COMMUNICATION**

**1.11 INFORMING THE COMMUNITY**

Informing to the community similarly takes a variety of forms, from routine postings of emerging issues, opportunities, and events on the UNAVCO Community email list service; a wealth of programmatic, technical, and community information available through the UNAVCO web site; booth, short course, workshop activities; to UNAVCO staff leading or participating in technical sessions that showcase Facility capabilities to the academic research user community in both national and international professional venues. At each weekly staff meeting, Senior Managers review needed communications to community, sponsors and staff, and develops a dissemination plan.

The UNAVCO Education and Outreach portfolio includes short courses and workshops, in-residence programs for undergraduate interns, educators and community members, materials and programs for teachers, and ongoing out-reach to the Earth sciences community through events and information technology. The events and activities within that portfolio engage the full range of UNAVCO staff, many external partners, and a broad range of print, web and social media technologies. Community participation in workshops and short courses has increased substantially (e.g. CSF Table 6.1) and requests for repeat or new workshops exceed schedule and resource availability. UNAVCO staff ensure the publication of technology reviews (EOS – Geodesy Applications) and of geodesy science planning.

**1.12 COMMUNITY OUTREACH AND EDUCATION**

UNAVCO EO staff members engage teachers, university faculty, community members, and other education professionals through professional development workshops, short courses, seminars and conference sessions throughout a given year. These courses and workshops include the biennial UNAVCO Science Workshop, courses and workshops focused on particular geodetic technologies or specific regional programs (e.g Polar technology or the US-Africa Array), and ongoing workshops covering processing software, data access, or basic geodesy (Appendix II Management Overview).

UNAVCO hosts and manages the flagship geoscience summer internship program RESESS: Research Experience for Solid Earth Science Students. RESESS specifically addresses the goal of increasing diversity in the geosciences as well as a more general goal of increasing the perceived relevance of geosciences among broad and diverse segments of the population. The EO effort at UNAVCO includes web sites, kiosk displays, and a UNAVCO presence at national and international conferences. UNAVCO EO applies a variety of assessment tools and continually revises and restructures its materials, services and events in response to evaluation and feedback information. Although small, the UNAVCO EO team broadens its reach and amplifies its impact through partnerships with research, education and outreach partners throughout the UNAVCO community. The EO cumulative impact since 2008 easily reaches into the hundreds of teachers, scientists, faculty, and other participants.
The mission-critical UNAVCO EO Program was established in 2004, at a time that no direct funding stream was available to support it. Because of the benefit of the fledgling program to all of UNAVCO’s awards and activities, the program leadership and most of the staffing and programmatic costs have been funded through indirect G&A costs. Work specific to particular awards has been direct funded as appropriate. The advantage of this funding model is that all awards to UNAVCO contribute to the available EOrsource base. One disadvantage of this funding model is that EO program activities and core support are vulnerable to funding volatility like the downturn in MTDC that occurred when PBO construction was complete; another is that EO does not equitably enjoy the programmatic mandate of direct funding. In its planning for the proposal for a 2013 Cooperative Agreement, UNAVCO intends a full review of the appropriateness, strengths and weaknesses of various funding models in light of the goals, activities, success, and growth of the program.

Review Objective #2:
Evaluate the contributions of Facility management towards addressing NSF’s Strategic Plan (NSF 06-48) vision ...“Advancing discovery, innovation and education beyond the frontiers of current knowledge, and empowering future generations in science and engineering” and the Strategic Outcome Goals of Discovery, Learning, Research Infrastructure and Stewardship.

2.1 Strategic vision for UNAVCO Facility services and the NSF Strategic Plan

At the onset of the current Cooperative Agreement in 2008 and guided by a new president, the UNAVCO Board of Directors and other key members of the UNAVCO governance, community, and senior management developed a plan to guide strategic direction and ongoing resource allocation for facility management in support of NSF priorities (2 Management Overview). The planning process carefully structured the engagement of the science community, sponsors, and other UNAVCO stakeholders. This plan guides annual priorities for UNAVCO staff and governance, ensuring that core Facility services and responsibilities support the NSF Strategic Plan.

UNAVCO’s Mission, Vision and their implementation directly support the NSF Vision: Advancing discovery, innovation and education beyond the frontiers of current knowledge, and empowering future generations in science and engineering (full vision in Strategic Plan).

Table 5. Positioning UNAVCO: Advancing Geodesy

<table>
<thead>
<tr>
<th>UNAVCO Strategy #1. Community</th>
<th>Continue to build the UNAVCO scientific community that uses geodesy by further developing core strengths in solid Earth science, while responding to emerging community needs and enhancing UNAVCO’s visibility at home and abroad</th>
</tr>
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<tbody>
<tr>
<td>UNAVCO Strategy #2. Scientific Diversity</td>
<td>Support expanded use of geodesy and integration of new communities across science disciplines (Table 3).</td>
</tr>
<tr>
<td>UNAVCO Strategy #3. Support Services</td>
<td>Provide effective and efficient support to the scientific community – through community planning, equipment acquisition and sharing, engineering and data services, and education and outreach activities</td>
</tr>
<tr>
<td>UNAVCO Strategy #4. Technology</td>
<td>Support innovative application of existing and novel technologies for the investigator community in funded science projects, education, and outreach</td>
</tr>
<tr>
<td>UNAVCO Strategy #5. Resources</td>
<td>Diversify the resource base in support of the science community</td>
</tr>
<tr>
<td>UNAVCO Strategy #6. Leadership</td>
<td>Continuously improve the leadership role and effectiveness of UNAVCO management and governance to support future growth</td>
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</tbody>
</table>

UNAVCO strategic goals specifically align with those of NSF:
NSF Strategic Goals and UNAVCO Strategies

NSF Goal #1: Discovery
Foster research that will advance the frontiers of knowledge, emphasizing areas of greatest opportunity and potential benefit and establishing the nation as a global leader in fundamental and transformational science and engineering.

- UNAVCO Strategies #1 & 2 (Table 5).
UNAVCO’s mission, vision, and foundational goals all speak directly to the advancement of transformative science and education, within the purview of the National Earth Science Geodetic Facility.

NSF Goal #2: Learning
Cultivate a world-class, broadly inclusive science and engineering workforce, and expand the scientific literacy of all citizens.

- UNAVCO Strategies #1-6 (Table 5).
The UNAVCO strategic plan deliberately and deeply integrates education and research in its mission, vision, and strategies. Each of the six strategies drives specific actions that support of broadening and strengthening the science and education community and workforce, and returning the benefit of UNAVCO undertakings to all citizens. RESESS, the model diversity student internship program, is a preeminent example of this integration.

NSF Goal #3: Research Infrastructure
Build the nation’s research capability through critical investments in advanced instrumentation, facilities, cyberinfrastructure and experimental tools.

- UNAVCO Strategies #3 & #4 (Table 5)
As an NSF–EAR Facility, through contributions to both research and cyber infrastructure as articulated in the strategies for Support Services and Technology for research, UNAVCO’s goals directly align with NSF Goal 3.

NSF Goal #4: Stewardship
Support excellence in science and engineering research and education through a capable and responsive organization.

- UNAVCO Strategies #5 & 6 (Table 5).
UNAVCO’s strategies for Resources and Leadership align with this NSF Goal.

In summary, UNAVCO’s vision is closely complementary to that of its core sponsor; UNAVCO strategies closely align with and support the sponsor goals.

Review Objective #3
Evaluate UNAVCO core Facility management evolution in response to the recently released GEO Vision Report (October 2009) and Challenges:

3.1 Strategic Vision for the Facility and E&O and their Relationship to GEO Vision
UNAVCO’s Strategic Plan directly supports NSF’s GEO Vision and the three challenges it presents. As with the NSF Strategic Plan, UNAVCO strategies and be directly mapped to each of the three challenges:

GEO Challenge 1: Understanding and forecasting the behavior of a complex and evolving Earth system

- Supported by the UNAVCO Vision and all six Strategies (Table 5)
- Supported by E&O Goals 1 & 2 (Table 6)

Table 6. UNAVCO E&O Strategic Goals

| E&O Goal #1: | Increase the understanding and public appreciation of geodynamics and Earth deformation processes and their relevance to society. |
| E&O Goal #2: | Broaden the use of UNAVCO data and products by a wide audience of educational and research users. |
| E&O Goal #3: | Increase the diversity and broader participation in geoscience education and research. |
| E&O Goal #4: | Build a sustainable community of UNAVCO scientists and educators engaged in education and outreach. |
| E&O Goal #5: | Collaborate with other organizations to provide systemic impact on geoscience education. |

Over the last five years, UNAVCO has experienced a renaissance driven by the diversification of its community and supported geodetic technologies. Part of this is the return on the Earth-
Scope investment: UNAVCO developed capabilities in construction of large autonomous GPS/GNSS networks, strainmeters and other borehole observational capabilities, geodetic imaging, and large project management acumen. This diversification has also been supported by community, sponsor, and facility initiatives that have expanded both legacy and EarthScope capabilities: the Data Center enhancements advance data mining and seamless access to GPS data, full integration of Polar services and development of autonomous observational capabilities in extreme environments, the WInSAR consortium selected UNAVCO as its umbrella organization, NSF invested in TLS (terrestrial lidar scanning) equipment pool and engineering support. The UNAVCO Education and Outreach program developed workshops and short courses to assist current and new users of these technologies, and incorporates these topics into public and educational materials to increase public understanding and appreciation of these applications and to expose the technologies to a widening audience of research users.

These enhancements have poised UNAVCO to serve an increasingly broad set of GEO disciplines.

GEO Challenge 2: Reducing vulnerability and sustaining life

Supported by the UNAVCO Vision and Strategies 1, 2, 3 & 4 (Table 5)
Supported by E&O Goals 1, 2 & 5 (Table 6)

UNAVCO’s Vision statement includes an explicit commitment “to investigate the processes that control natural hazards, including earthquakes, tsunamis, volcanic eruptions, and long term changes in climate, ice mass, global sea level, and coastal subsidence.” The perception of barriers between “pure science” and its applications have hampered some Earth science disciplines from fully embracing integration. The UNAVCO vision is deliberate in recognizing the intrinsic merit and broad impact of advancements in hazards science, and in committing the organization to their pursuit:

“UNAVCO commits its energies and resources to achieving these ends in three areas. We will support integrative scientific studies that link kinematics to dynamics, process-based science, and hazards, through the collection and stewardship of long-term geodetic observations. We will establish new collaborations with communities that use geodesy to understand the changing Earth. Further, we will support the development of a new generation of scientists to sustain this work and to return the scientific benefits to society through Education and Outreach.”

Supporting initiatives include strengthening of Event Response capabilities and protocols supporting investigation of four significant earthquakes in 2010; and development of the COCONet proposal, with a focus on plate boundary interaction and deformation, and earthquake cycle processes. It will also address atmospheric hazards with precise estimates of tropospheric water vapor to improve forecast of the dynamics of airborne moisture associated with the yearly Caribbean hurricane cycle. Open data design will strengthen broad impact and serendipity, with commensurate societal benefits and capacity building. Education and Outreach focuses on increasing public awareness of the societal relevance of UNAVCO investigator research, on broadening the research and educational audiences for geodetic information, and on building a community of science and educators engaged in effective education and outreach on hazards and vulnerabilities.

GEO Challenge 3: Growing the geosciences workforce of the future

Supported by the UNAVCO Vision and Strategies 1, 2, 3 & 4 (Table 5)
Supported by E&O Goals 3, 4 & 5 (Table 6)

The high impact, multi-year internship RESESS program is the most salient example of UNAVCO support for this GEO challenge. But many other UNAVCO activities directly support it. The UNAVCO short course series is particularly effective in equipping investigators and students with data analysis tools and other capabilities related to the suite of UNAVCO geodetic technologies. Science planning workshops also fulfill this goal, and differentially recruit early career and student participants. UNAVCO cooperation with federal and non-governmental
geoscience education partners contributes to a larger effort to increasing the perceived relevance of geosciences among broad and diverse segments of the population.

Review Objective #4: Review and assess the leadership of UNAVCO, Inc. in managing the National Earth Sciences Geodetic Support Facility to support the next generation of geodetic technology enabled research.

4.1 Leading Change for Future Applications

UNAVCO leadership tailors a number of activities to anticipate and shape opportunities for future enhancements and additions to the global constellation of GNSS. These include the professional contributions to international planning efforts such as those of IGS and other global organizations, as well as the focused efforts of UNAVCO Development and Testing.

On recommendation of the Facility Advisory Committee and in close collaboration with the sponsor, UNAVCO Facility established a nascent Development and Testing effort focused on evaluation of next-generation GNSS hardware. New multi-constellation receivers and broadband antennas are tested and rated for their ability to maintain legacy GPS observations while adding new observables, and without disrupting long-standing position time-series. Integral to this effort has been the modification of “TEQC” to handle new observables such as GPS L2C in ways that are compatible with existing data-flow and pre-processing routines. TEQC now contains well-defined logic to handle the dual L2 carrier phase observations when L2C is being tracked in modern receivers, and can translate all observations from all currently available GNSS receivers and constellations. With this capability, and newly acquired processing expertise, detailed analyses of new signals and their impacts on geoscience applications are underway. One goal of this study is that PBO can implement L2C tracking network-wide without impact on its existing time-series. The UNAVCO-operated NASA GGN has also implemented a large-scale hardware upgrade to allow L2C tracking at a large number of its stations (4.1.3 Management Overview).

The new generation of multi-constellation hardware uses a GNSS antenna design with a wider frequency band than previous GPS-only antennas. UNAVCO D&T has discovered that this design is much more susceptible to out-of-band radio frequency interference, such as that generated by the Iridium satellite communications system in widespread use at Polar GPS stations. Recently initiated detailed analyses of interference will support development of mitigation strategies.

The UNAVCO Facility also maintains high-level contacts with the GNSS community and manufacturers, in order to ensure participation in the GNSS modernization process. UNAVCO representatives serve on the IGS Infrastructure Committee and Antenna Working Group. The D&T Manager has worked closely with hardware manufacturer technical contacts on the development of new receiver firmware, hardware, and software. We are in communication with the GPS Control Wing of the U.S. Air Force, to keep abreast of GPS satellite deployment plans.

UNAVCO participates in development of the NASA Next Generation Geodetic Network, whose aim is to collocate observation stations using four techniques: GPS, SLR, DORIS, and VLBI. A critical goal is to determine sub-millimeter level ties between the four techniques at each site. For NASA, UNAVCO organized a workshop at Goddard SFC in 2007, to evaluate use of Terrestrial Laser Scanners for this application; further investigations are ongoing.

Also at the forefront of geodetic technology is the use of high-rate, low latency GPS data for ground-motion and atmospheric monitoring for warning systems and GPS seismology. UNAVCO D&T collaborated with an investigator on the use of outdoor shaketables to assess the accuracy of high-rate GPS positioning during simulated earthquakes. UNAVCO PBO has implemented real-time 1 Hz GPS streaming at hundreds of stations, using the open source nTrip system through primarily cellular data links and commercial software for quality monitoring.
4.2 Geodetic Infrastructure Development Planning

UNAVCO proactively plans for development of geodetic infrastructure to support community science goals through a variety of formal mechanisms.

The most comprehensive efforts are undertaken at a national and international scale, such as the workshop for a development of the plan Grand Challenges in Geodesy for the 21st Century, provision of nominations and formal reports to for the NRC Committee on Seismology and Geodynamics study on Global Geodetic Infrastructure, and the deep community involvement in developing UNAVCO’s Strategic Plan, as well as numerous topical workshops (Geo-Cybereducation, Africa Array, Polar Technology Conference, and Mexico; Appendix II Management Overview). The USGS held its first USGS Geodesy Workshop in Boulder in conjunction with the 2010 UNAVCO Science Workshop.

Secondly, UNAVCO also provides infrastructure planning through community and UNAVCO proposal processes. Successes in this arena include MRI awards for development of Polar networks, for expansion of TLS capabilities for NSF-EAR investigations, and for Africa Array. In addition, major awards have furthered support of TLS; real-time, high-rate data stream upgrades to PBO in Cascadia; and COCONet, a Continuously Operating Caribbean GPS Observational Network. Project-specific enhancements to geodetic infrastructure through RAPID awards support hazards science goals. Other small awards to develop a specific capability such as LiDAR workflow planning in anticipation of IceSAT II and the DESDynI mission, web services enhancements to the Data Archive Interface to expand its data mining capabilities, or NOAA supported augmentations of meteorological observations at PBO stations.

Thirdly, UNAVCO Development and Testing, discussed at length in 4.1, supports its history of success in anticipating and planning for changing technology. Some changes pose significant opportunity for expanded capabilities in support of transformative science; other changes threaten existing capabilities with the aging and erosion of global geodetic infrastructure and planned changes in GPS constellation capabilities that may drive infrastructure obsolescence.

4.3 Sponsor Partnerships

UNAVCO’s success critically depends on the relationships with and among its sponsors. UNAVCO’s core sponsor is NSF. The NSF – EAR Instrumentation and Facilities Program coordinates contributions to the Cooperative Agreement budgets on behalf of the EAR, the Arctic and Antarctic Programs in OPP, NASA, USGS, and other sources of opportunity. Contingent on the success of this review, NSF – EAR has announced its plan to integrate EarthScope funding with these other sources into a single overarching cooperative agreement for 2013.

UNAVCO develops proposals, annual plans, and budgets to support the partnerships that the NSF EAR I&F Program leads. Recent augmentations that involved sponsors beyond EAR include Africa Array, NASA ROSES support for a 21st Century Seamless Archive, and multi-agency support of WInSAR activities. Appendix VI (Management Overview) lists UNAVCO awards since inception.

4.4 Partnerships for International Collaboration, Data Sharing, and Infrastructure Development

UNAVCO aspires to international recognition as a model for geodesy collaboration and open data archiving (see inset, 4.1.6 Management Overview). This aspect of the UNAVCO vision has been advanced by numerous strategic initiatives during the current award period.

Through the overseas projects of the science community and through its international Associate Membership, UNAVCO has global reach. A spectrum of strategic objectives support expanded international activities. These include international collaborations for development and operation of state-of-the-art global geodetic infrastructure and EarthScope capabilities, advanced through planning activities and workshops like the U.S.–Africa Array, Polar Technology Conference, Toward a Unified GPS Network in Mexico, Workshop & Science Planning for the Evaluation, Monitoring and Communication of Volcanic and Seismic Hazards in East
Africa, the planned COCONet Workshop: Community Science, Station Siting, and Capacity Building.

These goals are further realized through funding of projects like Africa Array, COCONet, RAPID awards for Mexico and Chile event response, the Group on Earth Observations SuperSites, and the Polar Networks MRI. With NASA support, UNAVCO and its international collaborators partner on support for the Global GNSS Network that provides global data sets and data products that are critical to establishing the reference frame that enables high precision GPS applications. UNAVCO also supports activities of the IGS – the International GNSS Service.

UNAVCO staff participate in important international meetings including the EGU, the Meeting of the Americas, participation in international governing board such as EPOS, IAG-IGS advisory committees, and the WEGENER working group that focuses on circum-Mediterranean GPS observations for geophysics.

UNAVCO has formally endorsed two – as yet unsuccessful – proposals from the WEGENER governing board to the EU to establish an archive modeled on UNAVCO’s accessibility standards; these efforts will continue and eventually take hold. UNAVCO members are vocal advocates of open data in international venues.

UNAVCO has proactively advanced its goals of increased visibility within the international community to support and seed collaboration and the development of global data sets, to support European efforts to establish an archive modeled on UNAVCO, and to explore formal relationships that create a point of entry at UNAVCO for international data sets.

SUMMARY AND CONCLUSION

UNAVCO management and governance uses a formal, community- and sponsor-vetted strategic planning and implementation process to ensure stewardship of its public funding, and the effective and efficient provision of geodetic support to the academic research community. We are mid-course on a five-year strategic plan; it is time to assess both the activities that the plan guides and its continuing relevance. It is also timely to review the alignment of the strategic plan with planned changes in the period of future core funding.

NSF EAR has announced its plan to bring the UNAVCO and PBO awards into alignment under a single cooperative agreement effective October 2013, leaving a 9-month gap in Facility funding to be addressed.

Extraordinary opportunity has been extended to the UNAVCO community in the last two years: real-time augmentations to PBO in the Cascadia region, funding for acquisition and support for a TLS equipment pool that will vastly diversify the geoscience disciplines we serve, awards for new continuous GPS networks in the Caribbean and Africa, a dramatic increase in Polar investigations that build on IPY infrastructure, a Track 2 award from NSF GEO-OEDG for the extension and expansion of UNAVCO’s RESESSS program. These successes have rapidly advanced UNAVCO’s community goals. While our strategic goals are still fresh and little changed, it is time for the community to formally revisit those goals and the initiatives that advance them in light of these successes, in order to focus near-term plans and resources. Towards that end, in 2011, UNAVCO governance and management intends to refresh the strategic plan in light of progress and the feedback from this review, and in recognition of likely changes in federal fiscal constraints. This work will optimize our efforts in development of the proposal for a follow-on cooperative agreement for UNAVCO Facility support.

Thus, in the winter of 2011, UNAVCO staff and the board will again use the current strategic plan to set annual priorities. In the spring, UNAVCO governance and senior managers will review and refresh the goals and supporting activities to advise direction and planning for the following two years. This will support planning and proposal development for the 2013 CA, and bring the planning and funding cycles into better alignment.