Collaborative Research:

EarthScope: Facility Operations and Maintenance

From

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EarthScope:
Facility Operations and Maintenance
Project Summary

EarthScope is a scientific infrastructure initiative for new observational facilities that will address fundamental questions about the evolution of continents and the processes responsible for earthquakes and volcanic eruptions. The integrated observing systems that will comprise the EarthScope Observatory capitalize on recent developments in sensor technology and communications to provide Earth scientists with synoptic and high-resolution data derived from a variety of geophysical sensors. All data from the EarthScope Observatory will be openly available in real-time to maximize participation from the scientific community and to provide on-going educational outreach to students and the public.

The **intellectual merit** of EarthScope is derived from the coincidence of technological opportunity and scientific discovery. The design and implementation of the EarthScope Observatory has been shaped with input from a broad sector of the academic research community. Through a series of workshops and working groups, the research community, along with federal and state partners, has defined the tools they require to take the next steps in exploration of the fundamental processes that shape the structure and influence the deformation of continents.

The **broader impacts** of EarthScope will be achieved through applications in hazard assessment and resource management and through direct linkages with the EarthScope education and outreach program. While EarthScope is a national program, it will be installed and operated at a local level through interactions with literally hundreds of universities, schools and organizations across the nation. EarthScope will serve as a tool for communicating both scientific understanding, and perhaps as importantly, the nature of the scientific method. As EarthScope observatories are installed across the US, students and the public will be introduced to scientific questions and the role that their region plays in understanding the North American continent. Improved understanding of the natural environment is the first step towards improved land use, environmentally-sound development, and resiliency to natural hazards. The broad participation that is necessary for EarthScope to operate will provide clear pathways for underrepresented groups, especially in rural areas, to participate directly in a national experiment. Educational portals for EarthScope data will allow under-resourced schools to have equal access to state-of-the-art science and scientific infrastructure. EarthScope will provide a much-needed opportunity for students and the public to observe geological processes in real-time and to measure geological deformation within the time frame of an academic school year. EarthScope will provide the public with practical examples of how science advances as they see new data being collected and watch new theories being formulated and tested.

This proposal to the NSF R&RA account is being submitted in parallel with the MREFC proposal entitled "EarthScope: Acquisition, Construction, and Facility Management".

1. Collaborative Research: EarthScope Facility Operation and Maintenance

EarthScope is a multidisciplinary observing system designed to study the structure, evolution and dynamics of North America. The EarthScope Observatory consists of coordinated arrays of seismometers (USArray) and geodetic instruments (Plate Boundary Observatory) and a deep borehole observatory (SAFOD) drilled through the San Andreas Fault.

A proposal to establish the EarthScope Observatory - "EarthScope; Acquisition, Construction and Facility Management" – has been directed to the NSF Major Research Equipment and Facility Construction (MREFC) Account. This will be referred to in the following as "***EarthScope MREFC Proposal***". As the EarthScope Observatory is created, operational costs will be transitioned from the MREFC account to the Research and Related Activities (R&RA) account. Separate proposals are being submitted to NSF for the installation of EarthScope under the MREFC account, and operations and maintenance from the R&RA account. This proposal, therefore, is a complement to the MREFC proposal and is for support of operation of the PBO and USArray components of the EarthScope Observatory. It will be referred to in the following as the "***EarthScope O&M Proposal***".

The *EarthScope MREFC Proposal* describes the purpose and structure of the EarthScope Observatory and includes detailed descriptions and budget overviews for the construction of each of the facility components (USArray, PBO and SAFOD). The reviewer is directed to that proposal for the full project description, as the material is not repeated here. This proposal focuses on only those activities that relate to operation and maintenance of the facilities. The time period covered by this proposal is the first five years of EarthScope (2003 – 2008) in parallel with the *MREFC Proposal.* Estimates are also provided for out-year costs (2008-20013), following completion of the MREFC construction.

It should be noted that no separate proposal for expenses associated with the Operations and Maintenance of the SAFOD facility is being submitted for Years 1-5. As described in the *EarthScope MREFC Proposal*, SAFOD is being developed in distinct drilling stages which are closely integrated with phases of instrument deployment over the five-year period of this request; thus O&M costs for Years 1-5 are built into the SAFOD component of the *EarthScope MREFC Proposal.*

This collaborative proposal from IRIS and UNAVCO is for the Operation and Maintenance of the USArray and PBO components of the EarthScope Observatory.

2. Plate Boundary Observatory

2.1. Summary

The Plate Boundary Observatory (PBO) component of EarthScope is 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. When completed the facility will consist of a permanently installed backbone network of 120 Global Positioning System (GPS) stations, 775 permanent GPS stations focused on specific volcanic and tectonic targets, 175 borehole strainmeters, and five laser strainmeters. Other equipment purchased for PBO include a pool of 100 portable (campaign) GPS receivers for temporary deployment and rapid response activities. The permanently installed and portable instruments will generate data, which will feed data processing centers, which in turn will produce data products. Effectively, PBO as a major component of the EarthScope Observatory takes raw sensor data as an input and produces high quality data and products for the EarthScope community. The observatory will require maintenance in the form of field engineers to keep stations running and personnel to perform the management, analysis, and data archiving tasks.

This proposal to the NSF Research and Related Activities (R&RA) account requests funds for operations and maintenance (O&M) activities during the five-year development effort for EarthScope to keep PBO networks up and running once they are installed. Estimates are also provided for full O&M activities in years 6-10 following the Major Research Equipment and Facilities Construction (MREFC) installation phase. The proposal details non-staff operations expenses for years 1-5 and operations expenses and staff costs for years 6-10. Major cost categories covered in this proposal are listed in Table 2–1.

Table 2–1. PBO Operations and Maintenance Cost Categories.

Cost Category	Timeframe (years)
Maintenance of 975 new, permanent GPS stations	1-10
Maintenance of 175 borehole strainmeters	1-10
Maintenance of 5 laser strainmeters	1-10
Maintenance of 255 existing GPS stations	6-10
Maintenance of 1 existing laser strainmeter	6-10
Field staff for 6 PBO regional offices	6-10
Staff for two GPS archives	6-10
Staff for one strainmeter archive	6-10
Staff for two analysis facilities	6-10
Management and support staff	6-10

A separate proposal to the NSF MREFC account entitled EarthScope: Acquisition, Construction, Integration, and Facility Management includes details of the overall PBO management plan, individual job descriptions, and all aspects of building the observatory and generating data products. The PBO component of the EarthScope MREFC proposal can be found at: http://www.unavco.org/research_science/publications/proposals/pbo/pbo.html.

This proposal focuses on resources needed to keep PBO running once it is installed.

2.2. Operations and Maintenance

Operations and Maintenance Budget Strategy

Once funded, it will take five years to build the PBO geodetic observatory. As stations become operational they will require funds for ongoing O&M. The working strategy for PBO is that in years 1-5, any O&M personnel costs will be covered under the PBO MREFC proposal. The reasoning is that the same people will be managing the station installations (MREFC budget) and performing ongoing O&M (O&M budget) once stations are installed since the tasks cannot effectively be separated.

Table 2–2. Equipment Deployment Schedule For PBO.

Deployment (Actual Installations)				
Project Year	**CGPS**	**Campaign**	**BSM**	**LSM**
1	50	50	2	1
2	20	50	15	2
3	250		70	2
4	250		70	0
5	125		18	0
Total Sites	**875**	**100**	**175**	**5**

Note: CGPS = permanent GPS tectonic and volcanic cluster and backbone sites; Campaign = portable GPS systems; BSM = borehole strainmeter systems; LSM = laser strainmeters.

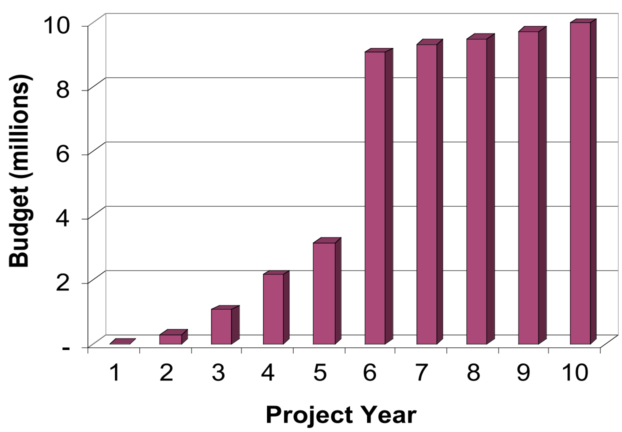


Figure 2–1. Operations and maintenance costs for years 1-10 of the PBO project.

For O&M purposes in years 1-5 we budget operational expenses (non-staff) for all stations that come on line in the following year. Thus, for the first five years, the O&M budget is closely tied to the GPS receiver and strainmeter deployment schedule (Table 2–2). For example, in year two we ask for enough money to support and maintain stations installed in year one (50 permanent GPS stations, 50 campaign GPS systems, and two borehole strainmeters). The consequence of this strategy is that O&M costs ramp up steadily in years 1-5 and then there is a large jump in costs in year six as personnel transition from installing instruments to O&M activities (Figure 2–1). This large increase in costs is further exacerbated by PBO taking on the O&M costs for 255 currently existing GPS stations in year six (described in detail later in the proposal).

	Current Value	Edit Value
Receiver Type:	ASHTECH UZ-12	ASHTECH UZ-12
Date Installed:	12-NOV-2001	12-NOV-2001
Serial Number:	ZR20011212	ZR20011212
UNAVCO ID:	12713	12713
Firmware:	CJ10	CJ10
Antenna Type:	ASH701945C_M	ASH701945C_M
Date Installed:	12-NOV-2001	12-NOV-2001
Serial Number:	CR6200 12903	CR6200 12903
UNAVCO ID:	12725	12725
Height (m):	0.0083	0.0083
Position:	VERTICAL	VERTICAL
Radome:	SCIT	SCIT

Figure 2–2. Sample from the UNAVCO Facility database metadata form stored for station PAS1.

Under normal conditions, the operation of PBO stations, once installed, will be largely automated. Regional Data Technicians will develop communications strategies whereby data are retrieved automatically from stations in the region and placed in a queue at a data transfer hub (for further information see section on *Data Management and Archiving* in the PBO MREFC Proposal). Data transfer software, such as the Unidata Local Data Manager (LDM) will retrieve the data and simultaneously deliver it to GPS Seamless Archive Center (GSAC) facilities for archiving and processing. All station metadata will be stored in a central database and kept up-to-date by the PBO Solution Coordinator, Data Manager, and Regional Engineers. A single point of origin for PBO metadata is critical so that Solution Centers, Regional PI's, and others interested in processing PBO data have concurrent and reliable metadata. The process of updating station metadata will also be simplified by having consistent data entry and update forms (for example Figure 2–2) and a single point of entry for updating station information. The single point of entry concept means that whenever a critical piece of equipment, such as an antenna or receiver, changes at a station the change propagates to all users of the data. Numerous organizations in the UNAVCO community, for example the Scripps Orbit and Permanent Array Center (SOPAC), the Southern California Integrated GPS Network (SCIGN), and the UNAVCO Facility, have implemented schemes for storing station site information and keeping it current.

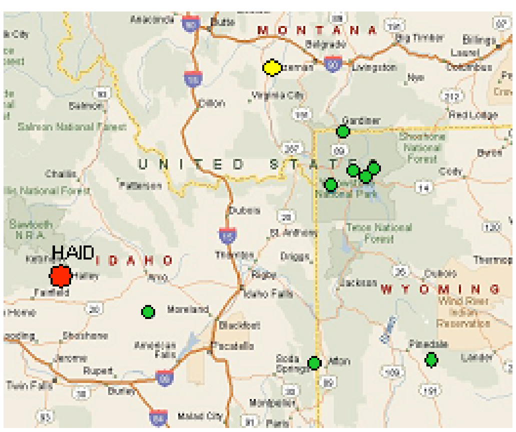
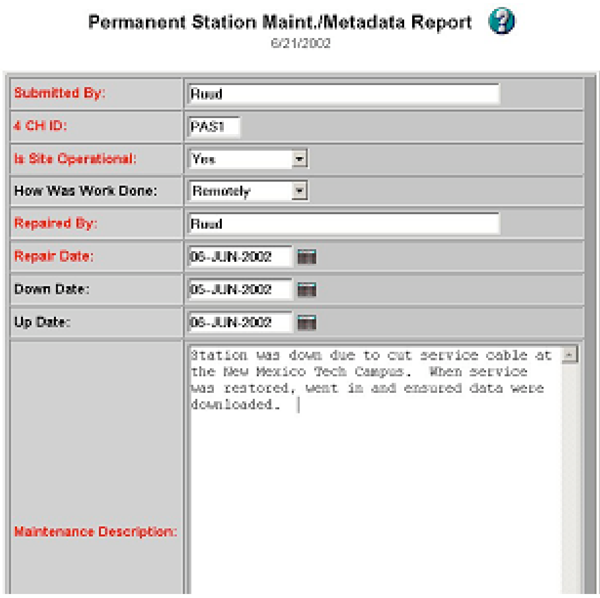


Figure 2–3. Graphical view of station operations. Red = no data in last 5 days, yellow = no data in last 2 days, green = data current. Station symbols are hyperlinked to plots of data availability, quality and station metadata.

Once a station is declared operational, it is the job of the Data Products Manager to oversee the quality and quantity of data flow from the network to the data archives. GPS and strainmeter stations will be monitored on a daily basis, and text and graphic-based reports that describe the status of network stations will be available over the web (Figure 2–3). As GPS data flow into the archive, automatic software will check for both volume and quality. Strain data will be quality checked for dynamic scale over the measurement period, quantity of data obtained versus data rate, and availability of barometric pressure data. If any of these values exceed a critical threshold, an automated alert will go out to Regional Engineers identifying the station and what triggered the alert. Regional Engineers and data technicians will try to troubleshoot the station remotely. If the problem cannot be rectified in five days, a field visit will be scheduled. Depending on season and location (e.g. Alaska), site visits can be deferred until logistics or weather permit. Once the site visit is made and the condition corrected, a maintenance report will be logged for all remote and field troubleshooting and repairs (Figure 2–4).

Yearly maintenance visits will be scheduled for all GPS and strainmeter stations. Yearly maintenance will include replacing gel cell batteries, cleaning solar panels, performing a site inventory, repairing broken equipment, updating documentation, visiting critical site contacts, and clearing vegetation around the site. Replacement equipment purchased through UNAVCO, Inc. will be tested by the UNAVCO Facility prior to shipment to regional offices. Strainmeter systems cannot be replaced because they are permanently cemented at the bottom of the boreholes. The UNAVCO Facility, currently an Ashtech and Trimble-certified repair center, will provide board level repair for all PBO GPS equipment. Personnel at the Scripps Institute of Geophysics and Planetary Physics (IGPP), under subcontract to UNAVCO, Inc. will conduct O&M activities of laser strainmeters.


Permanent Station Maint./Metadata Report
6/21/2002

Submitted By:	Ruud
4 CH ID:	PAS1
Is Site Operational:	Yes
How Was Work Done:	Remotely
Repaired By:	Ruud
Repair Date:	06-JUN-2002
Down Date:	05-JUN-2002
Up Date:	06-JUN-2002
Maintenance Description:	Station was down due to cut service cable at the New Mexico Tech Campus. When service was restored, went in and ensured data were downloaded.

Figure 2–4. Portion of UNAVCO Facility station metadata-maintenance form issued for station PAS1 at the IRIS/PASCAL facility. Maintenance forms can be quickly queried and concatenated into reports.

USArray and PBO will specify similar instruments (e.g. broadband seismometers and GPS receivers) and ancillary equipment (e.g. solar panels and communications equipment) so that maintenance crews can service equipment in either array. For example, the Backbone Network component of USArray is tasked with installing GPS instruments at selected sites. PBO will be installing 175 borehole strainmeters, some with broadband seismometers. Both projects will coordinate maintenance activities such that crews in the vicinity of a failed GPS or seismic station can hot-swap sensors and ancillary equipment if needed.

Operations and Maintenance of GPS Campaign Instruments

The PBO MREFC budget provides for the purchase of 100 portable geodetic quality GPS systems that will be used for focused, dense deployments within the PBO. Campaign receivers will facilitate PI-based EarthScope research, emergency response to earthquakes and volcanic eruptions, regional scientific investigations, and operational requirements such as reference mark surveys for permanent stations. The PBO O&M budget covers the costs of maintaining the instruments themselves, plus training and limited engineering support. The bulk of expenses for field operations during campaign experiments will come from the PI-based research proposals.

The PBO campaign pool will be centrally managed and maintained by the PBO Campaign Support Engineer based at the UNAVCO Facility. The Campaign Support Engineer will schedule the receivers to meet EarthScope science objectives and ensure the receivers and ancillary equipment are routinely maintained.

The UNAVCO Facility will inventory, maintain, and quality check all campaign equipment prior to deployment. The UNAVCO Facility will provide services to PBO including training and extensive web-based support for PBO campaign surveys, and supply campaign engineers on request to support large campaigns and new investigators.

Standardized campaign measurement and documentation procedures will be enforced to ensure unified and consistent data sets are collected. The PBO Campaign Support Engineer will work with the community to determine prescribed monumentation for new sites, robust antenna set-up methods, and standardized field documentation - all critical for the integrity of PBO campaign data. Electronic and hardcopy log sheets and site descriptions will be tailored to PBO, and data submittal procedures will be developed to specifically meet the rapid data archival requirements of PBO.

Incorporation of Existing GPS and Strainmeter Stations into PBO

Table 2–3. Existing GPS Networks and the Number of Stations Requesting PBO Support in Years 6-10.

Network	Name	# Stations	# Requesting support
AKDA	Alaska Deformation Array	14	5
BARD	Bay Area Regional Deformation Array	64	20
BARGEN	Basin and Range GPS Network	50	35
EBRY	Eastern Basin Range Yellowstone	19	15
PANGA	Pacific Northwest Geodetic Array	47	35
SCIGN	Southern California Integrated GPS Network	276	125
Other	Other	0	20
	Totals	470	255

There are currently over 400 permanent GPS stations in NSF-funded networks in the western U.S. (Table 2–3). These networks exist in Alaska, the Pacific Northwest, California, the Basin and Range, and in the eastern Basin and Range/Yellowstone areas and are the predecessor, and in fact the cornerstone of the PBO effort. PBO will be built on the experience gained by these networks and the decade-long position time series generated from the stations. These regional networks are currently funded through individual PI proposals. A UNAVCO, Inc. proposal is currently under review that requests five years of O&M support for 255 of these stations (see UNAVCO, Inc. proposal entitled: *Support for Existing Western U.S. GPS Networks* at http://www.unavco.org/). For the first five years, the networks will be maintained through subcontracts from UNAVCO, Inc. to the individual networks. Starting in year six, PBO will assume the maintenance and operations costs for these stations.

As indicated above, PBO station maintenance and data flow are handled by Regional Engineers located within specified PBO regions. Adding existing regional stations under the PBO umbrella will result in an additional 255 stations spread across the six regions of PBO. These stations will be folded into the PBO process in terms of station documentation, maintenance, data flow, and data processing and results, without increasing the personnel resources above those currently proposed for PBO O&M.

Similarly, we are requesting support for a long baseline laser strainmeter located at Verdugo Canyon (Glendale), north of downtown Los Angeles. The strainmeter was installed as part of the SCIGN project and will compliment the laser strainmeters proposed for PBO. Personnel at the Scripps IGPP, under subcontract from UNAVCO, Inc. will conduct O&M activities of laser strainmeters.

Data Management, Archiving, and Data Products

A key component of the PBO effort is to capture and archive the data generated by the PBO networks and distribute the raw data and data products to the scientific community. This will be accomplished by augmenting three existing archives, the UNAVCO Facility and Scripps Orbit and Permanent Array Center (SOPAC) GPS archives, and the UC-Berkeley Seismological Laboratory strain data archive with a mirror to the Incorporated Research Institutions for Seismology (IRIS) Data Management Center. GPS data products will be generated by two PBO processing centers. Strainmeter data products will be processed by separate borehole and laser strainmeter centers. In years 1-5, personnel costs associated with these tasks and initial hardware and software costs are covered as part of the MREFC proposal. As stations become operational, a yearly data maintenance fee of $250 per station per year for media and hardware/software upgrades are allocated as part of the PBO O&M budget. In year 6-10 all data management and data products personnel will be covered under the O&M budget.

2.3. Budget Discussion

Introduction

The activity described above will provide O&M support for the PBO network over a ten year time period. For all activities discussed in this proposal, UNAVCO, Inc. will serve as the project coordinator and prime contractor of the proposed work. Tables 2–4 and 2–5 provide summary budget tables for year 1-5 and 6-10 respectively. A brief budget discussion follows the tables.

Table 2–4. PBO Operations and Maintenance Budget Estimates for Years 1-5.

Yearly & Five-Year Budget Summary		**2003**	**2004**	**2005**	**2006**	**2007**	**Five Year TOTAL**
REGIONAL OPERATIONS & MAINTENANCE (in constant dollars)							
	Average O&M Cost/Station						
Campaign GPS O & M	$1,250	$-	$62,500	$125,000	$125,000	$125,000	$437,500
Borehole Strainmeter O&M	$3,680		$7,360	$62,560	$320,160	$577,760	$967,840
Long-Base Laser Strainmeter O&M	$43,500		$43,500	$130,500	$217,500	$217,500	$609,000
Continuous GPS Station O&M	$2,936	$-	$146,800	$734,000	$1,468,000	$2,202,000	$4,550,800
TOTAL REGIONAL OPNS & MAINT		$ -	$260,160	$1,052,060	$2,130,660	$3,122,260	$6,565,140

Table 2–5. PBO Operations and Maintenance Budget Estimates for Years 6-10.

PLATE BOUNDARY OBSERVATORY OPERATIONS, MAINTENANCE, AND MANAGEMENT (O&M) BUDGET PROJECTION							
Yearly & Five-Year Budget Summary		**2008**	**2009**	**2010**	**2011**	**2012**	**Five Year Totals**
REGIONAL OPERATIONS & MAINTENANCE	**MRE Average O&M Cost/Station**	**Steady State Annual Cost** (full deployment)					
Campaign GPS Operations & Maintenance	1,250	$ 125,000	$ 128,750	$ 132,613	$ 136,591	$ 140,689	$ 663,642
Borehole Strainmeter O&M	3,680	$ 644,000	$ 663,320	$ 683,220	$ 703,716	$ 724,828	$ 3,419,083
Long-Base Laser Strainmeter O&M	43,500	$ 217,500	$ 224,025	$ 230,746	$ 237,668	$ 244,798	$ 1,154,737
Continuous GPS Station O&M	2,936	$ 2,569,000	$ 2,646,070	$ 2,725,452	$ 2,807,216	$ 2,891,432	$ 13,639,170
Existing GPS Network Operated in PBO (1)	2,936	$ 748,680	$ 771,140	$ 794,275	$ 818,103	$ 842,646	$ 3,974,844
Glendale LB Laser Strainmeter in PBO (existing	43,500	$ 43,500	$ 44,805	$ 46,149	$ 47,534	$ 48,960	$ 230,947
Subtotal Non-Salary OPNS & MAINTENANCE		$ 4,347,680	$ 4,478,110	$ 4,612,454	$ 4,750,827	$ 4,893,352	$ 23,082,424
PBO Standing Committee		$ 22,258	$ 22,926	$ 23,614	$ 24,322	$ 25,052	$ 118,171
PBO Personnel & Support							
Total Salaries & Benefits Specific to PBO		$ 3,406,736	$ 3,508,938	$ 3,592,694	$ 3,700,475	$ 3,811,490	$ 18,020,333
Total Non-Salary Program Support Specific to PBO		$ 1,019,800	$ 1,037,000	$ 955,009	$ 950,577	$ 942,708	$ 4,905,094
UNAVCO, Inc. Corporate Support (30% of selected HQ costs)		$ 270,846	$ 296,186	$ 304,883	$ 317,647	$ 323,449	$ 1,513,011
Sub-Total		$ 4,697,382	$ 4,842,125	$ 4,852,585	$ 4,968,700	$ 5,077,647	$ 24,438,438
TOTAL OPERATIONS & MAINTENANCE		$ 9,067,320	$ 9,343,161	$ 9,488,653	$ 9,743,849	$ 9,996,050	$ 47,639,033

Note: Detailed budgets for all PBO cost components can be found on the UNAVCO, Inc. website at http://www.unavco.org/research_science/publications/proposals/pbo/budget/PBO_Budget_Details.html

The PBO is divided into six geographic regions that will be staffed with UNAVCO, Inc Regional Engineers. For each region, station maintenance costs were calculated based on the type of installation (strainmeter or GPS) and the logistics of getting to the site. Stations in Alaska are logistically more difficult, often requiring helicopter and boat transport, therefore requiring a larger share of the O&M budget. Likewise, stations in the Rocky Mountain and Basin and Range regions are dispersed, requiring long drive times for station maintenance and therefore increased costs.

Although the deployment schedule for stations is known, the installation sequence has not been decided. Because the exact time phasing of station installations is not known, the strategy taken was to provide average maintenance costs for each region, then use these to create a PBO-wide average station maintenance cost as seen in Tables 2-4 and 2-5. For the first five years, staff costs are excluded so the O&M budget is the product of the average station O&M cost multiplied by the number of instruments installed in that year as seen in Table 2–2. For example, if the yearly average GPS station maintenance cost is $2,936 and 50 Permanent GPS stations are installed in year one, the GPS O&M cost for year two is $146,800. As Figure 2–1 shows the O&M budget plateaus after year six with the only increase arising from an annual 3 percent cost of living increase.

For each line item in Tables 2–4 and 2–5, supporting spreadsheets detailing all budget assumptions can be found on the UNAVCO Inc. Web site.

Equipment Operations and Maintenance

Campaign GPS O&M costs include equipment replacement costs and five round trip shipments of each system to field projects. Costs for campaign O&M peaks in year 2, at the conclusion of the campaign equipment purchase, and remains steady state except for inflation starting in year six throughout the 10-year life of PBO.

Borehole strainmeter and GPS O&M costs are estimated on a single site visit per year per station and include ongoing costs such as telemetry (e.g. bandwidth and service provider charges), yearly power costs (e.g. batteries and utility bills), travel costs, equipment replacement, and an allocation for data archiving and data processing media and equipment upgrades.

In year six, PBO assumes O&M responsibilities for 255 existing GPS and one existing laser strainmeter. Maintenance costs for these stations are assumed similar to those for PBO installations. The O&M of the existing long baseline laser strainmeter will be subcontracted to Scripps IGPP. Funded O&M activities for long baseline laser strainmeters include staff for management, data handling, maintenance, and security. Non-staff related O&M costs include site power, equipment replacement, site and data communications, computer networking, and transportation to the site. Individual line items for O&M budget can be found on the UNAVCO, Inc. website.

PBO Standing Committee

Funds are requested for two PBO Standing Committee meetings per year over the lifetime of PBO. The budget provides support for eight attendees (seven committee members and one visitor). The meetings will allow interaction between the committee, the PBO Director, and the UNAVCO, Inc. President regarding the implementation and management of the PBO Facility. The chairman of the committee will be responsible for providing a meeting agenda and a summary report of the proceedings.

Personnel Support

For years 1-5, the PBO MREFC proposal requests a total of 55 personnel to install and provide initial data processing and archive capability. In this O&M proposal, no personnel support (with the exception of subcontracts for long baseline laser strainmeter personnel support) is requested for years 1-5. For years 6-10, Table 2–5 estimates the personnel costs required to support PBO networks and the existing GPS networks. The full compliment of personnel support is 41 employees including the PBO director, 39 professional staff (including field engineering, data archiving and solutions, and finance/administrative personnel), and one secretary (Table 2–5). This represents a 25 percent reduction in staff from the installation phase of PBO. Salary support costs include a 30.55 percent benefits rate. In addition, non-salary support costs to cover office and storage space, vehicles, phone, computer, Internet, and travel to meetings are requested. Supporting documentation, including detailed worksheets of personnel and necessary support costs can be found on the UNAVCO, Inc. website.

UNAVCO, Inc. Corporate Support

UNAVCO, Inc. serves as the prime contractor for the PBO and coordinates all business management, equipment purchasing, and financial activities of the project. The O&M budget includes funds covering 30 percent of UNAVCO, Inc. headquarters operations for years 6-10 of the PBO project. UNAVCO, Inc. headquarters costs include partial funding for senior personnel, staff allocations for finance, purchasing, and business management professionals, and support for secretarial-clerical staff. Additional costs include building, communications (e.g. phone, Internet) and business services (e.g. copier, office supplies).

3. USArray

3.1. Introduction

The USArray component of the EarthScope Observatory is a dense array of high-capability seismometers, designed to improve greatly our resolution of the continental lithosphere and deeper mantle beneath the North American continent. When completed, USArray's hierarchal design will allow us to capture images that span the continuous range of scales from global, through lithospheric and crustal, to regional to local.

The core of USArray is a transportable telemetered array of 400 broadband seismometers, deployed throughout the United States, which is designed to provide real-time data from a regular grid with dense and uniform station spacing of ~70 km and an aperture of ~1400 km. The Transportable Array will roll across the country with 18-24 month deployments at each site. Multiple deployments will cover the entire continental United States and Alaska over a period of 10-12 years.

As a complement to the Transportable Array, USArray's Flexible Array will include a pool of ~2400 portable instruments (a mix of broadband, short-period, and high-frequency sensors) that can be deployed using flexible source-receiver geometries. These instruments will permit high-density, shorter-term observations, using both natural and explosive sources, of key targets within the footprint of the larger Transportable Array. The EarthScope facility will provide the capital equipment and maintenance of this pool of instruments, Separately funded research projects will be responsible for the costs associated with the deployment of these instruments.

A third element of USArray is the development of a Backbone Network, through augmentation of permanent stations of the USGS National Seismic Network (NSN) and the IRIS/USGS Global Seismographic Network (GSN). Relatively dense, high quality observations from a continental network with uniform spacing of 300-350 km are important for tomographic imaging of deep Earth structure, providing a platform for continuous long-term observations, and establishing fixed reference points for calibration of the Transportable Array. Sixteen stations of the Backbone Network will be equipped with continuous GPS receivers. This permanent component of USArray will be coordinated with the USGS and complements the initiative underway at the USGS to install an Advanced National Seismic System (ANSS).

Thirty magnetotelluric (MT) field systems will be included in the Transportable Array, and ten will be installed at selected stations of the Backbone Network.

This proposal requests funds for the operations and maintenance (O&M) activities to ensure that USArray data continue to be acquired, quality controlled, archived and distributed to the community. The proposal details the strategy for ramping-up of O&M activities during Years 1-5 of the Major Research Equipment Facility Construction (MREFC), and provides an estimate for the annual operations and personnel expenses for out-years costs during Years 6 –10.

3.2. Operations and Maintenance Strategy

As the USArray facility is created, operational costs will be transitioned from the MREFC account to the Research and Related Activities (R&RA) account. NSF has indicated that separate proposals should be provided for the installation of USArray under the MREFC, and operations from the R&RA accounts. Details of the O&M costs for years 1-5, and an estimate of annual costs for years 6-10 are given in Table 3–1. These O&M costs are closely related to the MREFC budget presented in the *EarthScope MREFC Proposal,* yet make a clear separation between the building of the facility and the routine operations and maintenance.

	Year 1	Year 2	Year 3	Year 4	Year 5	O&M Total	Year 6
Transportable Array Hardware	**$ 106,508**	**$ 218,266**	**$ 329,117**	**$ 439,060**	**$ 439,060**	**$ 1,532,011**	**$ 452,232**
Maintenance (3% capital cost)	$ 106,508	$ 218,266	$ 329,117	$ 439,060	$ 439,060	$ 1,532,011	$ 452,232
Flexible Array Hardware	**$ 102,038**	**$ 205,073**	**$ 307,110**	**$ 408,150**	**$ 509,190**	**$ 1,531,560**	**$ 524,466**
Maintenance (3% capital cost)	$ 102,038	$ 205,073	$ 307,110	$ 408,150	$ 509,190	$ 1,531,560	$ 524,466
IRIS Facilities	**$ -**	**$ 106,978**	**$ 273,289**	**$ 447,289**	**$ 456,583**	**$ 1,284,139**	**$ 1,494,492**
Headquarters							
Staff	$ -	$ -	$ -	$ -	$ -	$ -	$ 274,035
Program Managers	$ -	$ -	$ -	$ -	$ -	$ -	$ 148,833
Other Direct Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ 166,200
Data Management Center (DMS)							
Staff	$ -	$ 55,620	$ 186,188	$ 309,788	$ 319,082	$ 870,678	$ 594,708
Other Direct Costs	$ -	$ 51,358	$ 87,101	$ 137,501	$ 137,501	$ 413,462	$ 210,716
E&O	$ -	$ -	$ -	$ -	$ -	$ -	$ 100,000
Subawards	**$ 121,662**	**$ 808,381**	**$ 1,330,215**	**$ 1,624,777**	**$ 5,643,094**	**$ 9,528,128**	**$ 9,441,228**
Array Operations Facility							
Staff	$ 85,952	$ 384,682	$ 396,223	$ 408,109	$ 420,352	$ 1,695,318	$ 1,496,990
Other Direct Costs	$ 14,470	$ 21,705	$ 28,940	$ 43,410	$ 43,410	$ 151,935	$ 43,410
Array Network Facility							
Staff	$ -	$ 125,419	$ 399,849	$ 500,549	$ 1,226,916	$ 2,252,734	$ 1,263,724
Other Direct Costs	$ -	$ 18,870	$ 31,450	$ 157,250	$ 191,845	$ 399,415	$ 229,585
ASL DCC							
Personnel	$ 14,800	$ 76,220	$ 78,507	$ 80,862	$ 83,288	$ 333,676	$ 85,786
Other Direct Costs	$ 6,440	$ 33,165	$ 34,160	$ 35,185	$ 36,240	$ 145,189	$ 37,327
MT Install & Ops	$ -	$ 148,320	$ 361,087	$ 399,412	$ 406,493	$ 1,315,312	$ 413,786
Transportable Array field operations							
Staff	$ -	$ -	$ -	$ -	$ 162,073	$ 162,073	$ 2,772,984
Other Direct Costs	$ -	$ -	$ -	$ -	$ 3,072,476	$ 3,072,476	$ 3,097,636
Subtotal - Direct Expenses	$ 330,207	$ 1,338,698	$ 2,239,731	$ 2,919,276	$ 7,047,927	$ 13,875,838	$ 11,912,418
IRIS Indirect Expenses	$ 40,766	$ 100,851	$ 161,523	$ 223,120	$ 244,773	$ 771,033	$ 475,791
Total	**$ 370,973**	**$ 1,439,549**	**$ 2,401,254**	**$ 3,142,396**	**$ 7,292,700**	**$ 14,646,871**	**$ 12,388,209**

Table 3–1: USArray Operations and Maintenance Budget Years 1-5, with an estimate (Year 6) of the annual costs for years 6-10. Year 6 breakout is shown in Figure 3–2.

This section defines operations and maintenance costs that will be incurred under the R&RA account during Years 1-5 of the MREFC-funded facility building, and estimates the routine cost of O&M in the out-years. Detailed budgets can be found at http://www.iris.iris.edu/earthscope/USArrayBudget.html.

3.3. Operations and Maintenance

Once each station within the Transportable Array is installed during the initial deployment, the station is declared to be running in a calibration mode. Data will be transmitted to the Array Network Facility (ANF) and IRIS Data Management Center (DMC), archived and distributed to the community on demand. This calibration period is important for confirming station operation, assembling meta-data appropriate for the site, repair of any system and installation errors, and field-crew training. This calibration period is expected to be 12-18 months in duration for the first stations deployed, and will shorten considerably as experience is earned. During this calibration period, all maintenance site visits, communications costs, etc, will be covered by the *EarthScope MREFC Proposal*. It is expected that late in Year 4 or early in Year 5 the Transportable Array will be deemed fully operational, and all costs associated with operations and maintenance will be transitioned to the R&RA funds. The Transportable Array will commence to "roll" in Year 5, and all costs associated with the redeployment of Transportable Array stations are included in this *EarthScope O&M Proposal*.

Site selection, permitting and documentation for the second and subsequent Transportable Array "footprints" beyond Year 6 are covered by the *EarthScope O&M Proposal*. Because of the long lead-time (up to 2 years) required for permitting and documenting Transportable Array sites, this process is likely to commence in Year 3 of the MREFC, even though second footprint sites will not be populated until Year 5.

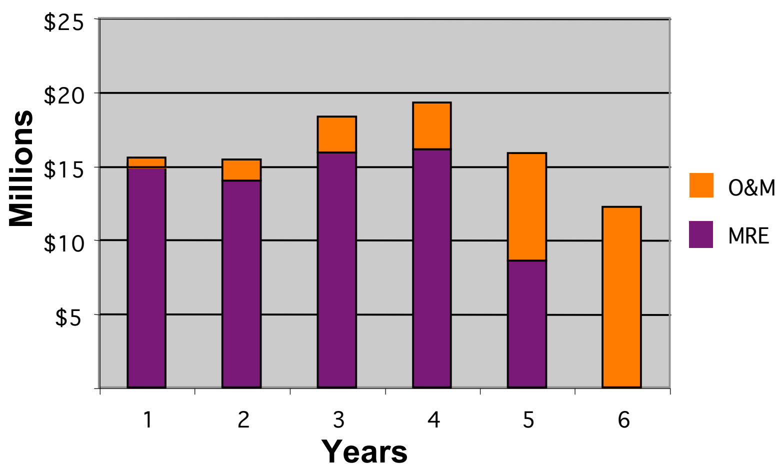


Figure 3–1: Ramping of O&M funds relative to MREFC spending in Years 1-5, and estimate for Year 6, for USArray.

Some Transportable Array and Backbone Network sites will complete their calibration period starting as early as Year 2; thus some staffing costs and other direct costs will be incurred at the Array Operations Facility (AOF), ANF and DMC. These costs will gradually increase through Years 2-5 until the full costs of maintaining these USArray facilities are covered under O&M in Year 6.

The O&M for the Transportable Array will be performed by the commercial contractor tasked in the MREFC phase with deploying the Transportable Array, in coordination with the AOF and ANF. All costs associated with the demobilization and redeployment of Transportable Array stations from the first footprint to the second footprint will be funded by O&M. This includes the addition of two extra staff for demobilization of sites, which involves packing and shipment, and returning the site to its original condition.

The Flexible Array follows the same model of current PASSCAL PI-driven experiments, with PIs funding deployments from their research grants. However, some operations and maintenance for the Flexible Array is to come from the R&RA account to cover maintenance of hardware at the AOF, shipping, replacement of broken or missing equipment, travel of AOF staff to assist PI's during installation, training of PIs, etc. These O&M activities related to the Flexible Array will be carried out by the personnel at the AOF in a manner similar to what is done now for the PASSCAL program.

Hardware budgets for the Transportable and Flexible Arrays under the *EarthScope O&M Proposal* include an annual cost of 3% of the capital cost as maintenance expenses to cover items that fail or are damaged during operations.

It is anticipated that the USGS will be responsible for O&M of the Backbone Network following the MREFC development. Spares are being purchased for the Backbone Network component out of the MREFC account, and all subsequent maintenance after installation is complete will be covered by the USGS.

Costs for routine operation of the ASL Data Collection Center (DCC) will come from the O&M account. This follows the current model of IRIS/DMS operations whereby IRIS provides support to the ASL DCC for the incremental costs of processing of data from IRIS/GSN stations.

All MT field operations will be supported from the R&RA account. All direct IRIS Corporate expenses specific to EarthScope construction for Years 1-5 will be covered by the MREFC. Indirect cost recovery through overhead covers IRIS Headquarters expenses for O&M.

MT Operations:

The deployment plan for the MT stations mirrors that for the Backbone Network and Transportable Arrays. Ten permanent MT stations will be installed for the duration of EarthScope. These will be collocated with the planned Backbone Network stations and rely on the infrastructure established for the permanent seismic station.

The remaining MT stations are for use within the Transportable Array footprint. Ten of the 400 stations in each Transportable Array deployment will have MT installations for the entire 18-month deployment. Twenty MT instruments will be collocated at some of the remaining Transportable Array sites for a period of one month, depending upon permitting restrictions. Collocated sites may be able to telemeter data to the AOF. Otherwise, MT sites will be permitted separately from Transportable Array sites and will be operated independently for the one-month duration. If permitting for the electric dipoles is not possible, then a minority of the sites could be equipped with magnetic field sensors only.

Because of the different strategy for deploying MT systems, an independent field crew of 3 personnel will be needed for installation and later removal of the MT sites. An additional 0.5 FTE is assigned to the AOF for instrument preparation, shipping, repair, testing, and calibration and 0.5 FTE is assigned to the ANF to provide QC for the real-time MT data streams. Some of the MT instruments may be used for deployment in special studies not directly related to observations at the Transportable Array sites, however, as with the Flexible Array seismic instrument, the costs associated with these deployments will be supported through separately funded PI-based experiments.

Data Management:

Once stations within the Transportable Array transition from calibration to operational status, data from these sites will be subject to routine quality assurance review. Some Transportable Array stations are expected to be declared operational commencing in Year 2. At this time, additional Data Technicians will be recruited for the DMC, their number increasing to 3 by Year 5 as the volume of data from operational stations increases. While already automated, some DMC procedures currently in place will need significant modification in order to receive USArray data in real time and without delay. Additionally, quality control of the data for USArray needs development in order to automatically flag problems with data flow and data quality. A software engineer is included in the O&M request for Year 3 to assist in the necessary new developments.

Data flow from the Backbone Network will initially flow to the Data Collection Center (DCC) at the USGS Albuquerque Seismological Laboratory (ASL). Real-time data will be made available to the DMC through the ASL DCC without significant delay. The ASL DCC will perform quality control of the data and forward the waveform and metadata to the DMC as quickly as possible. This is the model currently used by the GSN for controlling dataflow from over 80 USGS/GSN sites. Funding for the additional resources required by the ASL DCC will be provided under the O&M component. The O&M budget includes a new Data Technician for the ASL DCC to be recruited in Year 3. The volume of data generated by the various components of USArray is not expected to increase once fully operational. Thus USArray data management enters a steady-state and the costs for Years 7-10 should remain at a level similar to that for Year 6.

Personnel Support:

Staff support for Flexible Array operations is requested under the O&M funds. Under the MREFC, funding for the Flexible Array is provided only for purchase of equipment. Operations and maintenance of this equipment will be provided by O&M funding. Thus, 4.5 staff are requested for the AOF in Year 2, to support Flexible Array equipment shipping, maintenance, PI instruction and field support for each initial deployment of a Flexible Array experiment.

As data flow increases with the transition of Transportable Array sites from a period of calibration to operation, the number of staff at the ANF and IRIS/DMC supported with O&M funds increases through Years 2-5. In Year 2, the O&M funded staff includes 1.5 FTE and 1 FTE at the ANF and DMC respectively. At the end of Year 4, this number has increased to 5 and 4.5 respectively. When the Transportable Array is fully operational in Year 5, all ANF staff will be carried by O&M funds. In addition, two additional staff are added to the Transportable Array field crew to support the demobilization and moving of sites to the second deployment, as well as additional staff for the O&M of the MT stations.

At the end of Year 5, all staff funded under the MREFC will have been transitioned to O&M funding. More information on staffing levels, personnel requirements and the transition process can be found at: http://www.iris.iris.edu/earthscope/USArrayBudget.html.

3.4. Out-Year Support

USArray has been designed with a 10-12 year lifetime consisting of an initial five-year acquisition and installation phase (MREFC) with an additional 5-7 years of Transportable Array deployment and observations.

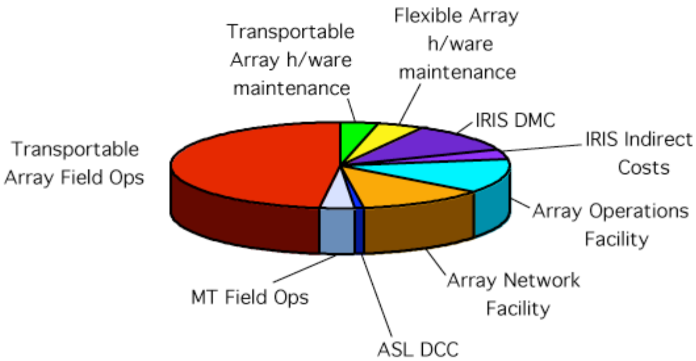


Figure 3–2: Graphical representation of USArray costs in Year 6. See Table 3-1 for more detail.

As described in the *EarthScope MREFC Proposal*, the Transportable Array will cover the entire continental US and Alaska with ~2000 sites in five deployments of 400 instruments. Each site within one of these "footprints" will remain in place for 18 months to two years. Allowing for a gradual start-up phase during the first four years, the first footprint of USArray will have been completed by the end of the five years of MREFC support, and some stations will have been redeployed into the second footprint. An additional 5-7 years will be required to complete observations in the remaining three footprints in the lower 48 states and Alaska.

The bulk of the estimated budget for out-year support (Table 3-1 and Figure 3-2) is for field operations, communications and data support related to the continuing deployments of the Transportable Array. During this phase of EarthScope operations, support for the Backbone Network will have been transitioned to USGS and acquisition and assembly of the Flexible Array will have been completed.

At the end of the last deployment of Transportable Array in year 10-12, the primary observational tasks of USArray will have completed and on-going costs will be limited primarily to maintenance of the data archive and support of the flexible array instrument pool. Depending upon the condition of the equipment used in the Transportable Array, hardware will be retired, used for other experiments or dedicated to E&O-related installations at schools, colleges or museums.

4. San Andreas Fault Observatory at Depth (SAFOD)

4.1. SAFOD Support – Years 1-5

As explained earlier, the full costs of SAFOD for the first five years are included in the *EarthScope MREFC Proposal* and, therefore, no SAFOD budget for years 1-5 is included in this submission.

4.2. SAFOD Operation and Maintenance – Years 6-10

Responsibility for the long-term operation and maintenance of downhole monitoring instrumentation, data telemetry and data archiving, and distribution for SAFOD will be shared by NSF-funded institutions and the USGS. After the SAFOD downhole monitoring array is installed and fully operational, in years 6 through 10 of SAFOD operations it is estimated that $450K/year from NSF will be required to cover O&M. This includes roughly $150 K/year for contracting with a workover rig to pull the long-term monitoring array from the borehole and then redeploy it, as well as $300K/yr to cover engineering costs, hardware, component fabrication, testing and travel associated with modifications and/or repairs to the downhole array and associated surface data processing and storage equipment. Some of these activities will be necessitated by routine equipment failures (due to the high pressures and temperatures at which the monitoring equipment must operate), whereas others will be the result of improvements in sensor design, clamping technologies, downhole telemetry and on-site data processing that will inevitably occur over the lifespan of SAFOD. Over this time span, the USGS will be responsible for maintaining the surface installation facility (building, power, etc.) and telecommunication links back to the centralized data repository.