HISTORICAL CONTEXT OF CURRENT OPERATIONS

The EarthScope facility operates on a dramatic scale—with literally thousands of instruments deployed in the field collecting terabytes of data that are distributed to thousands of users worldwide. IRIS operates the USArray component of EarthScope. USArray was completed on time and on budget as part of the initial five-year EarthScope Major Research Equipment and Facilities Construction (MREFC) phase of operations. The MREFC award was concluded in 2008 and at that time EarthScope transitioned fully into its current Operations and Maintenance (O&M) phase.

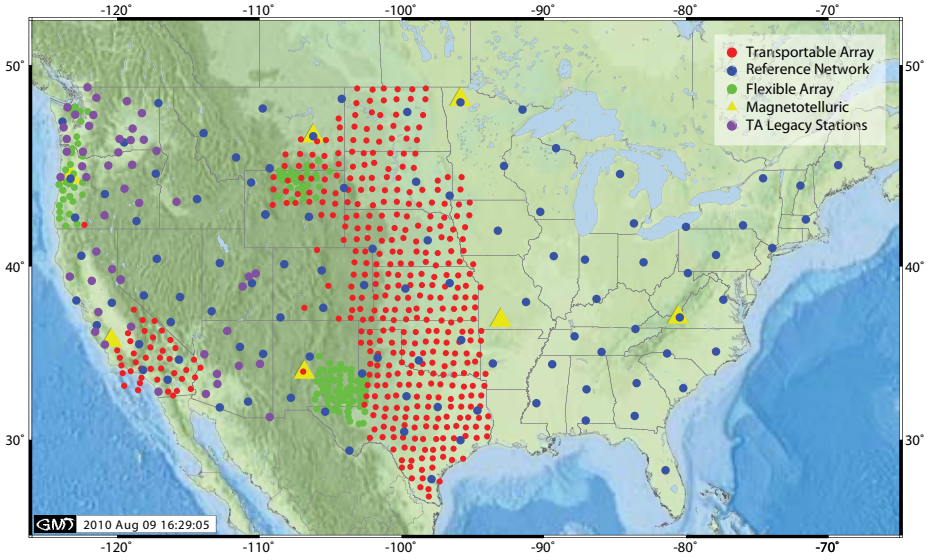

Figure A5.1. At-a-glance summary of the deployment of USArray instruments. For clarity, past FA deployments and MT campaign sites are not shown.

The EarthScope USArray facility consists of four observatory components (Figure A5.1): a Transportable Array of ~400 seismic stations; a Flexible Array pool of seismic instruments; a Reference Network of permanent seismic stations; and a Magnetotelluric observatory. USArray also includes comprehensive data management and siting outreach efforts.

TRANSPORTABLE ARRAY (TA)

The TA has occupied nearly 1000 sites across the western and central United States and continues its multi-year migration towards the Atlantic coast. The stations use a grid-like deployment with 70 km separation between stations. At any given time there are approximately 400 stations operational with each station being operated for two years before being relocated further east. Once the first 400 stations were completed in the western United States, the TA began to "roll." The TA has now been "rolling" for roughly three years, with ~18 stations deployed and ~18 stations removed every month, year round. Through the western mountains and now onto the central plains, the TA has stayed on budget and on schedule.

Each TA station is equipped with a three-component broadband seismometer (Figure A5.2). All data from the TA are collected in real time, and are subjected to a variety of automated and manual quality-control reviews. The data quality from TA stations has been extremely high, with low-noise performance that is very consistent across the array. The TA stations generate long, continuous (gap-free) time series with very high data availability. In 2009, the average data availability across the whole TA was 99.3%.

Figure A5.2. Installation of a Transportable Array station (left panels), instrumentation (middle and middle right panels), and completed station (right panel). The vault is under the mound of dirt in the foreground.

FLEXIBLE ARRAY (FA)

The FA has 346 broadband, 130 short-period, and about 1700 active-source instruments that are available for Principal-Investigator (PI)-driven experiments (Figure A5.3). The FA equipment pool is fully utilized, supporting a range of broadband, short-period, and active-source experiments. The FA provides essentially complete stations to the PI. It also provides data services that collate the raw data retrieved from the field and deliver these data, and their corresponding metadata, to the IRIS DMC. Data return from FA experiments has been 95%, on average. The combination of the large pool of readily available instruments coupled with full data-service support has resulted in very ambitious experiments. It is not uncommon for FA experiments to involve 75 to 200 stations for natural-source experiments, and many more instruments for active-source experiments. The scientific return from FA experiments has been enhanced through the joint interpretation of FA data in the context of the background observations provided by the surrounding TA station grid.

REFERENCE NETWORK (REFNET)

The Reference Network consists of ~100 stations located at ~300 km spacing across the continental United States to provide a fixed reference frame for the moving TA. The initial core of RefNet was the backbone network of the USGS Advanced National Seismic System (ANSS), supplemented with the USArray Permanent Array—a set of 39 stations that were installed or upgraded with USArray funds. These 39 stations have now become a permanent part of the USGS Advanced National Seismic System backbone network. To achieve a more uniform station coverage, the TA installed an additional 20 "advance deployed" stations (so named because many of the sites were installed to the east of the then-current TA footprint). The USGS is responsible for operation of the ANSS backbone network and USArray has no ongoing O&M responsibility or obligation for the RefNet stations, apart from the 20 TA stations that are considered part of the RefNet. These 20 TA stations will be operated for the duration of the USArray project.

MAGNETOTELLURICS (MT)

The MT component of USArray includes seven permanent observatories spanning the continental United States, as well as 20 station equipment sets that are deployed campaign-style each summer (Figure A5.4). During the summer campaign, each of the 20 portable station sets is deployed at two to three different locations on a 70-km station spacing grid (similar to the seismic TA), for about three weeks per location. Data have been collected from 221 temporary sites in the northwest quadrant of the United States over the past four summers. The MT effort has performed noise comparison tests to evaluate different electrode designs, and has standardized the production of uniform, consistent electrodes. Data quality has been high, with the permanent stations achieving response functions to periods of 100,000 s or more, and virtually all of the temporary sites yielding usable transfer functions (despite the last couple of years being in a solar minimum, which has greatly reduced source levels).

DATA MANAGEMENT (DM)

USArray data are archived and distributed via the IRIS Data Management Center. Over 27 terabytes of EarthScope seismic data have been archived to date, and these data are distributed at rates exceeding 8 terabytes per year. All USArray data are made available through the request tools supported by the DMC, and the TA data are also served through the real-time data streaming protocols supported by the DMC. USArray data usage has been very high, with more than twice

Figure A5.3. Training the deployment team at the beginning of an FA experiment.

FigureA5.4. Students installing magnetotelluric system during summer field campaign.

Figure A5.5. Participants in siting workshop jump to demonstrate the sensitivity of the nearby seismometer

Figure A5.6. Active Earth interactive touch-screen kiosk. Kiosks like this one have been loaned to institutions in states where the TA is currently active. This one is located at the University of Nebraska-Omaha.

as much data being delivered to researchers as is collected. There are hundreds of different users of USArray data every month, with some users obtaining USArray data at the rate of hundreds of gigabytes per month.

SITING OUTREACH (SO)

The Siting Outreach component of USArray is implemented in collaboration with IRIS E&O to facilitate siting of USArray stations and works with numerous state and local organizations to encourage the use and understanding of USArray. University PIs and students are recruited every summer to do the initial reconnaissance for TA stations sites. Over the last several summers, more than 100 students from 38 different universities have done site reconnaissance on 970 different TA stations sites. To further broaden the reach of USArray, the SO team works with the PIs and their respective Communications Office to issue press releases about their involvement in EarthScope. This activity has generated significant interest from local news media and has resulted in a growing number of print, online and broadcast stories about the project, including an article in *USA Today* in June 2010. The SO team also produces and distributes *onSite*, a publication prepared twice each year to communicate news about USArray and EarthScope to more than 1100 current and former hosts of Transportable Array stations. Additionally, SO has helped organize science cafes and workshops (Figure A5.5), developed content for the Active Earth Display interactive kiosk (Figure A5.6), loaned Active Earth Display kiosks to sites in the USArray TA footprint, and distributed AS-1 seismometers to teachers and trained them in the use of these instruments (Figure A5.7).

Figure A5.7. Teachers locate an earthquake during an EarthScope Workshop

INITIATIVES UNDER THE CURRENT COOPERATIVE AGREEMENT

Innovation is a fundamental element of USArray activities, because there is little or no precedent for seismological and magnetotelluric operations on the spatial and temporal scales of USArray. USArray's basic operating characteristics, such as the numbers of instruments and the number of station sites occupied per year, are defined under the current five-year Cooperative Agreement with NSF. A control process is used to manage changes to these activities. However, within the broad operating objectives of USArray's current Cooperative Agreement, there have been a number of innovations and initiatives aimed at enhancing data quality, data availability, and scientific value.

CASCADIA INITIATIVE

The USArray component of NSF's Cascadia Initiative is being undertaken as a special ARRA-funded supplemental activity under the existing Cooperative Agreement. This initiative is aimed at addressing fundamental questions about episodic tremor and slip and other processes along this important subduction zone. As part of the initiative, the TA has re-installed 27 TA stations along the Pacific coast, from the Canadian border to northern California. Besides the TA stations, the Cascadia Initiative will include the upgrade of some 232 Plate Boundary Observatory GPS stations to higher-rate sampling and will include 60 ocean bottom seismometers deployed offshore, in both shallow and deep waters. The TA stations are being sited with careful consideration given to the locations of any existing broadband stations so that the uniform station coverage of Cascadia is achieved.

Each of the TA stations deployed as part of the Cascadia Initiative is equipped with three-component broadband and strong-motion sensors. Data flows into the IRIS DMC and is part of the TA data flow. Virtual Network Definitions for the Cascadia Initiative have been set up to facilitate making single data requests to obtain all relevant Cascadia seismic data (the VND will include the offshore stations as well, once the data and metadata have been archived).

ATMOSPHERIC PRESSURE AND INFRASOUND OBSERVATIONS

To leverage the TA as a large-scale observing platform, investigators at UCSD sought and obtained NSF MRI funding to augment every TA station with barometric pressure and infrasound sensors. In effect, the TA becomes a telescope looking upward as well as downward. The regular grid of barometric pressure sensors will support studies of mesoscale atmospheric dynamics and the relation of pressure variations to seismic signals (e.g., tilt on the horizontal seismic components). The infrasound sensors will measure signals from energy that propagate long distances in Earth's upper atmosphere. These sensors will provide an order-of-magnitude increase in the worldwide infrasound station sites, providing observations of unprecedented spatial extent.

TA STATION DESIGN

The TA is engaged in a continuous, ongoing effort to refine station designs to provide uniform, high-quality, high-reliability stations. The TA has engineered refinements to vault design, such as the Vault Interface Enclosure (VIE) that enhances reliability. This design shields delicate parts from ambient conditions, reduces costs by providing a single hardened environment for multiple small components (saving costs on the packaging of the individual components), and provides comprehensive power management that improves station reliability. The VIE project is only a single example of the continuous refinement in procedures and practice that is part of the "rolling" of the TA. Enhanced collaboration between USArray, GSN, and PASSCAL under the Instrumentation Services component of the new RIS management structure, will help ensure that design refinements like these will be coordinated across all IRIS programs.

NEW OPPORTUNITIES AND DIRECTIONS

The approaching integration of the IRIS Core program and USArray Cooperative Agreements presents an opportunity to build on USArray's success to date. A tight integration already exists between USArray operations and the IRIS core programs. This relationship has been a key element to USArray's success while simultaneously enhancing the IRIS core programs. A unified Cooperative Agreement will provide an opportunity to further align management activities and practices, while at the technical level, it will reinforce the strong integration that already exists. A unified Cooperative Agreement places maximum importance on the net scientific return from the IRIS infrastructure by reducing programmatic differences and increasing efficiency.

By its original design, USArray leverages the existence and expertise of IRIS core programs by integrating activities wherever possible. Such integration played an essential role in the construction phase of USArray—providing a functioning and experienced management and infrastructure that allowed USArray to get off to a fast and efficient start while allowing the core programs to accommodate the growth associated with USArray-related activities in a holistic fashion. Several examples of the integrated USArray-IRIS core activities include:

- The FA effort shares facilities and personnel with the IRIS PASSCAL program. This arrangement makes efficient use of the specialized infrastructure and expertise that was initially developed to support PASSCAL. Both FA and PASSCAL investigators benefit from innovations developed in either program. A unified Cooperative Agreement will improve the structure for cost sharing of development activities that benefit both programs.
- USArray data management activities are provided within the context of the IRIS DMS. Setting up separate data management system for USArray would have been redundant with DMC services and would not have realized the economies of scale inherent in the DMS. The USArray waveform quality-control effort is, in part, based at the DMC and has enhanced the DMS program's expertise in this important area.
- USArray's siting outreach activities are managed and staffed by personnel shared with the IRIS E&O program. The E&O program incorporates a wide range of highly specialized expertise in outreach related activities. This relationship has allowed USArray to tap into a far greater range of expertise and resources, on an as-needed basis, than it otherwise could. The two programs, working together, have been able to take on several initiatives that would have been too large for either program individually—such as the Active Earth Display work and the development of the Teachable Moment slide sets.
- During the MREFC phase of USArray, the construction and upgrade of Permanent Array stations was facilitated by the IRIS GSN program staff and their network partners.

USArray and IRIS core program technical performance and scientific return are high. The existing, robust scientific/programmatic advisory structures are key to maintaining this high performance. USArray has a well-developed advisory structure, and the IRIS core program standing committees also feel a strong sense of involvement and ownership of USArray. The unified Cooperative Agreement will ensure that the advisory structure framework is integrated and adapts to the evolution of the programs.

A single Cooperative Agreement will also improve synchronization of the budget process across the USArray and IRIS core programs, facilitate both program planning and execution, and streamline the process for sharing resources.