PASSCAL Magnetotelluric Facility – WBS 1.1.4

Magnetotelluric (MT) studies record Earth's ambient electric and magnetic fields to produce conductivity models of the crust and mantle comparable in resolution to seismic imaging methods. Conductivity is a complementary physical property to seismic velocity and is particularly sensitive to the presence of fluids. Joint analysis of co-located seismic and MT data sets greatly improve the ability to determine the structure of the crust and mantle (e.g., McGary et al., 2014). To support these investigations of the continental lithosphere, IRIS proposes to establish a national, multi-user MT instrumentation pool at the PIC. This IRIS facility will be a resource for current and future MT investigators, bringing MT capabilities into the mainstream, and leveraging PIC expertise to facilitate new multidisciplinary geophysical investigations. These MT facility plans are in direct response to a recommendation in the "Futures" Facility Workshop Report (Aster and Simons, eds., 2015; p. 36) that "*future facilities should include centralized and maintained access to 100 long-period and wideband MT systems to support PI-led campaigns.*"

The EarthScope USArray MT community data set, collected by Oregon State University (OSU), has exposed many investigators to MT techniques and data. However, support for PIs to conduct their own MT experiments has been a relatively small part of the USArray MT activity, thus limiting potential for growth in the number and variety of experiments and users of MT techniques. In the NGEO, we will establish an environment where MT will flourish, using the same practices that have made the PASSCAL seismological program so successful.

Description and Capabilities of the Magnetotelluric Facility

Initially, the PASSCAL MT facility will utilize MT resources (**Figure MT-1**) developed under the EarthScope USArray MT program to support PIs in NSF-funded, PI-driven experiments. IRIS manages this existing capability through a subaward to OSU, who operates a depot of MT systems. As the NGEO proceeds, the existing obsolete instruments from the USArray MT program will be replaced with modern, more capable instruments, and the MT depot capability will transition to the PIC at New Mexico Tech to provide PIs with seamless, standardized tools and support across both seismological and magnetotelluric capabilities.

IRIS will procure new commercial-off-the-shelf (COTS) long-period systems with the goal of growing the MT instrument pool into a significantly larger and more diversified community resource than it is today. The existing instrument pool consists of 27 portable long-period Narod Intelligent Magnetotelluric Systems (NIMS) and one LEMI-417 long-period MT system. **Table MT-1** shows the instruments that will be available at the beginning of the NGEO award. The NIMS are no longer manufactured and will be replaced using an open, competitive procurement process, with careful validation and testing to ensure that the new instruments will meet all community performance objectives.

The MT operational model in the NGEO will transition from the present EarthScope program where MT data are collected by USArray staff as part of a community experiment to a PI-driven model, like PASSCAL, in which the facility primarily supports individual PI and larger community-funded experiments. A PI scheduling database will be employed with maintenance and logistics tracking systems—all part of the current PASSCAL capability. Links between U.S. MT practitioners and a robust overseas MT community are strong and, in many cases, collaborations have been essential to gain access to equipment and capabilities not available domestically. We will continue to support international collaborations and sharing of MT instrumentation and expertise.

Facility capabilities will include testing, repair, storage, staging, shipping/receiving of MT systems, training PIs on best practices for deployments, and assisting with fieldwork and data handling as needed. Deployments of MT instruments typically last several weeks, and the facility will initially have the capacity for at least one large deployment (15–20 systems) at any given time. Eventually, this will grow to three deployments. Software resources will be furnished to PIs for quality control, processing, and production of time-series data and data products for archiving at the IRIS DMC, with guidance available to PIs during this process. The facility will leverage several IRIS-related forums to promote the use of MT capabilities, including short courses, Research Experiences for Undergraduates (REU) opportunities, and webinars. Through both the PIC and its community activities, IRIS will create an atmosphere for the natural

FIGURE MT-1. The current fleet of community magnetotelluric (MT) systems, including three-component magnetometers (left) and receivers and electrodes (right), is sufficiently portable, but aging. New instruments will result in a more robust capacity for portable, PI-led surveys.

TABLE MT-1. Current inventory of MT systems.

INSTRUMENT	COUNT
NIMS transportable MT system	21
NIMS transportable MT system (converted from Backbone type)	6
LEMI-417 MT system	1
PbCl electrode pairs	~70

connection between seismic, MT, and near-surface geophysical investigators. With IRIS-facilitated OBSIP activities, we will be ideally situated to pursue cross-shoreline and marine MT collaborations.

Research Supported by the Magnetotelluric Facility

The MT facility will support PI-driven experiments funded through a diverse set of NSF programs. Electrical conductivity, the physical property measured by MT, provides a unique constraint on various Earth processes, especially those involving fluids. MT surveys can directly contribute to constraining the rheology of the crust and mantle (e.g., Jones et al., 2013), mapping the distribution and circulation of fluids and volatiles in Earth's interior (both aqueous fluids and partial melt), particularly in subduction settings (e.g., Soyer and Unsworth, 2006; Wannamaker et al., 2009; Worzewski et al., 2010; Heise et al., 2012; McGary et al., 2014; Evans et al., 2014), and understanding the structure and evolution of the lithosphere and underlying asthenosphere (e.g., Meqbel et al., 2014; Bedrosian and Feucht, 2014; Sarafian et al., 2015) (**Figure MT-2**). An emergent area where electromagnetic (EM) methods can play a critical role is in understanding the role fluids play in generating seismicity. MT instrumentation in the NGEO can contribute to cross-shore surveys of subduction zones or passive margins.

The constraints provided by EM methods are most powerful when viewed in combination with those from other geoscience disciplines. This includes a parallel analysis of conductivity with seismic properties (e.g., Jones et al., 2013), as well as incorporation of geochemical and laboratory constraints into a systems view of target areas. Although joint inversion of seismic and MT data is an emerging field, the use of seismic constraints to guide and improve MT models is well documented (e.g., McGary et al., 2014). Electromagnetic studies also provide unique and valuable constraints for assessing the vulnerability of power infrastructure to space weather.

Plans for the Facility Over the Next 10 Years

The MT facility will evolve over the first half of the award, transitioning from the current facility at OSU to become part of the PIC. This consolidation reduces the overhead of operating two similar facilities, makes efficient use of the larger, longer-term PASSCAL facility to broaden access to MT instruments, and facilitates joint seismic/MT experiment support. IRIS will ensure a smooth transition with minimal impact on continuing experiment support. Early on, OSU staff will focus on transmitting technical lessons learned from the operation of EarthScope MT-TA stations to the staff at the PIC. This will be done through a series of site visits and joint tasks, such as developing equipment training and field support programs. Initially, a small number of EarthScope NIMS and related equipment will be transferred to the PIC for training both staff and PIs. The PIC will serve as the primary point of contact for equipment requests and shipments. The MT systems will be available alongside the PIC's inventory of seismometers to encourage cross-disciplinary studies. Following the model of seismic equipment loans, no insurance or user fees will be charged to U.S. PIs.

IRIS will conduct one or more competitive procurements to add approximately 100 long-period and 40 wideband MT systems during the span of the award. Long-period MT provides similar resolution to many traditional lithosphere-scale seismic imaging methods. Wideband MT systems are sensitive to crustal-scale structures and will bridge the capabilities of the Near Surface Geophysics Facility and the long-period MT instrument pool. Our goal is to replace and exceed the current capacity of the existing NIMS systems by Year 3 of the award, to reach a new level of long-period MT capability and establish some wideband capability by Year 7, and have a full inventory of wideband systems by the end of the award. The procurement process will entail communication with vendors through requests for information and the purchase of pilot instruments for test and evaluation, proceeding quickly but deliberately toward larger procurements.

In addition, IRIS will create a community resource of open, shared MT data processing software tools. The tools will enable the PIC to support PIs with quality-controlled time-series data for archiving at the IRIS DMC. In addition, this software will produce MT Transfer Functions (MTTFs),

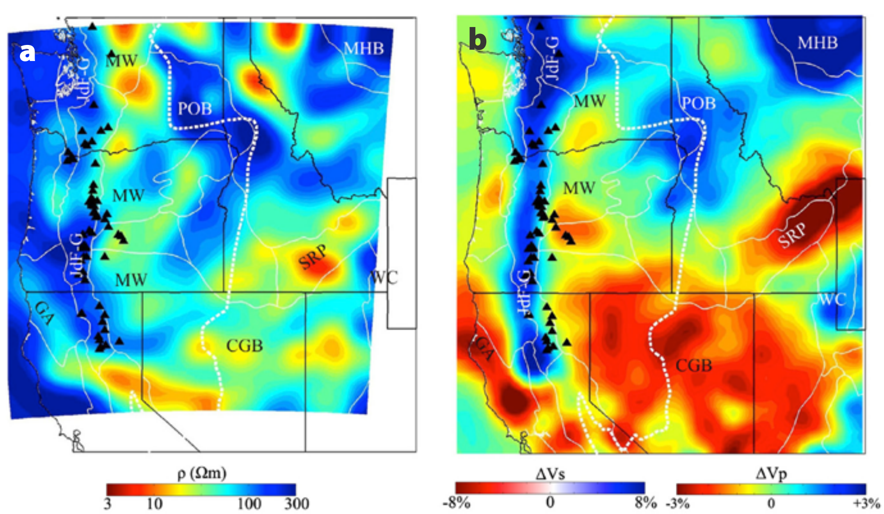

FIGURE MT-2. Joint seismic and electromagnetic studies have proven particularly useful in understanding the structure and evolution of the lithosphere and underlying asthenosphere. Comparison of (left) conductivity model at 100 km depth (Bedrosian and Feucht, 2014) to (right) P-wave velocity model at 90 km depth (Schmandt and Humphreys, 2010). Key features in common include the Juan de Fuca-Gorda Plate (JdF-G) variability in the mantle wedge (MW) above the subducting slab and magmatism in the Snake River Plain (SRP).

a standard data product used in MT analyses. Like time-series data, MTTFs will be freely and openly available to the broad community after the optional two-year data embargo for PI data sets. With IRIS Data Services, we will explore the potential automation of MTTF processing as a web service, available to PIs for all archived continuous MT data.

IRIS will broaden recognition, accessibility, and collaboration for MT science. IRIS and PIC staff will promote these capabilities through short courses and information sessions at NGEO-related workshops and other large Earth science meetings during Years 2-6, including the biennial and internationally focused Electromagnetic Induction of the Earth Workshop. We will sponsor a community science workshop in Year 6. MT practitioners will be engaged for data processing short courses and REU sponsorship. IRIS management and governance will ensure coordination with facility staff supporting shallow EM-related geophysics proposed under the Near-Surface Geophysics Facility.

Management and Organization

MT facility activities will be supported through subawards to OSU and NMT. During the first two years, there will be a transition from OSU to the PIC; however, the PIC will oversee day-to-day activities. The current IRIS MT Facility Manager will oversee the transition of the MT facility from OSU to NMT and associated subawards, equipment procurements, budgeting, and reporting. After the transition is complete, the IRIS PASSCAL Facility Manager will assume responsibility for the MT facility at the PIC.

The transition between subawards will be carefully structured and paced. Goals for technical interchange, software development, and acquisition of new instruments will be clearly articulated and closely managed by IRIS. When the NGEO award begins, we will have in place a working group of stakeholders composed of management and technical staff from IRIS, the PIC, and OSU, to oversee the progress of various elements of the transition. This group will meet regularly (virtually) to measure progress against milestones set out in the formal transition plan. It will also seek guidance with members of the MT community as needed. There is some specific risk in the recapitalization of instruments. The selection of COTS hardware may be relatively limited and from small vendors, thus requiring extra time for selection, testing, and delivery. As a result, OSU will continue to maintain the NIMS and leverage their reserve of instruments until new instruments are fully integrated at the PIC.

NGEO community input on the technical capabilities and operation of the MT facility will be provided by the Portable Geophysical Instrumentation Standing Committee and the Instrumentation and Network Services Advisory Committee. Input from the MT community will be especially valuable for this nascent program. As this will be a program in transition, we will assess the performance of the program and adapt, as necessary, to ensure that community needs are being met. Once the facility has fully transitioned to the PIC, we will conduct an independent community-led review of this facility to provide feedback and guidance to ensure an appropriate level of service to the MT community.