DIVISION OF
Earth Sciences

GUIDE TO MULTI-USER FACILITIES

Instrumentation & Facilities Program
Division of Earth Sciences
National Science Foundation

Available at: http://www.nsf.gov/geo/ear/if/facil.jsp

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Division of Earth Sciences – Instrumentation & Facilities Program

INTRODUCTION

At the time of this writing, the *Instrumentation & Facilities Program* of the Division of Earth Sciences (EAR/IF) at NSF supports twenty-two (22) national, multi-user facilities on behalf of the earth sciences research and education community. Although ranging widely in the scope and cost of their individual operations, all of the facilities share a common attribute. They provide to their respective basic research and education communities on a national or regional scale certain complex and expensive technical and logistical capabilities that would otherwise be impractical to make available to individual or small groups of investigators.

This ***GUIDE TO MULTI-USER FACILITIES*** is intended primarily as a service to the potential user who needs an introduction to the range of services available. In assembling the guide, each Director was asked to provide a description of their facility. Interested researchers are encouraged to contact the facility directly for further information.

All facilities described in this guide are reviewed on a regular basis by the *Instrumentation & Facilities Program* using the NSF merit review system. The ability of a facility to provide the basic research and education community efficient and timely access to its technical capabilities is one of the important criteria used by EAR/IF in reviewing performance. Comments on the performance of these facilities or on any other topic relevant to the material presented in this guide are welcome.

The reader of this guide should also explore research and education opportunities at other EAR-supported activities funded outside of the *Instrumentation & Facilities Program*. These include: the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (http://www.cuahsi.org/), the National Center for Earth Surface Dynamics (http://www.nced.umn.edu), Sustainability of Semi-Arid Hydrology and Riparian Areas (http://www.sahra.arizona.edu), the Southern California Earthquake Center (http://www.scec.org/), Computational Infrastructure for Geodynamics (http://www.geodynamics.org/), and EarthScope (http://www.earthscope.org). Access to many of these facilities may be requested in proposals submitted to the core science programs within the Division of Earth Sciences and the EarthScope Program (solicitations revised annually and available at the EAR website: http://www.nsf.gov/div/index.jsp?div=EAR).

Program Director:

Dr. David D. Lambert
Instrumentation & Facilities Program
Division of Earth Sciences, Suite 785
National Science Foundation
4201 Wilson Boulevard
Arlington, Virginia 22230
Tel: (703) 292-8558
FAX: (703) 292-9025
E-mail: dlambert@nsf.gov

Program Director:

Mr. Russell C. Kelz
Instrumentation & Facilities Program
Division of Earth Sciences, Suite 785
National Science Foundation
4201 Wilson Boulevard
Arlington, Virginia 22230
Tel: (703) 292-8558
FAX: (703) 292-9025
E-mail: rkelz@nsf.gov

WWW Home page URL: http://www.geo.nsf.gov/ear/if/facil.htm

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Seismological Facilities for the Advancement of Geoscience and EarthScope (SAGE)

Scientist in Charge:

Bob Detrick, President
IRIS
1200 New York Avenue, NW #400
Washington, DC 20005
Tel: (202) 682-2220
FAX: (202) 682-2444
E-mail: detrick@iris.edu

Contact Person:

Leslie Linn
IRIS
1200 New York Avenue, NW #400
Washington, DC 20005
Tel: (202) 682-2220
FAX: (202) 682-2444
E-mail: leslie@iris.edu

Facility Description:

SAGE (Seismological Facilities for the Advancement of Geoscience and EarthScope) is a multi-user facility operated by IRIS (Incorporated Research Institutions for Seismology: www.iris.edu). IRIS was formed in 1984 by twenty-six universities to provide a national focus for the development, deployment, and support of modern digital seismic instrumentation. Today, membership in this nonprofit consortium includes 122 U.S. research institutions as full members, 2 U.S. Affiliates, 22 Educational Affiliates and 122 Foreign Affiliates. IRIS is dedicated to the operation of science facilities for the acquisition, management, and distribution of seismological data. IRIS-managed programs contribute to scholarly research, education, earthquake hazard mitigation, and verification of the Comprehensive Nuclear-Test-Ban Treaty. IRIS is funded primarily through a Cooperative Agreement from NSF – Seismological Facilities for the Advancement of Geoscience and EarthScope (SAGE). The SAGE Facility components include the Global Seismographic Network, a Portable Seismology instrumentation pool that supports PI-driven experiments and comprises elements of the former PASSCAL and EarthScope/Flexible Array instrument pools, the Transportable Array, magnetotelluric instruments and data, Polar Support Services, a comprehensive Data Management System, and Education and Public Outreach activities. These comprehensive, high-quality geophysical facilities that enable exciting discoveries in seismology and the Earth sciences.

Portable Seismology

The Portable Seismology pool supports PI-drive cutting-edge seismological research into Earth's fundamental geological structure and processes. The facility provides portable instrumentation for National Science Foundation, Department of Energy, and otherwise funded seismological experiments around the world including the polar regions. Portable Seismology experiment support includes seismic instrumentation, equipment maintenance, software, data archiving, training, logistics, and field installation. Over 850 multi-channel and 1000 single-channel recorders, 450 broadband, 270 short period and 400 high frequency sensors and support equipment are available. Over 50 individual experiments ranging from a few to more than 2500 instruments are supported annually. The PASSCAL Instrument Center at the New Mexico Institute of Technology in Socorro, NM is responsible for supporting field experiments; maintaining equipment; implementing improvements in hardware; and developing software for efficient data collection and initial processing. Data from experiments supported by Portable Seismology are distributed through the IRIS Data Management Center.

Bob Woodward, Director of Instrumentation Services
IRIS
1200 New York Avenue, NW #400
Washington, DC 20005
Tel: (202) 682-2220
FAX: (202) 682-2444
E-mail: woodward@iris.edu

GLOBAL SEISMOGRAPHIC NETWORK

The Global Seismographic Network (GSN) is a 150+ station, globally distributed, state-of-the-art digital seismic network providing free, realtime, open access data through the IRIS DMS. The Global Seismographic Network (GSN) is the focused effort of the U.S. seismological research community to provide a permanent state-of-the-art, broadband, digital network of

seismic instrumentation for research on the three-dimensional structure of the Earth and the study of earthquakes and other seismic sources. The GSN is a partnership between IRIS and the U.S. Geological Survey, cooperating under a Memorandum of Understanding. GSN stations are installed and operated by the U.S. Geological Survey Albuquerque Seismological Laboratory and, via a subaward from IRIS, by the University of California, San Diego. GSN global siting plans are coordinated with other international networks through the Federation of Digital Seismic Networks (FDSN), of which IRIS is a founding member. Beginning in late 1986 with the installation of the first broadband seismometers, the GSN has seen steady progress and serves as a fundamental resource in the study of earthquake dynamics and tomographic analyses of the elastic and anelastic structure of the Earth.

Kent Anderson, Program Manager – GSN
1200 New York Avenue, NW #400
Washington, DC 20005
Tel: (505) 228-3082
FAX: (202) 682-2444
kent@iris.edu

DATA MANAGEMENT SYSTEM

The Data Management System (DMS) is the primary conduit for data flow within IRIS and to the broad scientific community. The DMS acts as the archive for all data collected by the SAGE Facility. The DMS also receives, archives and distributes data from a variety of other data sources, most notably the international Federation of Digital Seismographic Networks (FDSN). All broadband data from the GSN, Portable Seismology, Transportable Array, and FDSN are available in a seamless fashion from the DMC in SEED format. Active source data are available in SEG-Y format. As of May 1, 2014, the Data Management Center (DMC) had more than 260 terabytes (260×10^{12} bytes) of seismic waveform data from over 9000 submitting stations. Fully redundant copies of waveform data, database tables, and operating software are available at an active backup location in Livermore, California. The DMS shipped almost 400 terabytes of data to the research community in 2013.

The core of the DMS is the IRIS Data Management Center (DMC) located in Seattle. Other nodes of the system include the GSN Data Collection Center at UCSD, the USGS GSN DCC at Albuquerque and the DMC Host at the University of Washington. A mirror site of the data at the DMC is located at Lawrence-Livermore National Laboratory in California. In addition to its role of archiving and distributing data, the DMS is responsible for quality control of IRIS generated data and has a well-established mechanism in place to monitor and correct data problems as they are discovered.

The DMS is now generating many data products defined by the research community, drawing from the primary observational data managed at the DMC. Ground Motion Visualizations, the EARS system that automatically calculates receiver functions, synthetic waveform data generated at Princeton, tomographic models of the Earth through the Earth Model Collaboration effort, and a suite of event-based products are among the products being supported at the DMC.

Tim Ahern, Program Manager - DMS
1408 NE 45th Street Suite #201
Seattle, WA 98105
Tel: (206) 547-0393
FAX: (206) 547-1093
tim@iris.edu

EDUCATION AND PUBLIC OUTREACH

The seismological community recognizes the potential for coordinated Education and Public Outreach (EPO) activities in seismology to contribute significantly to the advancement of national awareness, interest, and understanding of science and mathematics. EPO Program activities are targeted at audiences ranging from K-16 students to the general public, and are focused on areas where IRIS is well-positioned to make substantive contributions stemming from its strong research and data resources. The EPO staff works in close collaboration with diverse allies, including IRIS members, K-12 teachers, undergraduate institutions, science museums, and other national and regional Earth science organizations. Current efforts include a Research Experiences for Undergraduates program where students conduct research with seismologists throughout the US, a range of K-16 educator workshops, widely distributed teaching modules and associated tools, and an Educational Affiliate membership for undergraduate institutions desiring to improve their seismology instruction. The Seismographs in Schools program provides

seismographs and software for viewing and interpreting seismograms as well as an online community where schools throughout the world share data and resources. Outreach to the general public is enhanced through a very successful Distinguished Lecture Program (in collaboration with the Seismological Society of America), permanent exhibits at major museums and "Active Earth" displays designed for installation at visitor centers, parks and universities. Improved access to and use of seismic data are facilitated via our website, along with other informational materials including Teachable Moment slide sets released shortly after major earthquakes, and educational animations and videos.

John Taber, Program Manager – EPO
1200 New York Avenue, NW #400
Washington, DC 20005
Tel: (202) 682-2220
FAX: (202) 682-2444
taber@iris.edu

TRANSPORTABLE ARRAY – COMPONENT OF EARTHSCOPE

EarthScope brings a new suite of facilities for research on the structure and dynamics of the North American continent. The Transportable Array, now part of SAGE, is a network of 400 high-quality broadband seismographs that are being placed in temporary sites across the conterminous United States from west to east, and Alaska, in a regular grid pattern. With station spacing of about 70 km in the lower 48 and about 85 km in Alaska, Transportable Array data are extremely useful for mapping the structure of Earth's interior. After a residence time of two years, each instrument is picked up and moved to the next carefully selected location on the eastern edge of the array. When completed, nearly 2000 locations will have been occupied during this program. In August 2007, the first footprint was established from north to south along the westernmost quarter of the United States.

Each of the Transportable Array stations consists of a three-component broadband seismometer with associated signal processing, power, and communications equipment. In the early phase of the experiment, significant effort was devoted to the design of the temporary vaults to house the instruments, which resulted in a configuration that provides both high-quality data and a data return of greater than 90%. Data from each station are continuously transmitted to the Array Network Facility at the University of California, San Diego, where initial operational and quality checks are performed, and then sent to the DMC, where all data and associated metadata are archived.

Bob Busby - Transportable Array Manager
1200 New York Avenue, NW #400
Washington, DC 20005
Tel: (508) 801-7628
FAX: (202) 682-2444
busby@iris.edu

MAGNETOTELLURICS - COMPONENT OF EARTHSCOPE

The magnetotelluric (MT) component of EarthScope consists of both permanent and portable elements that measure naturally occurring electric and magnetic fields. The backbone component consists of seven permanent MT stations installed across the United States as a reference network. These data are integrated with other geophysical data to identify Earth's thermal structure and study the significance of fluids in the crust.

Twenty transportable MT systems complement the seven permanent MT stations. The transportable MT instruments are being used for deployments of approximately one-month duration on a nominal 70-km grid spacing for imaging of crustal and lithospheric conductivity structure in areas of special interest as proposed by the MT community and approved by NSF.

The MT stations and instruments are operated and maintained by Oregon State University under a subaward from IRIS.

Andy Frassetto – Project Associate
1200 New York Avenue, NW #400
Washington, DC 20005
Tel: (202) 682-2220

FAX: (202) 682-2444
andyf@iris.edu

IRIS, SEISMOLOGY, AND THE PUBLIC INTEREST

While the advancement of science is the primary goal of IRIS, perhaps an equal achievement of the Consortium has been to demonstrate that national and international scientific communities can cooperate on programs that not only advance our understanding of the physical world, but also address the current needs of our society. IRIS works with federal, state and international agencies to enhance IRIS facilities into multi-use resources for applications in earthquake hazards, global earthquake monitoring and the international verification of nuclear test ban treaties. Many nations use IRIS GSN stations as their contribution to the International Seismic Monitoring System. Instruments from the IRIS PASSCAL Program are used by scientists funded with Department of Defense and Department of Energy research grants to characterize seismic wave propagation in areas of concern for treaty monitoring. IRIS also works in partnership with the U. S. Geological Survey, both in developing the IRIS GSN and the U. S. Advanced National Seismic System (ANSS), and in making the data from these stations available for use by the National Earthquake Information Center in their location and cataloging of national and global seismicity. Through the PASSCAL Program, the RAMP initiative (Rapid Array Mobilization Program) provides portable instruments for use in the detailed study of aftershocks immediately following important earthquakes.

IRIS produces publications available to the scientific and educational communities. These include an IRIS Electronic Newsletter, educational posters and "1-pagers", an on-line DMS Newsletter and numerous technical reports. Many publications, including the IRIS Newsletter, are available online at www.iris.edu/hq/publications.

Ray Willemann – Director of Planning
1200 New York Avenue, NW #400
Washington, DC 20005
Tel: (202) 682-2220
FAX: (202) 682-2444
ray@iris.edu

MEMBERSHIP IN THE IRIS CONSORTIUM

Educational and not-for-profit institutions chartered in the U.S., with a major commitment to research in seismology and related fields, may become Members of IRIS. Two and four year colleges and universities with a commitment to teaching undergraduate Earth science including seismology may become Educational Affiliates. Research institutions and other not-for-profit organizations both inside and outside the U.S. engaged in seismological research and development, which do not otherwise qualify for IRIS membership, may be elected Affiliates or Foreign Affiliates.

Additional information on membership can be obtained by completing the membership request form at
http://www.iris.edu/hq/about_iris/membership/become_a_member

WWW Home page URL: http://www.iris.edu

Consortium for Materials Properties Research in the Earth Sciences (COMPRES)

Scientist in Charge:
Jay D. Bass
COMPRES
Geology Department
University of Illinois Urbana-Champaign
605 E Springfield Ave.
Champaign, IL 61820
Tel:(217) 333-1018
FAX:(217) 244-5149
E-mail: jaybass@illinois.edu

Contact Person:
Stephen Picek
COMPRES
Geology Department
University of Illinois Urbana-Champaign
605 E Springfield Ave.
Champaign, IL 61820
Tel : (217) 333-6379
FAX: (217) 244-5149
E-mail: spicek2@illinois.edu

Facility Description:

The Consortium for Materials Properties Research in the Earth Sciences (COMPRES) has been established to promote research, technology development, and educational activities related to the behavior of materials at extreme pressure-temperature conditions typical of the deep Earth and other planetary bodies. Membership in this consortium currently includes 60 US institutions and 43 foreign affiliates. Over the past decade, a variety of sophisticated tools have been developed to study Earth materials at extreme conditions. Many of these technological developments have involved the exploitation of national X-ray synchrotron facilities. The mission of COMPRES includes providing access to these advanced facilities for the broader Earth science community, further development of technology, and educational outreach at a variety of levels (including professional workshops). Full information on how to request use of COMPRES facilities (including synchrotron beamtime), becoming a member of the consortium, submitting proposals for projects under COMPRES, or participating in other activities can be found on the COMPRES website (http://www.compres.us).

CENTRALIZED FACILITIES

COMPRES supports a variety of facilities for research at high pressures and temperatures, and experimentation on phases that exist under extreme P-T conditions. There is currently great demand for beamtime to perform high-pressure experiments at national synchrotron facilities. COMPRES is responding to help meet that demand by providing expanded access to synchrotron facilities for high-pressure research at Brookhaven National Laboratory (the National Synchrotron Light Sources NSLS and NSLS-II), Argonne National Laboratory (the Advanced Photon Source, APS), and Lawrence Berkeley National Laboratory (the Advanced Light Source, ALS). Depending on the size of the user team and their experience, support provided by COMPRES can include training in the use of equipment, assistance in performing experiments, and help with the analysis of data. Information and applications for beamtime can be obtained through the COMPRES website: http://www.compres.us. Much of the experimental capability involves diamond anvil cells (DAC) or large-volume multi-anvil presses (LVP or MAC).

NSLS: National Synchrotron Light Source at Brookhaven National Laboratory

Facilities include three experimental stations (*X17B2, X17B3* and *X17C*) on the superconducting wiggler beamline X17, and the infrared (IR) beamline (*U2A*). Equipment is available for high-pressure X-ray studies using multi-anvil presses and diamond cells, and IR studies with the DAC. The types of experiments that can be performed include measurements of the P-V-T equation of state, phase transformations, crystal structures, stress state and rheological properties, absorption, reflectance, P and S acoustic wave velocities, dilatometry, kinetics, and infra-red spectroscopy under a range of extreme P-T conditions. The NSLS will stop operating on September 30. 2014. The commissioning of the new synchrotron source at BNL, the National Synchrotron Light Source II (NSLS-II) is currently in progress and parts of the high pressure program from NSLS will transition to NSLS-II, whereas other parts will transfer to beamline 6 (BM6) at APS (see below).

X17C is dedicated to diamond-cell applications, using focused white radiation for energy dispersive X-ray diffraction (EDX) or a focused monochromatic beam for angle dispersive X-ray diffraction (ADX) experiments in the photon energy range 20 – 40 keV. The facility provides the following experimental capabilities:

- EDX and ADX for polycrystalline samples in diamond cells at temperatures to 1100K with resistance heating.

- Single-crystal X-ray diffraction up to 100 GPa, on samples as small as 1 micron.
- Ruby fluorescence spectroscopic system for pressure calibration.
- Off-line laser-heating equipment for temperatures up to 4000K at high pressure.

X17B3 is a dedicated DAC hutch with focused high-energy monochromatic beam up to 100keV and white radiation for ADX and EDX studies. The hutch is larger than X17C and provides complementary capabilities that are unfeasible in the restrictive X17C space. X-ray studies of Earth materials can be performed at cryogenic temperatures (in liquid helium cryostat to 4K) and along the entire geotherm from the crust to the core using double-sided laser-heating equipment for high temperatures up to 4000K.

X17B2 is a dedicated hutch for studies using multi-anvil large-volume presses. The capabilities include:
- A DIA apparatus (SAM 85), capable of 10 GPa and 2000 K on cylindrical samples 2 mm in length and 1 mm in diameter.
- A D-DIA apparatus for significant axial deformation (up to 50% shortening) of sample in biaxial compression.
- A "T-cup" two-stage (6-8 or Kawai-type) device, routinely capable of 20 GPa and 2000 K with smaller samples.
- Both white and monochromatic X-rays for ADX and EDX experiments.
- X-radiography experiments to measure sample length changes and absorption.
- Ultrasonic interferometry measurements of P and S velocities to P -T conditions representative of the transition zone.
- Ability to measure differential stress on samples, rheologic properties and yield strength.

U2A is an infrared facility dedicated to high-pressure spectroscopy and microspectroscopy studies, and in particular, using diamond and gem anvil cells. The capabilities include:
- Far- and mid-IR reflectivity and absorption measurements from ambient to multimegabar pressures and temperatures in the range of 4 - 1000 K.
- Two Bruker FT-IR spectrometers (Vertex 80v and IFS/66v) for the spectral range 30-25,000 cm -1 and four IR microscopes including a Bruker Hyperion 2000 and IRscopeII microscope, a custom made vacuum microscope for far-IR absorption, and an integrated microscope system for both IR and Raman experiments at high pressure and variable temperature.
- Companion Raman, UV-visible absorption/reflectivity and ruby fluorescence capability together with DPSS lasers, cryostats, and furnaces.

NSLS-II: National Synchrotron Light Source II at Brookhaven National Laboratory

The NSLS high-pressure X-ray and infrared programs will transition to NSLS-II beamlines starting in October 2014. The X-ray Powder Diffraction (XPD) beamline at the National Synchrotron Light Source II, which will be open to general users October 1, 2015, will provide facilities for multi-anvil press and diamond anvil cell experiments. The FIS beamline will provide capabilities for infrared high-pressure experiments using the diamond anvil cell.

XPD hutch D is a shared hutch with a high-energy monochromatic beam. A multi-anvil large-volume-press and diamond anvil cell program will be established in hutch D of XPD. XPD will operate with monochromatic focused, unfocussed or parallel beam in the energy range between 30-70 keV. The facility will extend capabilities now at X17-B2/B3/C of NSLS for diamond cell experiments and large-volume multi-anvil experiments, with greatly enhanced performance.
Capabilities for diamond anvil cell experiments will include, ADX for polycrystalline and single-crystal samples, resistive heating and laser heating for simultaneous high pressure and temperature experiments from room temperature to ~4000 K, ruby fluorescence spectrometric system for pressure determination.
The large volume press facilities include a 1000 ton press driving several apparatusses:
- A D-DIA apparatus for axial deformation (up to 50% shortening) of samples in biaxial compression.
- A "D-T25" two-stage (6-8 or Kawai-type) device, routinely capable of 20 GPa and 2000K with biaxial compression.
- X-radiography experiments to measure sample length changes and absorption, ultrasonic interferometry measurements of P and S velocities at high P -T conditions, measurements of differential stress, rheologic properties, and yield strength.

Frontier Synchrotron Infrared Spectroscopy Beamline under Extreme Condition (FIS) at NSLS-II: FIS is the successor of the U2A IR-DAC facility at NSLS, the only dedicated high-pressure synchrotron IR facility in the world.
It will adapt one of the novel design features of NSLS II – the large-gap IR dipole– to provide unparalleled brightness and more than an order of magnitude more flux compared to U2A throughout much of the IR spectrum. It will also have the improved far-IR capabilities that have made the high-pressure synchrotron IR program at NSLS unique. The IR source will also have exceptional stability for spectroscopic studies under extreme conditions such as static and dynamic compression and variable temperatures. Construction of the beamline hutch will be completed and all existing equipment at U2A moved to FIS by early 2015. At that time, the integrated optical facility for far-IR to UV absorption and reflectance spectroscopy with conventional sources, together with laser Raman and photoluminescence spectroscopy will open to users for experiments – *i.e.*, during the

NSLS/NSLS-II "dark period." Full synchrotron IR capability will be available no later than October, 2017, with early completion anticipated pending efforts to obtain supplemental funding.

Advanced Photon Source (APS) at Argonne National Laboratory:

Multi-Anvil Press: Beamline BM6 will house a significant portion of the large-volume high-pressure facility that has been in service at X17B2 at the NSLS and will be available for general users January 1, 2015. It will be equipped with the white radiation (EDX) equipment and capabilities from the superconducting wiggler beamline at NSLS (X17B2). The equipment uses a 250 ton press (SAM-85) with various tooling, including:

- A DIA apparatus, capable of 10 GPa and 2000K on cylindrical samples 2mm in length and 1 mm in diameter
- A Deformation DIA (D-DIA) apparatus for significant axial deformation (up to 50% shortening) of a sample in biaxial compression
- An RDA (Rotational Drickamer Apparatus), which provides large shear strain at pressures and temperatures near the top of the lower mantle

Single crystal and powder diffraction: In collaboration with Sector 13 (GSECARS), COMPRES is supporting a new facility for high-pressure diamond anvil cell research at the APS, Partnership for eXtreme Xtallography (PX^2), which is located at experimental station 13BMC of GSECARS. The new beamline offers a focused, monochromatic 30 keV incident beam and a unique 6-circle heavy duty Newport diffractometer, optimized for variety of advanced crystallography experiments, including structure determination, equation of state, and diffuse scattering analysis. Currently under construction is state of the art optical spectroscopy and laser heating system that will enable heating single-crystal samples to temperatures of thousands of K and allow data collection during heating. The PX^2 facility will support diamond anvil cell experiments with both single- crystal and powder samples with state-of-the-art resolution in the pressure range 0-100 GPa.

COMPTECH is the COMPRES Technology Center at Argonne, with a staff Technology Officer. The main goals of COMPTECH are to:

- Identify experimental technology needs and development opportunities of importance for the COMPRES community
- Spearhead partnerships with existing beam line facilities at the Advanced Photon Source that are of interest to the COMPRES community
- Lead community-oriented development of infrastructure and experimental methodology projects at these facilities.
- Coordinate activities of collaborative user groups that utilize these facilities.

APS Gas Loading Facility: COMPRES and GSECARS jointly operate a gas loading facility for diamond anvil cells at sector 13 of the Advanced Photon Source at Argonne National Laboratory. This facility is capable of loading non-flammable, non-hazardous gases (He, Ne, Ar, CO_2, etc.) at pressures up to 25,000 PSI in the diamond anvil cell. The gases can be used as a quasi-hydrostatic sample environment, or as high-pressure samples themselves.
This facility operates in two modes:

1. Mail-in mode is available for users who are not conducting their experiments at the APS. Cells are mailed to the APS where the staff scientist will load the desired gas and then return the cell to the user. At this time mail-in service is only provided for He and Ne gases in the standard symmetrical (Princeton) diamond anvil cell. This service is available to staff and visitors at COMPRES member institutions in the United States.
2. On-site mode is available for users who are conducting their experiments at the APS, either at GSECARS or any other APS beamline. In this mode the staff scientist will assist the users in loading their cells and training them to do so. Once users are proficient in the loading technique they can load their cells without assistance. This service is available to any user at the APS, regardless of affiliation or nationality.

Nuclear Resonant and Inelastic X-ray Scattering at 3-ID and Mössbauer spectroscopy: Beamline 3-ID of the APS is dedicated for high-resolution ($\Delta E = \sim 1$ meV) inelastic X-ray scattering and nuclear resonant scattering studies. It is comprised of 3 experimental stations: 3-ID: B, C, and D. 3-ID. It is a dedicated beamline for inelastic X-ray scattering studies, optimized in the energy range of 7-27 keV. There are microfocusing capabilities in each station, and proper infrastructure for high-pressure research, such as ruby fluorescence, laser and external heating, and cryogenic cooling. Measurements performed provide phonon dispersion curves and phonon density of states for single-crystal or powder samples, allowing observation of pressure-induced amorphization, magnetic and structural phase transitions. Velocities Vp and Vs, elastic moduli, Gruneisen parameters, Debye sound velocity, and force constants are among the measured parameters. There are unique capabilities for iron, which is important for Earth sciences applications. Using nuclear resonance technique, valence change, crystal lattice distortions, spin transitions and magnetic phase transitions can be determined. 3-ID maintains fiber laser heating infrastructure to measure melting point and Debye sound velocity at temperatures exceeding 3000 K, and pressures exceeding 2 Mbar.

Access to 3-ID beamline is through a currently active Partner User Proposal, as well as through the General User proposal system. Over 40 % of the total beamtime at 3-ID is dedicated to high-pressure research.

Mössbauer: Attached to the 3-ID beamline, there is a dedicated Mössbauer spectroscopy laboratory, with two spectrometers. COMPRES users are offered support for characterizing Fe-bearing samples using this laboratory, and expert assistance in analyzing results.

ALS: Advanced Light Source at Lawrence Berkeley National Laboratory (West Coast Synchrotron Facilities)
COMPRES-funded facilities for high-pressure X-ray experimentation are available to the geosciences community at beamline 12.2.2 of the Advanced Light Source at Lawrence Berkeley National Labs. This source is a superbend, 1.9 GeV, 500 mA source equipped with a Si(111) monochromator with an operational energy range between 6 and 40 keV, and a multilayer monochromator for energies between 14 and 28 keV. This beamline is typically used for high-pressure powder and single-crystal diffraction or scattering studies with a focused X-ray beam. Simultaneous external heating and laser-heating capabilities allow probing of a wide suite of pressure and temperature conditions: specific topics probed by users include equations of state, phase equilibria, element partitioning, glass and melt structural studies, kinetics of phase transitions, preferred orientation/strength/slip systems of minerals, and the behavior of nanocrystals. Complementary measurements are frequently conducted (with COMPRES assistance) at microdiffraction beamline 12.3.2. Potential users should contact Alastair MacDowell at aamacdowell@lbl.gov A partial list of the present capabilities includes:

- X-ray diffraction on polycrystalline and single-crystal samples using diamond cells with high resolution CCDs, including both a MAR 345 and a Bruker P200 detector; corresponding X-ray scattering measurements are also conducted on amorphous samples at extreme pressures.
- Diamond cells available to users for X-ray diffraction or X-ray spectroscopic studies at both ambient temperatures and with resistance heating to 1700 K.
- Two-sided infrared laser heating coupled with spectroradiometric temperature determinations for diffraction at simultaneous pressure and temperature in high-pressure diamond cell samples. Temperatures to ~6000 K are accessible at high pressures. This set-up is supplemented with high-quality sample imaging capabilities.
- Radial diffraction capabilities for texture measurements at high-pressures and temperatures: our radial experiments are interfaced with both external and laser-heating capabilities, and allow characterization of preferred orientation throughout the pressure/temperature range of Earth's mantle.
- On-site ruby fluorescence for pressure measurements both on-line and off-line at the beamline, and extensive state-of-the-art sample preparation facilities, including a high-quality micromachining laser mill for gasket preparation and a high-pressure gas loading system constructed on the well-known GSECARS design. The latter equipment is designed to ensure hydrostaticity at high pressures, and represents a key part of our sample preparation facilities.

Multi-anvil Cell Assembly Development Project at Arizona State University.
The multi-anvil cell assembly project is a centralized effort to develop, produce, and distribute multi-anvil cell assemblies numerous institutions including both synchrotron facilities and home laboratories. This facility is engaged in the supply of standard and specialized designs multi-anvil cell assemblies. Currently about 15 different multi-anvil cell designs are available, for both online (for beam lines) and offline (conventional) applications. The project also engages in the development of new assemblies in response to COMPRES community needs, results in the development of several new assembly designs each year. Cell designs are readily available for the two most common types of multi-anvil apparatus: the 6-8 Kawai-Endo type, and the DIA devices (regular and D-DIA). Conventional assemblies, assemblies designed for in-situ X-ray diffraction, and specialized measurement assemblies such as ultrasonic, deformation, and electrical conductivity assemblies are in continuous development. This facility responds to inquiries about different designs and enhanced capabilities from the community. Contact Kurt Leinenweber (KURTL@asu.edu) for more information.

COLLABORATIVE RESEARCH AND DEVELOPMENT

In addition to supporting facilities, COMPRES promotes the development of new technology through Infrastructure Development projects. Current Infrastructure Development projects include development of new cryogenic techniques for low-temperature high-pressure for nuclear resonant and inelastic X-ray scattering, and upgrading of the COMPRES-GSECARS gas loading facilities for diamond anvil cells, and simultaneous Brillouin scattering with X-ray diffraction. Submissions of new Infrastructure Development projects are encouraged; contact Abby Kavner (akavner@igpp.ucla.edu) or Jay Bass (jaybass@illinois.edu). COMPRES also cultivates and nurtures collaborative scientific projects that utilize the facilities it manages or which build on the infrastructure development projects it sponsors. These projects are typically multi-institutional initiatives and are submitted and reviewed by the existing Programs in the Division of Earth Sciences at the NSF. For additional information on such collaborative research programs, contact Jay Bass (jaybass@illinois.edu) or see the COMPRES website for additional details.

EDUCATION AND OUTREACH

COMPRES education and outreach promotes the scientific investigation of the Earth, its materials, and its processes among students, researchers and the general public. The education and outreach program includes:

- Distinguished Lecturer Series: COMPRES supports visits by distinguished lecturers from the COMPRES community to science departments within the US. Priority is given to colloquia at four-year undergraduate institutions, and non-COMPRES-member institutions. Visits are free of charge to the host institutions. See www.compres.us for more information.
- The development of an "Introduction to Mineral Physics" course (MP101) which consists of readings, recorded lectures and homework assignments that is available on-line at https:/faculty.unlv.edu/pburnley/COMPRESMP101.html.
- The development of a collection of modular instructional materials for teaching and learning mineral physics available from the NAGT On the Cutting Edge - Professional Development for Geoscience Faculty project (http://serc.carleton.edu/NAGTWorkshops/mineralogy/mineral_physics/index.html)
- A careers and education section of the COMPRES website, which includes listings of positions, career profiles, advice on choosing graduate programs, advice for grad students and post docs and a page for graduate students and post docs to post their profiles. Educational resources are also available from the website including links to the COMPRES course and modular educational materials as well as relevant pages on Wikipedia that have been initiated or edited by members of the mineral physics community.
- Promoting the dissemination and advancement of knowledge through topical workshops. We strongly encourage the participation of the entire Earth science community (particularly students and post-docs) in these efforts, and encourage proposals for new projects. For more information on COMPRES education &outreach activities, see www.compres.us, or contact Jay Bass (jaybass@illinois.edu).
- With funding from the Geosciences Directorate at NSF, the Photon Sciences Division of Brookhaven National Laboratory and the Graduate School of Stony Brook University, a new diversity program has been established at Stony Brook in Geosciences Instrumentation. Graduate students in this program pursue an M.S. degree via formal courses and a thesis research project related to the facilities at the National Synchrotron Light Source of BNL. The goal of this new initiative is to position graduates for employment as Science Associates at the national laboratories of the U. S. Department of Energy, such as BNL. This program is led by Robert Liebermann and Lars Ehm at Stony Brook (Robert.Liebermann@stonybrook.edu, lars.ehm@stonybrook.edu) and Gabriel Gwanmesia at Delaware State University (ggwanmesia@desu.edu).

MEMBERSHIP IN THE COMPRES CONSORTIUM

Educational and not-for-profit US Institutions are eligible to become members. Other organizations and non-US institutions are eligible to be affiliated members with a non-voting representative. Detailed information on the application process is described on the COMPRES website (www.compres.us), or contact Jay Bass (jaybass@illinois.edu).

WWW Home page URL: http://www.compres.us

Geodesy for the Advancement of Geoscience and EarthScope (GAGE)

Scientist in Charge:

M. Meghan Miller, President
UNAVCO, Inc.
6350 Nautilus Drive
Boulder, CO 80301-5554
Tel: (303) 381-7514
FAX: (303) 381-7501
E-mail: meghan@unavco.org

Contact Person:

Charles Meertens, Director, Geodetic Services
UNAVCO, Inc
6350 Nautilus Drive
Boulder, CO 80301-5554
Tel: (303) 381-7465
FAX: (303) 381-7451
E-mail: meertens@unavco.org

Facility Description:

GAGE (Geodesy Advancing Geoscience and EarthScope) is a multi-user facility operated by UNAVCO (www.unavco.org) to facilitate geoscience research and education using geodesy. UNAVCO is a non-profit, university-governed consortium which includes 106 US academic members that participate in its governance and science community. Another 93 Associate Members include organizations that share UNAVCO's purpose at home and abroad, giving UNAVCO global reach in advancing its mission. This academic community shares a collective vision to transform human understanding of the changing Earth and its hazards by enabling the integration of innovative technologies, open geodetic observations, and research, from pole to pole. The UNAVCO Consortium operates UNAVCO Inc., a 501(c)(3) that provides services in instrumentation, engineering, data, cyberinfrastructure, and education and outreach. UNAVCO's core funding, provided by NSF-Divisions of Earth Sciences and Polar Programs, as well as the NASA Solid Earth and Natural Hazards Program, supports the GAGE Facility. Smaller awards from a number of agencies and sponsors extend UNAVCO's work, often with a focus on developing new geodetic capabilities or data system enhancements to extend community reach.

GAGE facilities managed by UNAVCO supports geoscience investigations through coordination and planning with the geosciences community, and the provision of services in field engineering and community equipment pools, data curation, archiving, discovery, access and integration, technology innovation, and testing, acquisition, and deployment of new technologies and capabilities. Further, it maintains and enhances state-of-the-art global geodetic infrastructure that is developed and operated through international collaborations.

GAGE services are grouped in three broad research and education support programs:

1. *Geodetic Infrastructure (GI):* integrates activities and resources in support of geodetic instrumentation, observing systems and networks across a heterogeneous suite of technologies;

The GI program integrates all geodetic infrastructure and data acquisition capabilities for continuously operating observational networks and shorter-term deployments. Supported activities include development and testing, advanced systems engineering, the construction, operation, and maintenance of permanent geodetic instrument networks around the globe, and engineering services tailored to PI project requirements. The GI program also provides engineering services to individual PIs for shorter-term GPS and TLS projects, and other investigator-led data acquisition that were formerly part of the "core" geodetic facilities managed by UNAVCO. The GI program coordinates closely with Geodetic Data Services to assure the highest standards of data quality control, integrity of metadata, ease and transparency of data access for the GAGE user community, and to provide appropriate and timely metrics on data usage for sponsors.

The EarthScope Plate Boundary Observatory (PBO) – the preeminent geodetic facility on Earth of integrated geodetic sensor networks – is the largest component of the GAGE Facility. PBO includes more than 1,100 continuous Global Positioning System (GPS) stations distributed across the United States, and concentrated on the active plate boundaries in the western contiguous US and southern Alaska. PBO also includes 75 borehole strainmeters and 78 borehole seismometers deployed along the San Andreas Fault and above the Cascadia subduction zone and volcanic arc. Tiltmeters (26) and pore pressure sensors (22) are also collocated with the other borehole instruments. The integrated nature of EarthScope observations has been especially important in Cascadia, where broadband seismic observations from over 70 stations (27 of them established through EarthScope) and high-rate, low-latency real-time GPS geodetic observations at 372 PBO stations are being supplemented with offshore

observations at over 60 ocean bottom seismic stations and a number of temporary USArray FA deployments. Geodetic imagery and geochronology services supported under GeoEarthScope extend fault histories to millennial timescales.

2. The GAGE Facility also includes a number of other continuous GPS networks, such as the Global GPS network, foundations to the International GNSS Service (IGS) global network and the International Terrestrial Reference Frame (ITRF), and supports installation and operation of arrays including, the Continuously Operating Caribbean GPS Observational Network (COCONet), the Trans-boundary, Land and Atmosphere Long-term Observational and Collaborative network (TLALOCNet) that is under construction in Mexico. EarthScope provides integrated geophysical observations that result in community data sets sampling across the temporal spectrum of Earth deformation processes. In particular, the Plate Boundary Observatory (PBO) including GeoEarthScope provides unprecedented geodetic imaging of plate boundary deformation. Through the GAGE Facility, UNAVCO is committed to enabling efficient testing, adoption, and implementation of rapidly evolving geodetic technologies needed to support cutting edge geodynamics research. The geodetic component of the multi-disciplinary AfricaArray, built with MRI support, and several other smaller continuously observing geodetic networks continue to be supported in collaboration with community stakeholders.

3. *Geodetic Data Services:* data operations, metadata integrity, enhanced community data products and cyberinfrastructure for data security, discovery and accessibility.

Geodetic Data Services (GDS) program, with its subaward partners, provides a comprehensive suite of services including sensor network data operations, data products and services, data management and archiving, and advanced cyberinfrastructure (Figure 3.2-1). Like GI, GDS is a newly configured program within UNAVCO, optimized to enable access to high-precision geodetic data, products, and metadata for use by researchers, and also adapted for accessibility and interpretation for educators, policymakers, and the public. The needs of the geodesy PI community focus enhancements for GDS, with major accomplishments under the current award. Examples include a powerful new Data Archive Interface for discovery of GPS data, web services modernization of the underlying seamless archive with key U.S. partners, and the recent rollout of a new web interface for accessing and ordering SAR data, optimized for a single point of entry to a now coordinated array of holdings with improvements to ease of data access. Close coordination of efforts formerly distributed between UNAVCO Facility and PBO programs supports better utilization of talent and enhanced effectiveness in meeting community needs.

3. *Education and Community Engagement:* supports and integrates education and outreach strategies within and integrated across the organization.

Since its establishment in 2004, activities of the UNAVCO Education and Outreach program have supported the geodetic and broader geosciences community and other focused public constituencies (Figure 3.3-1). The program now operates as Education and Community Engagement (ECE), renamed to better reflect the participatory nature of current and planned initiatives. The UNAVCO and broader geosciences communities rely on ECE to support development of a forward-looking, diversified workforce that draws on and cultivates talent across the demographic spectrum of gender and ethnicity, across international boundaries, and across scientific disciplines, and to inform the public interest and to support the development of partnerships, collaborations, curricula, and student opportunities. ECE collaborates with GI and GDS to ensure stakeholder outreach needs are met. Ongoing core support by ECE includes communicating scientific results from the geodetic community; fostering education through workshops, short courses, and online materials; providing professional development for secondary and higher educators; supporting geo-workforce development including increasing diversity in the solid Earth sciences; strategic support to community members in communicating the broader impacts of their science, and coordinating communications and showcasing results during community-driven response to earthquakes.

Services. In summary, UNAVCO-provided services to the scientific community include:

- UNAVCO manages a community pool of high accuracy portable GPS receiver systems that can be used for a range of applications. These complete systems – receivers, antennas, mounts, power and optional communications – can be deployed for days in episodic campaigns or for many months for longer duration observations. Systems are also available for precision mapping applications.
- UNAVCO manages a community pool of Terrestrial Lidar Scanners suitable for precise geodetic imaging of Earth and ice surfaces. The Facility also provides engineering and data services to support investigator studies.
- UNAVCO acquires, archives, and/or distributes a number of community data sets including GPS, strainmeter, borehole seismometer, tilt meter, and geodetic imaging with radar and lidar, as part of EarthScope's Plate Boundary Observatory.

- UNAVCO provides administrative and logistical support for the WInSAR consortium of universities and research laboratories. With WInSAR, UNAVCO helps coordinate requests for satellite radar remote sensing data acquisition and for data purchase, aiding individual investigators by simplifying interactions with data providers and with government agencies funding science, including NASA, NSF, and the USGS. UNAVCO also provides an InSAR data archive, recently enhanced with web services.
- Engineering resources are available to provide classroom and in-the-field training, project design and implementation, field engineering, TLS or GPS network operations, and technology development for GPS, TLS and other applications.
- Data archiving and distribution are supported for GPS data collected by investigators in campaigns and continuous networks, of as part of community projects coordinated by UNAVCO such as EarthScope and Africa Array. GPS data are available both via ftp and via a data-mining interface: http://facility.unavco.org/data/dai2/app/dai2.html. In a collaborative project, UNAVCO developed web services capabilities to update Seamless Archive Centers (GSAC) for sharing of metadata with GPS archive at Scripps Oceanographic Institution (SOPAC) and Goddard Space Flight Center (CDDIS). This system modernizes seamless access by sharing of metadata, allowing users to obtain data without knowledge of the individual archive holdings or data structures.
- Contributed investigator science products are shared via the UNAVCO velocity and strain archives and a suite of advanced Internet mapping tools and related on-line resources that serve the science and education communities.
- UNAVCO provides guidance to PIs with broader impacts proposal planning and budgeting, pedagogical review of field education materials, development, review and dissemination of geodesy education and outreach materials, and communication of community science results.
- UNAVCO is principally organized to support NSF- and NASA-funded Earth science investigators and projects but it also provides keystone support for wider interdisciplinary geodetic applications across agencies and at the international level. Many of the geodetic tools and techniques developed by the UNAVCO community are publicly accessible via the UNAVCO Web site.

Strategic Partnerships. UNAVCO's mission and capabilities are unique, yet highly collaborative. UNAVCO gains considerable leverage in meeting the needs of the investigator community and in providing value to NSF by working closely with other NSF facilities and collaborations. OpenTopography, NCALM, IRIS, UCAR, NEON, the EarthScope National Office, GEOPRISMS, and OOI all partner with UNAVCO in ways large and small. The UNAVCO Director of External Affairs provides outreach to policymakers and coordination with the international geodesy community.
Membership. UNAVCO Members are academic institutions chartered in the United States (US) or its Territories with a commitment to its mission of promoting geodesy for geosciences research and education. Members must also be willing to make a clear and continuing commitment to active participation in governance and science activities. Associate Membership is available to organizations other than U.S. educational institutions, when those organizations share UNAVCO's mission and otherwise meet the qualifications for membership. To view the current list of UNAVCO's members visit http://www.unavco.org/community/membership/members-map/members-map.html, and to learn about becoming a Member, visit http://www.unavco.org/community/membership/membership.html

Governance. A Board of Directors is charged with UNAVCO oversight and governance, and is elected by designated representatives of UNAVCO member institutions. The Board works with the science community to promote a broad interdisciplinary research agenda based on applications of geodetic technology, to identify investigator needs for infrastructure support, to develop proposals to appropriate sponsors to maintain that infrastructure capability, and to ensure that UNAVCO and its activities provide high quality, cost-effective, and responsive support. UNAVCO also undertakes community-wide activities, including science planning, development and distribution of community data sets for geodesy, professional development for faculty and students, structured student internships for diversity, and related activities.

E-Mail List Service. UNAVCO distributes e-mail of interest to its community through an e-mail distribution list with more than 600 aubscribers around the world. Unav_all e-mail list: http://ls.unavco.org/mailman/listinfo/unav_all.

UNAVCO welcomes inquiries from prospective users of GPS and other geodetic techniques for science applications of these powerful tools.

WWW Home page URL: http://www.unavco.org

GeoSoilEnviroCARS Synchrotron Radiation Beamlines at the Advanced Photon Source (GSECARS)

Scientist in Charge:

Mark L. Rivers
Center for Advanced Radiation Sources
The University of Chicago
Building 434A
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439
Tel: (630) 252-0422
FAX: (630) 252-0436
E-mail: rivers@cars.uchicago.edu

Contact Person:

See Scientist in Charge

Facility Description:

GeoSoilEnviroCARS (GSECARS) is a national synchrotron radiation user facility for earth science research at the Advanced Photon Source (APS), Argonne National Laboratory. The APS is a 7 GeV storage ring producing extremely high brilliance X-ray beams using undulators, wigglers and bending magnets. The GSECARS sector, consisting of an undulator beamline and a bending magnet beamline, is operated by the Center for Advanced Radiation Sources at the University of Chicago.

The principal synchrotron-based analytical techniques in demand by earth scientists are available at GSECARS including:

- X-ray diffraction and spectroscopy in the diamond-anvil cell using monochromatic radiation. Double-sided laser heating is available on the undulator beamline, and resistive heating and single-sided laser heating are available on the bending magnet beamline. Online Brillouin spectroscopy is available on the bending magnet beamline. Both powder diffraction and single-crystal diffraction techniques are available.
- X-ray diffraction, imaging, ultrasonics, and acoustic emission in the large-volume press. Both monochromatic and energy-dispersive techniques are available. The facilities include a 250-ton press on the bending magnet beamline and a 1000-ton press on the undulator beamline.
- Powder diffraction, surface diffraction, and single-crystal micro-diffraction on large Newport 6-circle diffractometers on both the undulator and bending magnet beamlines.
- X-ray absorption spectroscopy including micro-spectroscopy, with beam sizes near 1 μm, and surface studies.
- X-ray fluorescence microanalysis with beam sizes near 1 μm.
- Inelastic X-ray scattering with ~1eV resolution.
- 3-D computed microtomography with samples sizes from 1 to 25 mm and resolutions down to ~1 μm.

Principal research areas include (1) speciation and microdistribution of metals and radionuclides in soils, (2) redox reactions and transport processes and kinetics of metals in soils, (3) sorption processes and reactions of metals at mineral-water interfaces, (4) role of biota in transport processes, (5) oxidation states of igneous systems, (6) metal partitioning and speciation in hydrothermal fluids, (7) crystal chemistry of rare, complex minerals, (8) dynamics of fluid transport in rocks, (9) equations-of-state of mantle phases, (10) rheology studies at high pressure, (11) determination of melting points and the densities and viscosities of melts, and (12) phase transitions and relationships in mantle minerals and candidate core materials.

A research environment is provided where users receive expert assistance in planning and conducting experiments, and with data analysis. This service-oriented mode of operation allows the facility to be accessible to the entire spectrum of synchrotron radiation users from novices to experienced investigators. There are currently no user fees.

Beam time at the GSECARS facility is available to all interested earth scientists through the APS web-based proposal system (http://www.aps.anl.gov/Users/Scientific_Access/General_User/index.html). The APS web page (http://www.aps.anl.gov/Users/Calendars/GUP_Calendar.htm) contains announcements of proposal deadlines. The GSECARS web page (http://www.gsecars.org) contains GSECARS staff contacts for experiment design information, descriptions of available instrumentation and capabilities, hardware and software tutorials, photographs of the facility, recent scientific results

and a publication list. Each year approximately 400 beam time proposals are submitted and 400 unique visiting scientists conduct experiments at GSECARS. Over 200 experiments are performed at GSECARS each year, with over 100 each on the undulator beamline and bending magnet beamlines.

In addition to the experimental stations, GSECARS has laboratories for sample preparation and characterization. For diamond-anvil cell experiments, these include off-line laser heating, Raman and ruby fluorescence spectroscopy, Brillouin spectroscopy, and a gas-loading facility. GSECARS provides office space with computer workstations for users. Convenient lodging for visitors is available on the Argonne Campus at the Argonne Guest House (http://www.aps.anl.gov/travel/anlghhome.html).

WWW Home page URL: http://www.gsecars.org

Purdue Rare Isotope Measurement Laboratory (PRIME Lab)

Scientist in Charge:

Marc Caffee
PRIME Lab
Purdue University
1396 Physics Building
West Lafayette, IN 47907-1396
Office Tel: (765) 494-2586
PRIME : (765) 494-5381
FAX: (765) 496-7228
Email : mcaffee@purdue.edu

Contact Person:

see Scientist in Charge

Facility Description:

Purdue Rare Isotope Measurement Laboratory (PRIME Lab) is a dedicated research and service facility for accelerator mass spectrometry (AMS). AMS is an ultra-sensitive analytical technique for measuring low-levels of long-lived radionuclides and rare trace elements. We routinely measure both man-made and cosmic-ray-produced radioisotopes such as ^{14}C (half-life 5730 years), ^{10}Be (1,380,000 years), ^{10}Be (730,000 years), ^{26}Al (300,000 years), ^{36}Cl (100,000 years) and ^{129}I (16,000,000 years) in natural samples having isotopic abundances down to 10^{-15}.

Although the instruments and detection methods are those of nuclear physics, research applications are concentrated in Earth and planetary sciences. Applications include measuring the exposure time and erosion rate of rocks on the Earth's surface in the range 5,000 to 1,000,000 years, dating and tracing of ground water, ^{129}I as an oceanographic tracer, measuring solar and atmospheric variability using ^{10}Be and ^{36}Cl in precipitation and ice cores, radiocarbon dating of archaeological artifacts, tracing the global carbon cycle with ^{14}C, determining terrestrial ages of meteorites recovered from the Antarctic ice sheet, and tracing of ^{14}C-labeled compounds, aluminum, and calcium in biological systems. We are also currently building a dedicated laboratory for in-situ ^{14}C analyses. Our publications, newsletters, and annual report are available on request.

PRIME Lab is an active teaching facility training graduate and undergraduate students in the departments of Physics, Chemistry, and Earth and Atmospheric Sciences. Every year several Purdue students obtain advanced degrees using AMS and over 100 external scientists and their students use PRIME Lab.

PRIME Lab is based on an upgraded FN (nominal 8 MV) tandem electrostatic accelerator. With higher energies than most accelerators dedicated to AMS, it has the capability to measure the full range of radionuclides including ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca, and ^{129}I. The PRIME Lab is located within the Physics building on the Purdue campus and contains 31,000 sq. ft of floor space, housing offices for PRIME Lab staff and chemical preparation laboratories.

Chemistry operations are an integral part of PRIME lab, offering users not wishing to prepare their own samples the unique opportunity to have their samples physically and chemically prepared for AMS measurements. Separate laboratories allow us to analyze samples covering a wide range of specific activities. Analytical methods have been established for diverse sample matrices, such as rock, soil, sediment, and water, for all nuclides measured by AMS at PRIME Lab. Methods include physical pretreatment as well as chemical separation procedures. We also assist users in planning their sampling trips, to ensure maximum scientific quality. In-house training programs are available for users to learn to prepare their own samples. We also welcome visiting students and scientists. Arrangements are routinely made for visiting scientists to perform the mineral separation or chemical preparation steps themselves after receiving training from PRIME Lab staff.

Purdue University dedicated its tandem accelerator to accelerator mass spectrometry in 1989; external funding began in April 1990; and the first AMS measurements took place in early 1991. The internal upgrade of the accelerator, which included new acceleration tubes and a new charging system, took place from December 1993 through April 1994. We chemically prepare over 800 samples per year and perform AMS measurements on over 5000 samples per year. We are constantly striving to improve AMS methods and develop detection of new nuclides.

PRIME Lab facilities are available to the research community for measurements of the nuclides ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca, and ^{129}I. Sample requirements, performance for each nuclide, and prices are available on our web site. Contact us if you have any questions.

WWW Home page URL: http://primelab.physics.purdue.edu

Institute for Rock Magnetism (IRM)

Scientist in Charge:

Bruce M. Moskowitz, Director
Department of Geology and Geophysics
University of Minnesota
310 Pillsbury Drive SE
Minneapolis, MN 55455-0219
Tel: (612) 624-1547
FAX: (612) 625-7502
E-mail: bmosk@umn.edu

Contact Person:

Mike Jackson, Laboratory Manager
Institute for Rock Magnetism
University of Minnesota
100 Union Street SE
Minneapolis, MN 55455-0128
Tel: (612) 624-5274
FAX: (612) 625-7502
E-mail: irm@ umn.edu

Facility Description:

The Institute for Rock Magnetism (IRM) was established in the fall of 1990 to provide the Earth Science research community with access to advanced facilities and technical expertise for magnetic material characterization. Visiting scholars and resident researchers use the resources of the IRM to study contemporary topics in rock magnetism, paleomagnetism, and a broad range of interdisciplinary fields such as biomagnetism, paleoclimatology, archaeology, planetary science, and nanomagnetism of iron oxides. More than 300 Visiting Fellowships have been awarded since 1990 for advanced experimental or characterization studies involving magnetic properties of natural materials or synthetic analogs.

The same physical principles that govern magnetic information storage in audio/video recording media and in computer disks also operate in geological recording media: rocks and sediments. The processes involved in natural magnetic recording are both complex and inefficient, and the characteristics of natural particulate storage media vary strongly with the mineral composition and grain size of the ferromagnetic particles. The recorded signal of geomagnetic field behavior through time is inevitably distorted by variations in these properties of the recording medium, and the signal is moreover subject to degradation and overprinting by stress, thermal perturbations and chemical alteration. High-fidelity geomagnetic signal recovery depends on separating out this geological "noise," which itself, of course, contains significant information about Earth processes that have affected the medium. Research at IRM thus aims at separate recovery of both the geomagnetic and geological signals in the magnetism of Earth materials as well as understanding the magnetic signatures in extraterrestrial materials.

The instrumentation at IRM enables measurement of the magnetic properties of materials, including AC and DC magnetic moments and Mössbauer spectra, over a wide range of temperatures (4.2 K - 1000 K) and magnetic fields (10^{-5} T - 5 T). In addition, magnetic domain structures may be imaged by various means, including the magneto-optic Kerr effect (MOKE) and magnetic force microscopy (MFM). A recently-built field-free room and newly-acquired magnetometer enable measurement of very weak moments ($\geq \sim 10^{-11}$ Am^2), characteristic of geological and biological materials. This system also allows for the automated measurement of intact sediment core sections.

Research goals have both fundamental and applied aspects. Fundamental rock-magnetic and mineral-magnetic studies are leading to a better understanding of the origin and geological stability of remanent magnetization in fine particles (10 nm - 100 μm) of magnetic oxides, sulfides, and other natural materials or synthetic analogues. Fundamental research is also leading to improved understanding of how measured magnetic properties depend on particle size, shape, stress, and other physical characteristics. This knowledge is simultaneously being applied throughout the geosciences with the development of sensitive magnetic proxies of chemical and grain-size changes caused by tectonic activities, and climatic and environmental change.

Areas of recent research by resident scientists and Visiting Fellows include magnetic phenomena in nanophase and poorly-ordered materials; magnetofossil occurrences and properties; synthesis and magnetic characterization of basaltic Martian-crust analogs; magnetic interactions and exchange in fine-scale hematite-ilmenite intergrowths; magnetic imaging of domain structures in experimentally shocked pyrrhotite, with the goal of understanding planetary magnetic anomalies; and magnetic signatures of climate-driven periodic variations in the physical and chemical characteristics (particle size distribution, mineral composition) of marine sediments, cave sediments and atmospheric mineral dust. Undergraduates from the University of Minnesota and from small colleges and universities in the upper Midwest carry out senior thesis research under guidance from IRM faculty and staff. Each summer, the IRM additionally hosts several undergraduate interns from across the United States. Starting in 2011, the IRM began offering a biennial summer school for rock magnetism for US and international graduate

students. Since 1992, nine biennial conferences have been held in Santa Fe, NM, organized by IRM to advance new interdisciplinary research utilizing rock-magnetic techniques. Similar conferences organized jointly by the IRM and several European institutions were held in Erice, Sicily in 2002, and in Corsica, France in 2008, and have broadened perspectives and promoted international collaborations..

Interested scientists are encouraged to apply to become Visiting Fellows, in one of three categories: (1) Visiting Research Fellowships allow up to ten days use of the full set of *IRM* instruments for in-depth experimental or characterization studies; (2) U.S. Student Fellowships allow up to five days of more closely supervised studies aimed at integrating research and learning; (3). U-Channel Fellowships provide access to the IRM's new u-channel magnetometer system for detailed investigations of natural and/or artificial remanent magnetizations in continuous sediment cores or discrete samples. Applications are accepted twice a year for work to be done during the following half year, and are evaluated by an external Review and Advisory Committee (RAC), comprising experts from paleomagnetism, rock magnetism, solid-state physics and materials science. Proposals are due by October 30 for stays during the following January 1 to June 30 interval, and by April 30 for stays during the following July 1 to December 31. Shorter, less formal visits from other researchers are readily arranged through the laboratory manager. Visiting Fellows receive a substantial exemption from facility usage fees, and other academic researchers are charged at discounted rates.

The *IRM Quarterly* includes abstracts of current articles, news about IRM equipment, reports from Visiting Fellows, updates on meetings, and other relevant information. It reaches people on all continents. Contact the lab to be added to the mailing list. The IRM web site contains information on visiting IRM, and a collection of experimental data from a variety of magnetic minerals.

WWW Home page URL: http://www.irm.umn.edu

UCLA SIMS Laboratory (UCLA SIMS)

Scientist in Charge:

T. Mark Harrison and Kevin D. McKeegan (Co-directors)
Department of Earth and Space Sciences
University of California, Los Angeles
2667A Geology Building
Los Angeles, CA 90095-1567
Tel: : (310) 825-7970 (TMH) (310) 825-3580 (KDM)
Lab: (310) 825-4328
FAX: (310) 825-2779
E-mail: tmh@epss.ucla.edu
mckeegan@epss.ucla.edu

Contact Person:

Axel K. Schmitt
Department of Earth and Space Sciences
University of California, Los Angeles
3667B Geology Building
Los Angeles, CA 90095-1567
Tel: (310) 206-5760
Lab: (310) 825-4328
FAX: (310) 825-2779
E-mail: axel@oro.epss.ucla.edu

Facility Description:

The UCLA SIMS laboratory is supported by NSF's *Instrumentation & Facilities Program* to develop and maintain a national facility for *in situ* microscale isotopic analyses of geologic materials and to provide access to its special capabilities to the broader community to address important problems in earth and planetary science.

Since the inception of facility operations (1996), more than 300 scientists have undertaken projects in the UCLA SIMS lab. Facility productivity has averaged 23 papers per year – including 19 papers in Nature and Science – with a citation impact that is at least 250% higher than the average for publications in geochemistry and geophysics. The UCLA SIMS laboratory is an active teaching facility, training graduate and undergraduate students involved in the Earth and Space Sciences. Since 1995, over 72 completed Ph.D. and M.S. theses relied heavily upon data students collected using our facility. The UCLA SIMS student workshop, an annually event since the last 4 years, has attracted nearly 100 undergraduate and graduate students that were trained in geochemical SIMS applications during a week-long course. Two dozen post-doctoral students have also been trained in the laboratory and several of these now run SIMS laboratories at their home institutions.

The UCLA SIMS laboratory features a continuously upgraded CAMECA ims 1270 that uses both the standard Cs^+ (microbeam) and duoplasmatron (mainly O^-) primary ion sources. In addition, the instrument is equipped with a Ga^+ liquid metal source, a unique feature for a large magnet radius SIMS instrument. Lateral ion beam resolution of ~1 µm in diameter can routinely be achieved (~0.5 µm for Ga^+), although most isotopic analyses utilize beam diameters in the 10 to 30 µm range to quickly achieve desired precision. Like the SHRIMP ion probe, the 1270 routinely attains a mass resolving power (MRP) of up to 5,000 without significant loss of secondary ion intensity; this is necessary for isotopic analysis of certain trace elements at high sensitivity (e.g., Pb in zircon). Oxygen flooding of the sample chamber can further enhance yields for certain trace elements, and mitigate crystal-orientation dependent inter-element bias (e.g., for baddeleyite U-Pb geochronology). Dynamic mass range is 300 (H to UO_2). Like the smaller CAMECA instruments, the 1270 also functions as an ion microscope by direct ion imaging of the sample (with ~0.5 µm lateral resolution), which is a key component for achieving good (~nm scale) spatial resolution during depth-profiling (because it enables elimination of crater edge contributions). Isotopic and elemental variations can also be imaged via scanning ion imaging. For the analysis of negative secondary ions from electrically insulating samples (e.g., O isotope measurements in silicates or carbonates), a normal incidence electron flood gun provides charge compensation which is a prerequisite for high-precision oxygen isotope measurements. A five moveable collector ion detection system (equipped with electron multipliers and Faraday cups enabling a dynamic range of $>10^{10}$) is operational for several types of isotopic analyses. In some favorable cases, precision of isotopic ratios achieved in multicollector mode is comparable to that typical of other traditional high-precision mass spectrometric methods although with SIMS the spatial information regarding complex isotopic distributions in a sample is preserved. The multicollector enables precise and rapid isotopic analysis, and is routinely utilized by visitors to the facility, particularly for investigations of C, O, and S isotopes.

The facility offers access to peripheral instrumentation that is useful for pre- or post-analysis sample characterization. This includes a Tescan Vega3 Scanning Electron Microscope (SEM) which is equipped with a backscattered electron detector (BSD), as well as an EDAX energy dispersive X-ray analysis (EDS) system and integrated monochromatic and color cathodoluminescene detectors. The "VP" option indicates that the SEM can operate under variable pressure mode, meaning that

BSD, CL, and EDS analysis can be performed on uncoated samples. A contact-free surface mapper (ADE Phase Shift MicroXAM) is available for surface characterization and sputter pit analysis. Users also can access a range of optical microscopic imaging tools for documentation.

UCLA SIMS is currently available to the research community for *in situ* microscale isotopic analyses of geologic materials. Please contact us for additional information if you have questions.

WWW Home page URL: http://sims.epss.ucla.edu

Arizona State University SIMS Laboratories

Scientist in Charge:

Richard L. Hervig, Director
School of Earth and Space Exploration
Arizona State University
550 E. Tyler Mall
Tempe, AZ 85287-1404
Tel: Office (480) 965-8427
Lab: (480) 727-7282
FAX: (480) 965-5081
E-mail: hervig@asu.edu

Contact Persons:

Lynda Williams, Manager
School of Earth and Space Exploration
Arizona State University
550 E. Tyler Mall
Tempe, AZ 85287-1404
Tel: Office (480) 965-0829
Lab: (480) 727-7282
FAX: (480) 965-5081
E-mail: lynda.williams@asu.edu

Facility Description:

The Arizona State University secondary ion mass spectrometer (SIMS) laboratories are supported by NSF's *Instrumentation & Facilities Program* to maintain a national facility for the microanalysis of geologic materials. There are multiple emphases at these laboratories: 1) the analysis of light elements and their isotopic ratios (hydrogen to sulfur), 2) training visitors in the use of these instruments, and 3) developing new analytical techniques to match the needs of geochemical researchers.

The instruments available are a Cameca ims 6f SIMS and Cameca NanoSIMS 50L. The Cameca 6f SIMS is suitable for ~10µm spatial resolution isotopic microanalyses of trace levels of selected lithophile trace elements. We commonly measure B and Li as well as S in sulfides. Relatively low precision (±2‰) O-isotope microanalyses can be achieved. The Cameca 6f excels at analysis of volatile elements, including trace hydrogen, carbon, and halogen microanalysis in minerals and glasses. The 6f also maintains high transmission at mass resolving powers up to ~6000. The Cameca 6f can be used for depth profile analyses (e.g., in characterizing diffusion profiles) with depth resolution on the order of 50 nm. The NanoSIMS 50L has a co-axial design with normal primary ion incidence and secondary ion extraction. The design reduces the working distance between the extraction lens and sample surface to 400µm, resulting in small beam sizes and high ion collection efficiency. The high spatial resolution (~50nm for Cs^+ beam and ~200nm for O^-) differentiates the NanoSIMS from other SIMS instruments. High transmission at high mass resolution (e.g., 70% relative transmission at a mass resolving power of 6000), essential for the analyses of small volumes, is achieved by an electrostatic analyzer, a magnetic sector (650mm radius magnet) and optimized transfer optics configuration. Up to seven ionic species can be collected simultaneously from the same sputtered volume through multi-collection by either electron multipliers or Faraday cups. Multi-collection in conjunction with magnetic-field peak jumping can also be performed to measure more than seven species. Relatively precise measurements (~several ‰ (2σ) for O and Mg isotopes) are possible with the NanoSIMS. Both SIMS instruments allow analyses with Cs+ or oxygen primary ion beams (O_2^+, O^-, O_2^-), and both instruments have a normal incidence electron gun for those approaches requiring charge neutralization (e.g., oxygen isotope analyses of insulating phases). The Cameca SIMS instruments can be used to obtain elemental maps of sample surfaces via direct ion imaging with <1 µm lateral resolution, and can be operated in scanning ion imaging mode.

Please contact us for access to or questions about the ASU SIMS laboratories.

WWW Home page URL: http://sims.asu.edu

University of Texas High-Resolution X-ray Computed Tomography Facility (UTCT)

Scientist in Charge:

Richard A. Ketcham
Department of Geological Sciences
University of Texas at Austin
Austin TX 78712
Tel: (512) 471-6942
FAX: (512) 471-0959
E-mail: ketcham@jsg.utexas.edu

Contact Person:

Jessica Maisano, Facility Manager
Department of Geological Sciences
University of Texas at Austin
Austin TX 78712
Tel: (512) 471-0260
FAX: (512) 471-0959
E-mail: maisano@jsg.utexas.edu

Facility Description:

The high-resolution X-ray computed tomography (CT) facility at the University of Texas at Austin (UTCT) makes top-quality X-ray tomographic imaging capabilities available to the scientific community. Our principal focus is on research applications in the earth sciences. The facility combines a variety of tomographic scanning systems with a digital image-analysis laboratory to provide data analysis and visualization.

High-resolution X-ray CT is a completely non-destructive technique for visualizing and measuring features in the interior of opaque solid objects, and for obtaining information on their 3-D geometries and properties. It is useful for a wide range of materials, including rock, bone, ceramic, metal, and soft tissue. High-resolution X-ray CT differs from conventional medical CAT-scanning in its ability to resolve details as small as a micron in size, even when imaging objects made of high-density materials. Examples of tomographic imagery are maintained on the facility's website.

Applications include internal inspection of rocks, fossils, artifacts, organisms, organic tissues, and man-made materials; quantitative textural analysis of crystalline rocks; porosity/permeability assessment; description of 3-D fracture patterns in aquifer and reservoir rocks; quantification of fabric strength, anisotropy and orientation in network materials such as trabecular bone and foams; determination of physical heterogeneity and flow properties of sediment columns; and any physical, morphological, or textural analysis that formerly required tedious physical serial sectioning combined with photography or drafting to document or measure features.

The facility hosts a pair of tomographic instruments to enable imaging across a wide range of sample sizes and data resolutions. Our NSI instrument features two x-ray sources that can be paired with either a linear detector array (LDA) or a Perkin Elmer flat panel detector in a single radiation-safe enclosure. The high-energy 450-kV X-ray source is optimized for imaging relatively large (~7-60 cm diameter; up to 75 cm high) and massive (up to 100 kg) objects at resolutions in the 100's of µm using either detector. The 225-kV X-ray microfocal source, capable of a focal spot size as low as 5 µm, is optimized for imaging smaller objects from ~5-300 mm in diameter and achieves resolutions in the 10's of µm. Our high-efficiency 2048x2048 40-cm Perkin Elmer flat panel detector can be used for both volume and helical CT scanning, with scan durations ranging from a few minutes to hours. The 60-cm LDA permits fan-beam single-slice acquisition and can accommodate larger samples. Our other instrument, an Xradia MicroXCT 400 scanner, is especially suitable for imaging materials that are less attenuating (e.g., foam) and smaller objects (especially < 6 mm) at ultra-high resolution (0.25-5 µm). It features a 150-kV X-ray source, 2048x2048 detector and six objectives ranging from 0.4X to 40X in magnification.

The facility also features a multi-platform computer lab for visualization and quantitative analysis of tomographic data sets, which visiting researchers are encouraged to use. Available software includes both commercial visualization packages and programs developed in-house for specialized processing and analysis.

The facility is strongly oriented toward serving external investigators. More than three quarters of the imaging done is for outside users. Investigators working on NSF-GEO-funded projects (EAR, OCE and AGS) receive priority scheduling and a 50% reduction in user fees. Full information on the facility's capabilities, costs, procedures for access, and answers to FAQs are available on the facility's website.

WWW Home page URL: http://www.ctlab.geo.utexas.edu/

National Center for Airborne Laser Mapping (NCALM)

Contact person:

Bill Dietrich
Department of Earth and Planetary Science
University of California
Berkeley, CA 94720-4767
Tel: (510) 642-2633
Fax: (510) 643-9980
E-mail: bill@eps.berkeley.edu

Contact person:

Ramesh L. Shrestha
University of Houston
NCALM
5000 Gulf Freeway, Building 4, Room 216
Houston, TX 77204-5059
Tel: (832) 842-8882
Fax: (713) 743-0186
E-mail: rlshrestha@uh.edu

Facility Description:

The National Center for Airborne Laser Mapping (NCALM) supports and promotes the application of Airborne Laser Swath Mapping (ALSM) technology in the scientific community. The Center is operated jointly by the Department of Civil & Environmental Engineering, College of Engineering, University of Houston (UH) and the Department of Earth and Planetary Science, University of California-Berkeley (UCB). NCALM uses Optech Inc. Gemini and Aquarius LiDAR systems based at the UH Geosensing Systems Engineering Research Center.

The ALSM observations collected by NCALM are analyzed both at UH and UCB, and made available to the PIs through an archiving and distribution center at UCB. Both the UH and UCB groups contribute to software development that increases the processing speed and data accuracy. NSF-supported researchers should contact UH during proposal preparation to obtain guidance on cost estimates, scheduling and related issues. Once funded, PIs and their students may participate in all phases of the research.

CENTER OBJECTIVES

Primary goals of NCALM are to:

- Make airborne laser swath mapping (ALSM) widely available at affordable cost to the national research community.
- Advance both the technology and the scientific discoveries made possible as a consequence of ALSM.
- Track and evaluate other geosensing and remote sensing technologies that complement ALSM, and develop methods for multi-sensor data collection and fusion.
- Provide training for students to meet the rapidly growing needs of industry and academia.

NCALM MANAGEMENT AND GOVERNANCE

NCALM is overseen by a nine-member Steering Committee (SC), including one elected Chair, from universities across the United States. The SC meets once a year in San Francisco in association with the Annual meeting of the American Geophysical Union. The SC provides guidance and review on the following issues:

- Prioritizing projects
- Cost effective management of the Center
- Information dissemination
- Recommendations for seed project awards
- Opportunities and necessities for technological upgrades
- Liaison and coordination with major NSF programs and Centers such as UNAVCO and OpenTopography, other Federal agencies (NASA, FEMA, USGS, etc.), and Community outreach and workshops.

INFRASTRUCTURE

The NCALM instrumentation is used to collect data in areas selected through the competitive NSF proposal review process. The major components of the LiDAR systems include a Gemini near infra-red sensor (NIR) head, an Aquarius green water penetrating sensor head, and a Waveform Digitizer. Both the Gemini and Aquarius sensors provide up to 4 discrete returns stops for each laser pulse, and simultaneously digitized waveforms for as many as 100,000 per second of the returning pulses of laser light. The discrete and waveform data contain complementary information on the density and distribution of vegetation and the "bare earth" terrain below surface vegetation. The waveform digitizer eliminates the dead time between returns and provides, in the place of 4 discrete returns, an intensity profile of the return signal. These intensity profiles may enable PIs to better detect and map the forest canopy, brush, and structures hidden by the vegetation. The systems operate from a small twin-engine (Cessna 337) aircraft and the laser pulses are directed towards the ground by a scanning mirror. The round trip travel time of the laser light allows researchers to compute the precise three dimensional locations of the points on the ground. The result is a set of latitudes, longitudes and heights of many millions of points on the ground. Research-grade ALSM data can be used to produce a highly-accurate, three-dimensional, digital topographical map of a large area of land surface, including areas covered by shallow bodies of water, including lakes, streams and coastal waters. ALSM data can also be used to map vegetation canopy structure.

NCALM has contracted with Optech Inc. for the construction of a new three color airborne LiDAR sensor, based on the Pegasus system. The new sensor will contain two lasers, with one being frequency doubled, to provide three colors of light with pulse rates up to 300,000 pps (a total of 900,000 pps), and collect range measurements at wavelengths of 0.5320, 1.0640, and 1.550 micrometers. The system will record up to 4 discreet returns per laser pulse, and will be capable of recording full waveform data at rates up to 125,000 pps, at each of the wavelengths. The new Pegasus system will also have an integrated high resolution digital camera. The new sensor is currently being assembled at the Optech facility in Toronto, Canada, and is expected to ready for field tests in September 2014.

OUTREACH

The NCALM budget includes funding for "seed" projects. The fund is used for small demonstration projects for graduate student PIs who need ALSM data sets in different areas of research in the geosciences. The seed funds also provide support for educational and visiting fellowships and/or student programs. The motivation for such seed projects is to have PIs start their preliminary scientific research and subsequently develop larger NSF proposals to make scientific discoveries using observations and data sets from ALSM technology.

WWW Home page URL: http://www.ncalm.org

Arizona LaserChron Center (ALCC)

Scientist in Charge:

George Gehrels, Director
Department of Geosciences
University of Arizona
Tucson, Arizona 85721
Tel: (520) 349-4702
FAX: (520) 621-2672
E-mail: ggehrels@email.arizona.edu

Contact Person:

Mark Pecha, Lab Manager
Department of Geosciences
University of Arizona
Tucson, AZ 85721
Tel : (520) 419-8934
FAX : (520) 621-2672
E-mail: mpecha@email.arizona.edu

Facility Description:

The Arizona LaserChron Center is an NSF-supported multi-user facility that generates U-Th-Pb geochronologic and Hf isotopic information by Laser Ablation-ICP Mass Spectrometry (LA-ICPMS). Our primary goals are as follows:

- Maintain a facility that generates U-Th-Pb ages and Hf isotope ratios of the best precision and accuracy available from a Laser-Ablation Multicollector ICP Mass Spectrometer.
- Provide opportunities for NSF-supported researchers to use our instruments and expertise to address geologic problems.
- Push the development of new applications of laser ablation ICP mass spectrometry.
- Provide opportunities for researchers and students to learn the theory and methodologyof U-Th-Pb geochronology and Hf geochemistry.

The primary instrumention at the Arizona LaserChron Center consists of a Nu Plasma HR MC-ICPMS coupled with a 193 nm Excimer laser (Photon Machines Analyte G2). This configuration is capable of generating U-Th-Pb ages rapidly (~40 per hour), with a precision of 1-2% (2-sigma), utilizing a beam size of 6 to 60 microns. This rapid throughput is optimal for applications that require large data sets (e.g., detrital zircon provenance studies), and allows for a cost of only $4 per age determination for NSF-supported users. During a typical 24 hour analytical session it is possible to generate ~700 ages, which would be sufficient for analysis of ~15 igneous rock samples or 7 detrital zircon samples.

We are excited to announce the recent addition of a Thermo Scientific Element 2 single-collector ICPMS along with a second Photon Machines Analyte G2 laser. This addition provides new opportunities for integration of U-Pb geochronologic and complementary geochemical information (e.g., Hf isotopes and trace element/REE concentrations) through independent operation or split-stream applications.

The spatial resolution enabled by laser ablation also provides a powerful tool for unraveling complex growth/disturbance histories commonly encountered in igneous and metamorphic terranes. Such studies are facilitated by the use of back-scatter and cathode luminescence images acquired with a dedicated Hitachi 3400N SEM (equipped with Gatan Chroma CL-2 and Oxford EDS/EBSD detectors). We are able to routinely conduct U-Th-Pb age determinations on zircon, titanite, apatite, baddeleyite, and monazite. Efforts to develop analytical methods for analysis of rutile are ongoing.

The center presently generates ~50,000 U-Th-Pb ages in support of ~100 separate projects per year. Most of these projects are conducted in close collaboration with LaserChron staff members, who are commonly involved in all aspects of the research (including project design, sample collection, data acquisition, and data interpretation). We find that this helps ensure that the data are acquired and interpreted correctly. Likewise, we encourage researchers to visit the facility and conduct their own analyses so that they fully understand the strengths and limitations of the

geochronologic information. This also takes advantage of the spatial resolution and instantaneous age determination of the LA-ICPMS, which allows an operator to adjust the analytical strategies real-time depending on project goals and complexities encountered.

We particularly encourage students to use the facility, as spatial resolution coupled with real-time age calculation provides a powerful tool for learning the theory and techniques of U-Th-Pb geochronology. To facilitate student involvement, funds are available to subsidize student visits to the LaserChron center.

WWW Home page URL: http://www.laserchron.org

The University of Wisconsin SIMS Lab (WiscSIMS)

Scientist in Charge:

John W. Valley, Professor
Department of Geoscience
University of Wisconsin
Madison, Wisconsin 53706
Tel: (608) 263-5659
Lab: (608) 265-9528
FAX: (608) 262-0693
E-mail: valley@geology.wisc.edu

Contact Person:

Noriko Kita, Lab Director
Department of Geoscience
University of Wisconsin
Madison, Wisconsin 53706
Tel: (608) 262-7118
Lab: (608) 265-9528
FAX: (608) 262-0693
E-mail: noriko@geology.wisc.edu

Facility Description:

The University of Wisconsin SIMS lab (WiscSIMS) was installed in 2005 and became a National Facility for Stable Isotope Geochemistry in 2008 with support from NSF. WiscSIMS provides experienced and inexperienced SIMS users with the highest possible analytical precision and accuracy for in situ analysis of stable isotope ratios at the scale of 1 to 10 micrometers. These ion microprobe capabilities permit analyses in thin section or polished mount to be correlated with textures and information from optics, imaging, or other forms of instrumental analysis. In combination, such data can potentially provide fundamental new levels of understanding for samples of Geological, Planetary, or Biological interest. The advantages are especially great for samples that are zoned, precious, or very small, which cannot be analyzed by other means. Since 2006, over 200 scientists from 60 universities and institutes have worked with WiscSIMS.

The WiscSIMS lab houses the first CAMECA ims-1280. The ims-1280 is a large radius multi-collector ion microprobe incorporating many improvements designed to enhance precision of isotope ratio analysis, including: better focusing of the primary and secondary beam, continuous monitoring of primary beam current during analysis, better control of external magnetic fields in the sample chamber and mass spectrometer, NMR control of analyzer magnet, six sample airlock for changing samples, oil-free rough pumping for cleaner vacuum, all digital electronics, and PC computer control. Sample viewing reflected light microscope has been upgraded using UV-light optics and high definition CCD camera with optical resolution of ~1.5µm. The detector assembly includes 10 electron multiplier and Faraday Cup detectors with five moveable trolleys for simultaneous analysis of a wide range of isotope systems. Both alkali metal (Cs^+) and duoplasmatron (O^-, O^+) sources are available. Spot sizes as small as 250 nm are possible (with Cs), but more generally, a spot of 3 to 10 µm diameter by 1 µm deep is used to increase sample size (~1ng/analysis) and optimize precision. Precision for $\delta^{18}O$ and $\delta^{17}O$ in well-polished silicates is typically better than ±0.3‰ (2 SD, spot-to-spot) with 10µm diameter beam (Kita et al. 2009 Chem. Geol. 264:43-57; Valley and Kita 2009 MAC Short Course 41:19-63).

As of April 2014, the lab has experience with analysis of Li, C, O, Mg, Si, S, and Fe isotope ratios. Best results come from well-prepared samples that are vacuum stable; have a smooth, flat, low-relief surface; and are 25.4 mm in diameter and <5 mm thick (max. 12 mm). Surface relief is minimized by careful polishing and is measured at nm-scale by white light profilometer. Other materials are possible. Accurate analysis requires well-characterized, homogeneous standards with similar chemistry and crystal structure to samples. For oxygen isotope ratios, WiscSIMS has many silicate, carbonate, and oxide standards. Other standards exist or are being developed. Potential users should enquire about standard availability.

Use of associated instrumentation at nominal cost can be arranged in support of projects at WiscSIMS including: an Hitachi S3400N Variable Pressure Scanning Electron Microscope with capability for imaging uncoated samples,

HKL Electron Back Scatter Diffraction (EBSD), Gatan color-filtered CL, Thermo EDS, and BSE detectors; CAMECA SX-51 electron microprobe with 5 crystal spectrometers, EDS, CL, and BSE; and a ZYGO NewView 6300 white light optical profilometer. A new CAMECA FE-SX-5 (field emission electron microprobe) will be delivered late in 2014.

For more information about the capabilities of WiscSIMS and applying to use the facility, please consult our web site (below) and contact John Valley or Noriko Kita (above).

WWW Home page URL: http://www.geology.wisc.edu/~wiscsims/

Center for Transformative Environmental Sensing Programs (CTEMPs)

Scientist in Charge/Contact person:

Scott W. Tyler
Dept. of Geological Science and Engineering
MS 172
University of Nevada, Reno
Reno, Nevada
Tel: (775) 784-6250
E-mail: styler@unr.edu

Scientist in Charge/Contact person:

John S. Selker
Dept. of Biological and Ecological Eng.
210 Gilmore Hall
Oregon State University
Corvallis, Oregon 97331
Tel : (541) 737-6304
E-mail: John.Selker@oregonstate.edu

Facility Description:

The Centers for Transformative Environmental Monitoring Programs (CTEMPs), jointly operated by Oregon State University and the University of Nevada, Reno are multi-user facilities providing field-deployable high-precision fiber-optic temperature measurement systems and wireless self-organizing multi-parameter sensor stations. CTEMPs expanded in 2013 to include Smith College as a collaborating undergraduate facility serving the eastern US. Fiber-optic temperature sensing relies on Raman backscatter to infer temperatures along optical fibers deployed in a wide variety of environmental settings. Typical applications of distributed temperature sensing (DTS) include borehole monitoring, stream environment monitoring, ocean and lake circulation, and soil heat flux. Unlike traditional sensors, DTS systems provide continuous temperature measurements at sampling resolutions as small as 0.12m, yet extending for kilometers. Measurements can be made at frequencies as fast as 1 Hz, thus providing the user with a very high spatial and temporal density of temperature measurements. CTEMPs provides short and intermediate term access to eight field-deployable fiber optic DTS systems, including two ultra-high resolution Silixa Ultimas, which can be shipped directly to project sites. Use fees are very low, and experiment design, installation, and data analysis is supported by a staff of scientists. Instruments are obtained rapidly through an online request form. All non-commercial projects for discovery and education are welcome.

CTEMPs is operating as an instrumentation node of the Hydrologic Measurement Facility of the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. (CUAHSI) and in its four years of operation to date (2009-2013) supported over 55 research projects including 11 Ph.D. and MS dissertations. These projects covered a wide range of topics, including river restoration, aquifer storage and recovery, snow hydrology, glaciology, geomechanics, oceanography, atmospheric science and ecological research. Systems have been deployed across the US, as well as deployments in the Arctic, Costa Rican rainforest, Antarctica Australia and Europe. , CTEMPs has also supported research activities well beyond the Division of Earth Sciences (EAR) including the Divisions of Atmospheric and Geospace Sciences, Ocean Sciences, Biological Infrastructure and the Directorate/Division of Polar Programs. A complete listing of projects and publications can be found at www.ctemps.org/selected-references. DTS systems can be configured for a wide variety of environmental measurements, data storage/data transmission protocols, and operating conditions. CTEMPs also provides as part of the field-deployable systems, wireless autonomous meteorological stations to augment the thermal data collection, as well as advice, guidance, and logistical services to the user community. CTEMPs users have access to instrumentation as well as technical support for experiment design, field deployment, and data interpretation.

CTEMPs also provides a program of no-cost instrument leasing to young investigators and students through its Pilot Program. The Pilot Program provides instruments and services at no cost to innovative projects proposed by these investigators. The CTEMPs Pilot Program call for proposals is quarterly. Each proposal is first reviewed by the CTEMPs PI's to insure only that the proposed effort is consistent with the instrumentation capabilities of the Centers. The proposals are then reviewed by the independent CTEMPs Advisory Board for final approval or recommendation for revision.

CTEMPs in-house instrumentation includes DTS systems capable of operating in a wide range of settings to address diverse experimental needs. CTEMPs DTS instrumentation includes units which may operate in harsh environments (-40 to 60 ^{o}C), and the sensing cable may span temperatures from -100 C to temperatures exceeding 200 ^{o}C. Instruments are typically run on solar power systems, provided by CTEMPs, or can be run on generators or line power, as needed. The instruments have a range of capabilities, with spatial resolutions from 0.25 m to 2.0 m, and temporal resolution from as fast as 1 s to 15 s, and precision from 0.01 to 1 ^{o}C. CTEMPs instruments are focused on measurements over the <5 km range, though instruments capable of reading cables up to 10 km are available as well. For field installation, the Centers maintains a stock of over 30 km of field deployable optical fiber designed for a variety of environments, including deep borehole (high pressure), expanded spatial resolution, high temperature environments and high traffic sites. Both at Nevada and Oregon, a full set of optical fiber testing, fabrication and repair tools are maintained and available either as a service to the user, or for loan during field deployment.

CTEMPs also provides programs focused on developing and advancing the field of distributed environmental sensing for the research community. CTEMPs, working with industry partners, has developed extended resolution (spatial and temporal) DTS systems available to address the most demanding applications of this technology. Additionally, CTEMPs is testing a suite of other sensing systems, including fiber optic distributed strain and acoustic sensing, and a spectrum of low-cost and high precision point-sensors suitable for traditional and wireless networked sensing systems.

CTEMPs conducts a range of hands-on training courses. Primarily, CTEMPs puts on regularly-scheduled two-day intensive trainings on DTS methods including an annual short course preceding the Fall AGU meeting. These have very low registration fees, and include both theory and hands-on use of DTS. These short-courses are designed to help potential users assess the suitability of the DTS tool for their projects. For investigators who have decided to move forward with the application of DTS in their research, CTEMPs conducts multi-day, in-depth trainings, which cover all aspects of DTS theory, experimental design, installation and operation, calibration, and data analysis.

Complete information on how to request use of CTEMPs instrumentation, submitting proposals for projects under CTEMPs and access to training and training materials can be found on the CTEMPs website (www.ctemps.org). CTEMPs training videos on the set-up and operation of DTS systems can also be found on YouTube at: http://www.youtube.com/user/ctempsdts

WWW Home page URL: http://www.ctemps.org

International Seismological Centre (ISC)

Scientist in Charge:

Dmitry A. Storchak
International Seismological Centre
Pipers Lane
Thatcham
Berkshire
RG19 4NS
United Kingdom
Tel: +44 (0)1635 861022
Fax: +44 (0)1635 872351
E-mail: dmitry@isc.ac.uk

Contact Person:

Maureen Aspinwall
International Seismological Centre
Pipers Lane
Thatcham
Berkshire
RG19 4NS
United Kingdom
Tel: +44 (0)1635 861022
Fax: +44 (0)1635 872351
E-mail: admin@isc.ac.uk

Facility Description:

The ISC is an international non-governmental non-profit organization that was set up in 1964 with the help of the UNESCO and IASPEI to compile and distribute the ISC Bulletin – the most definitive and complete summary of world seismicity. In addition to the NSF, the ISC is funded by 61 research and operational institutions and agencies around the world, with major contributions coming from the US, UK, Japan, Russia, China, India, Canada, Germany, France and Italy. The ISC operates from its own building in the UK and collects seismic bulletin data electronically from 130 seismic networks, data centers and observatories worldwide.

Soon after earthquakes or other seismic events occur, preliminary seismic bulletins from networks are received electronically in a large variety of formats and parsed into the ISC database. Data for the same natural events are merged and made freely available from the ISC website as part of the *automatic preliminary* ISC Bulletin. One after the other, preliminary reports from networks are deleted from the ISC database in favor of the revised reports. Once all revised bulletins from networks are available (approximately two years after event occurrence), the ISC runs its own procedure of re-computing parameters of seismic events based on the wealth of all seismic recordings made worldwide and its own location algorithm that uses standard velocity model. The *final* ISC Bulletin is thoroughly reviewed and revised by a team of professional seismologists and made freely available via web and ftp-sites.

OBJECTIVES

- Collection, automatic merging and association of reported bulletin data from networks and data centres around the world, including NEIC, EMSC, USArray, JMA etc;
- Manual Review of hypocentres, phase readings, and related data for events simultaneously reported by several networks approximately of magnitude 3.5 and above;
- Distribution of the ISC Bulletin, both reviewed and un-reviewed, by means of the web-search, ftp, CD-ROMs and the printed ISC Bulletin Summary.
- Maintenance and development of the International Seismograph Station Registry jointly with WDC for Seismology, Denver (USGS) and in coordination with FDSN;
- Maintenance of the IASPEI Collection of Reference Events (GT0-5);
- Update and distribution of the EHB bulletin data collection
- Extension and update of the ISC-GEM Global Instrumental Earthquake Catalogue
- Maintenance of the ISC Event Bibliography

MANAGEMENT AND GOVERNANCE

The ISC is governed by the ISC Governing Council (GC) that comprises representatives of all 62 funding agencies, including NSF. The Governing Council meets every two years and makes fundamental decisions on scientific, operational and financial issues. In addition, the GC elects an Executive Committee (EC) that meets once a year, hears the ISC Director's report and plans and makes recommendations on further development, operation and funding of the ISC between the meetings of the GC. In addition to elected members, the EC includes representatives of both IASPEI and the host institution – Oxford University.

INFRASTRUCTURE

The ISC operates from its own building that it maintains from its own resources. In order to fulfill its mission, the ISC runs a network of web, file and database servers connected with workstations used by 17 members of staff. Internet connection is used to receive original data from networks and also to distribute ISC data to users. Internet connection is maintained via a dedicated high-speed internet link in addition to a number of broad-band channels. The ISC database is also mirrored at three separate servers maintained remotely at IRIS DMC, ERI/University of Tokyo and Lawrence Livermore National Laboratory. Another mirror is maintained for the use by the CTBTO Preparatory Commission and the National Data Centers. All three mirrored database servers are used to operate additional remote ISC web and ftp sites in US, Japan and Austria to provide uninterrupted access to the ISC data.

BROADER IMPACT and OUTREACH

The broader impact of the ISC operations is through basic and applied research based on the Bulletin, ultimately including mitigation of earthquake disasters through planning reliant on realistic seismic hazard analysis and monitoring of the Comprehensive Test Ban Treaty. The ISC Bulletin is the principal data source for some 100 research papers each year, and many more papers depend on the ISC data to select events or stations to be studied, or to establish the seismotectonic setting. The types of studies for which the ISC data are virtually indispensable include seismotectonics, seismic tomography, seismic hazard analysis, earthquake physics, earthquake prediction, and explosion monitoring.

The ISC-GEM Catalogue has become an important source of information for seismic hazard and risk assessment studies.

Members of the ISC staff maintain high visibility in professional scientific organizations and often take part or lead in setting up international standards of scientific data measurement and exchange.

The ISC serves as a unique valuable tool for education in geophysics, routinely provides training to young seismologists from developing countries and broadens opportunities by enabling participation to all citizens, men and women, of many different nationalities. The ISC often answers queries from the media and members of the public following destructive earthquakes or tsunamis.

WWW Home page URL: http://www.isc.ac.uk/ or http://colossus.iris.washington.edu/

LacCore: National Lacustrine Core Facility

Scientist in Charge:

Emi Ito
Department of Earth Sciences
University of Minnesota
Minneapolis, MN 55455
Tel: (612) 624-7881
Fax: (612) 625-3819
E-mail: eito@umn.edu

Contact Person:

Amy Myrbo, Anders Noren, Kristina Brady
University of Minnesota
500 Pillsbury Dr SE
Minneapolis, MN 55455
Tel: (612) 626-7889
Fax: (612) 626-7750
E-mail: laccore@umn.edu

Facility Description:

LacCore, the National Lacustrine Core Facility, centered on the Minneapolis campus of the University of Minnesota, supports the paleolimnological and broader terrestrial community that utilizes core samples for studies that contribute to our understanding of a range of geological and ecological systems, such as past climates and biogeochemical dynamics, on the continents through detailed lithological analysis and archival services of cores and samples. LacCore operates as an open facility to allow community access to specialized field equipment, laboratory instrumentation, and staff expertise for initial core description (ICD) methods including: core splitting; non-destructive multi-sensor core logging; digital linescan core photography; X-ray computed tomography (CT scans); preparation and/or analysis of subsamples for: palynology, diatom and phytolith analysis, imaging and elemental characterization through scanning electron microscopy and energy-dispersive X-ray spectroscopy (SEM/EDS), grain size, carbon coulometry, sulfur coulometry, mineral and phase identification via X-ray diffraction (XRD), biogenic silica, charcoal, thin sectioning, stable isotopic analysis, and optical petrography/smear slide analysis. The Large Lakes Observatory at the University of Minnesota-Duluth campus operates a node of LacCore, providing X-ray fluorescence (XRF) core scanning and digital X-radiographic imaging services for rapid down-core elemental analysis. LacCore provides ambient, refrigerated, and frozen core storage and permanent curation, and as the National Lacustrine Core Repository curates the world's largest and most diverse collection of lacustrine sediment cores, as well as a growing archive of other continental core samples. Samples from the collection are carefully appropriated for the ongoing efforts of researchers, museums, and other educational institutions. LacCore maintains and continually develops a broad array of specialized field equipment available for rental or purchase, for accessing and coring the full range of lacustrine environments and collecting highest-quality cores of maximum length; and serves as the institutional scientific, logistical, and curatorial interface in lacustrine and other continental scientific drilling operations. LacCore staff members are responsible for capture, curation, and dissemination of core metadata and the routine transmission data to the NOAA National Geophysical Data Center. LacCore collaborates with programmers developing cutting-edge software for core description, data visualization, data discovery, and remote collaboration. LacCore is a training ground for several hundred researchers annually, particularly graduate and undergraduate students, in coring and core analysis techniques, and serves as a focal point for and a clearinghouse for best practices to the international scientific community. LacCore funding was renewed for five years in June 2010. In 2014, LacCore staff extended facility services to begin formal operations as the NSF Continental Scientific Drilling Coordination Office (see associated facility description).

LACCORE MISSION, VISION, CORE VALUES

Mission
LacCore advocates for, coordinates, and facilitates core-based research on Earth's continents through collaborative support for logistics, field and laboratory, and data and sample curation and dissemination.

Vision
LacCore strives to be the top facility for seamless coordination and collaborative assistance in all aspects of continental core-based research and education.

Core Values
- Core-based research is essential for developing records of past climate, environment, and biota.
- Building consensus on best practices through long-term community engagement enables acquisition of top-quality cores and data.
- Science, education, and public good must guide LacCore activities.

LACCORE GOVERNANCE

LacCore is governed by a five-member External Advisory Group (EAG), including one Chair from US institutions. The EAG provides guidance remotely as needed, and meets occasionally to discuss and guide major transitions in facility operations. The EAG provides guidance on the following issues:
1. Facility policies, especially those applicable to data and sample access
2. Identification and prioritization of upgrades in facility infrastructure
3. Evaluation of requests for curated sediment samples as needed
4. Selection of LacCore Visiting Graduate Student Fellows
5. Liaison and coordination with NSF

INFRASTRUCTURE

LacCore infrastructure consists of field, laboratory, curatorial, and information technology resources. Physical space includes approximately 3,660 square feet of laboratory, office, and meeting space, 4,280 square feet of sample repository space, and 6,070 square feet of storage for equipment and supplies.

The extensive public pool of coring devices for rental or purchase provides suitable equipment at low cost for nearly all coring environments and protocols. Site survey equipment includes a ground-penetrating radar (GPR) system for sub-bottom profiling of lake sediments or dry land; collaboration with the associated Large Lakes Observatory faculty provides the possibility for access to other geophysical survey equipment including CHIRP and airgun seismic reflection equipment, multibeam sonar, and passive seismic instrumentation. Coring platforms include several watercraft: two 19-foot Carolina Skiff boats (for 5m x 5m Kullenberg piston coring platform with 6.5m tower and moonpool), pontoon boat with moonpool (2.5m x 5m), three 18-foot row/motorboats, cataraft with moonpool (2.5m x 4m), two canoes, two kayaks, and small inflatables for hike-in access to remote lakes. Shipping large equipment, and field storage and climate-controlled transport of sediment cores is accomplished through a set of intermodal shipping containers, including 20-foot and 40-foot climate-controlled containers with electrical generators, and 20-foot and 40-foot standard (“dry”) containers.

Major laboratory instrumentation includes a Geotek MSCL-S standard multi-sensor core logger, for whole or split core logging for magnetic susceptibility (both loop and high-resolution point sensors), gamma density, acoustic velocity, non-contact electrical resistivity, and natural gamma radiation; a Geotek MSCL-XYZ multisensor core logger, for automated sequential logging of up to nine split core sections for high-resolution magnetic susceptibility and color reflectance spectrophotometry; a Geotek MSCL-CIS digital linescan camera, for core scans of up to 40 pixels/mm resolution; a DMT CoreScan Colour digital linescan camera; a Hitachi TM-1000 benchtop SEM with TM-SDD EDS attachment for rapid imaging and elemental analysis; a Horiba LA-920 laser diffraction particle size analyzer; an ITRAX XRF core scanner for elemental scans and X-radiographic imaging, housed at the Large Lakes Observatory, University of Minnesota-Duluth; UIC CM150 carbon coulometer (TIC/TOC/TC) and CM320 sulfur coulometer (TS); two Leica DM2500P petrographic microscopes with DFC 420 5.0 megapixel camera for smear slide analyses (and additional basic petrographic microscopes); several reflected/refracted light binocular microscopes (including camera for live view and image capture) for picking; specialized microscopes for pollen and

diatom analyses. Associated labs in the Department of Earth Sciences host the NSI X5000 industrial X-ray computed tomography scanner, Rigaku MiniFlex X-ray diffractometer, and 2G DC-SQUID U-channel magnetometer.

LacCore maintains ~36 PCs, including high-end graphics processing workstations and multipanel core visualization workstations. Data are stored on professionally-managed high-capacity servers in the University of Minnesota Data Center with disk failure redundancy and automated nightly backups to multiple offsite servers.

OUTREACH

LacCore staff are continually engaged in education and outreach at a range of educational levels, including Research Experiences for Undergraduates (REU) projects, class field and lab projects, routine facility tours, and a large-scale ongoing collaborative project with NSF-OEDG funding aimed at study of the paleoenvironments of wild rice lakes in northern Minnesota with tribal college students and teachers from the Fond du Lac Band of Lake Superior Chippewa and Fond du Lac Tribal and Community College.

WWW Home page URL: http://www.laccore.org/

OpenTopography

Scientists in Charge:	***Contact Persons:***
Chaitanya Baru (PI) Viswanath Nandigam (co-PI) San Diego Supercomputer Center University of California La Jolla, CA 92093-0505 Tel: (858) 534-5035 E-mail: cbaru@ucsd.edu	Christopher Crosby (co-PI) UNAVCO Tel: (303)-381-7466 E-mail: crosby@unavco.org Ramon Arrowsmith (PI) School of Earth and Space Exploration Arizona State University E-mail : ramon.arrowsmith@asu.edu

Facility Description:

OpenTopography is a cyberinfrastructure facility that provides online access to Earth science-oriented topography data, processing services, related tools and resources. A particular emphasis is placed on high-resolution (meter to sub-meter scale) data collected with lidar technology. Datasets are contributed to the facility via collaborations with a wide range of partners, including other NSF facilities and projects, federal, state and local government agencies, and private companies. OpenTopography harnesses advanced cyberinfrastructure to provide *scalable* and *extensible* discovery, access, processing, and analysis capabilities by co-locating processing services with data. Users are provided streamlined web-based access to lidar point cloud data and derived products, including pre-computed digital elevation models, Google Earth-oriented hillshade images, and SRTM[1] digital elevation data. The *extensible* services-based framework supports contributions of processing algorithms by the research community. OpenTopography is also a community hub for information exchange and education about high-resolution topography and has a strong following on Facebook and Twitter.

The OpenTopography Facility is based at the San Diego Supercomputer Center at the University of California, San Diego; education and outreach activities are coordinated by Prof. Ramon Arrowsmith, School of Earth and Space Exploration, Arizona State University; and, community support and coordination and data ingestion activities are led by Christopher Crosby at UNAVCO. Web-based lidar data access and processing were initially prototyped as the *GEON LiDAR Workflow (GLW)* as part of the NSF Information and Technology Research (ITR) program-funded Geoscience Network (GEON) project. Subsequently, OpenTopography was proposed as a cyberinfrastructure-based community facility that leveraged the early success of the GLW prototype. Currently, OpenTopography serves more than 700 billion lidar returns from 167 individual point cloud datasets, covering approximately 170,000 km^2, and has processed and delivered nearly a trillion returns. New datasets are regularly ingested and registered into the system. In its current, second round of funding, the OpenTopography team is working to develop a "pluggable" infrastructure for processing services to enable generation of higher-order data products—such as topographic and hydrologic derivatives, and maps of change between spatially overlapping and temporally varying datasets—using community-contributed processing services.

CENTER OBJECTIVES

The mission of the OpenTopography Facility is to employ modern cyberinfrastructure methods to democratize access to high-resolution (meter to sub-meter scale) Earth science-oriented, topography data acquired with lidar and other technologies, by co-locating online processing services with data.

[1] SRTM—Shuttle Radar Topography Mission

The facility objectives are to:

- Serve as a community hub for high-resolution topography data as well as processing services and tools via easy-to-use, highly interactive web-based interfaces.
- Foster and support a vibrant user community for high-resolution topography data and services via the OpenTopography web portal and associated social media services.
- Provide support for ingestion of data and contribution of processing services to ensure a low barrier to entry for the research community.
- Harness leading-edge cyberinfrastructure in providing online access to innovative services for data access, processing, and analysis that are scalable and extensible.
- Promote discovery of data and software tools through community populated metadata catalogs.
- Provide training and expert guidance in data management, processing, and analysis.
- Foster interaction and knowledge exchange in the Earth science topography user community.

OPENTOPOGRAPHY MANAGEMENT AND GOVERNANCE

OpenTopography is a collaborative effort. The primary cyberinfrastructure facility is based at the San Diego Supercomputer Center, where Dr. Chaitan Baru is the PI and Viswanath Nandigam (co-PI) is the Technical Project Manager. Education and training activities are coordinated by PI Prof. Ramon Arrowsmith at Arizona State University. Community interactions, user support, and support for data ingestion are provided by co-PI Christopher Crosby at UNAVCO.

An Advisory Committee (AC) consisting of community members from universities and geoscience organizations across the United States, including one elected Chair and a student member, oversees the activities of OpenTopography. The AC meets once a year, alternating at ASU and SDSC. The AC provides guidance and review related to:

1. Liaison and coordination with major NSF and other data acquisition groups and data providers, including individual PIs.
2. Types of downstream processing to be supported
3. Information dissemination regarding activities of the facility as well as for new collaborations
4. Feedback on the online capabilities of the portal / website.

INFRASTRUCTURE

OpenTopography uses advanced cyberinfrastructure capabilities for storage, processing, and access to point cloud lidar data and a variety of derived products, including SRTM data. The facility currently has access to over 35TB of scalable high performance storage and a dedicated high performance large memory compute server for efficient storage and processing of data. The OpenTopography portal and databases are hosted on a virtual machine provisioned and maintained by SDSC. Pre-computed data products such as Google Earth hillshades and bulk download lidar point cloud files are stored on the SDSC Cloud, a scalable redundant storage system based on OpenStack Object Storage. Through NSF's XSEDE program (Extreme Science and Engineering Discovery Environment, www.xsede.org), OpenTopography has also received an allocation of one Gordon I/O node, containing 4.8 Terabytes of solid-state disk (flash memory), which enables high-performance processing of lidar data. Gordon is an NSF-funded supercomputer resource located at SDSC. The use of advanced cyberinfrastructure capabilities available at SDSC serves the OpenTopography user community by providing not only faster access and processing of data but additional processing capabilities previously restricted by commodity hardware.

OUTREACH

Education and training activities are an essential component of OpenTopography. Training workshops are offered at various venues, such as GSA, and as standalone events in collaboration with other NSF facilities such as UNAVCO and SCEC. These sessions educate the community on the use of high-resolution topographic data and tools, and introduce the resources and services available via OpenTopography. These events also serve as a venue for obtaining feedback from the OpenTopography user community. Education and outreach related videos are made available at the OpenTopography website and via its YouTube channel. OpenTopography actively employs social media outlets such as Twitter and Facebook to interact with the user community. Open Source software developed by the OpenTopography project is also distributed to the user community through its GitHub page.

WWW Home page URL: http://www.opentopography.org
Twitter: www.twitter.com/opentopography
Facebook: www.facebook.com/opentopography
YouTube: http://www.youtube.com/OpenTopography
GitHub: https://www.github.com/OpenTopography

Global Centroid-Moment-Tensor Project

Scientists in Charge/Contact persons:

Göran Ekström and Meredith Nettles
Lamont-Doherty Earth Observatory of Columbia University
61 Route 9W
Palisades, NY 10964
Tel: (845)365-8427, (845)365-8613
E-mail: ekstrom@ldeo.columbia.edu, nettles@ldeo.columbia.edu

Facility Description :

The goal of the Global Centroid-Moment-Tensor Project (GCMT Project) is to analyze and quantify all large earthquakes occurring worldwide using seismic data, and to provide the most comprehensive record of global seismic strain release available. The GCMT Project is overseen by Principal Investigator Göran Ekström and Co-Principal Investigator Meredith Nettles at the Lamont-Doherty Earth Observatory (LDEO) of Columbia University. The project was founded by Adam Dziewonski at Harvard University and operated there as the Harvard CMT Project from 1982-2006, led first by Prof. Dziewonski and later by Prof. Ekström. During the summer of 2006, the main activities of the project moved with Prof. Ekström to LDEO. The GCMT Project has been funded by NSF since its inception. Since 2008, funding for the GCMT Project has come from the EAR I&F Program, and the project is now operated as a national, multi-user facility.

FACILITY OBJECTIVES

The major objectives and activities of the GCMT Project are

1. Systematic determination of moment tensors for earthquakes with magnitude M>5 globally, and archiving of the results in the GCMT catalog.
2. Rapid determination of moment tensors for earthquakes with M>5.5 globally, and quick dissemination of the results ('quick CMTs').
3. Curation and distribution of the CMT catalog, which contains moment-tensor results for the period 1976 to the present, currently more than 35,000 earthquakes.
4. Routine detection and location of seismic sources using surface waves.
5. Investigation and reporting of the quality of seismic waveforms from the Global Seismographic Network and other seismic networks.
6. Systematic analysis of earthquake sequences of special importance.

DISSEMINATION OF RESULTS

We maintain the internet domain and web site www.globalcmt.org for the purpose of dissemination of results from the GCMT Project. The web site provides an easy-to-use interactive search tool for the GCMT catalog, as well as ftp download of the catalog in a well-defined format. Rapid results – quick CMTs – from the GCMT Project are disseminated via e-mail to several hundred recipients worldwide, and are redistributed by the United States Geological Survey, the European-Mediterranean Seismological Center, IRIS, and others.

WWW Home page URL: www.globalcmt.org

Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) Water Data Center

Scientist in Charge:
Richard P. Hooper, Executive Director
CUAHSI
196 Boston Ave., Suite 3000
Medford, MA 02155
Tel: (339) 221-5400 ext. 200
Fax : (781) 219-4029
Email : rhooper@cuahsi.org

Contact Person:
Alva Couch, Interim Director
CUAHSI
196 Boston Ave., Suite 3000
Medford, MA 02155
Tel: (339) 221-5400 ext. 203
Fax : (781) 219-4029
Email : acouch@cuahsi.org

Facility Description :

CUAHSI was formed in 2001 by thirty-six universities to bring together the multidisciplinary water science community to define infrastructure needs. Since that time, the consortium has grown to 102 university members, 8 affiliate members, 20 international affiliate members and 3 corporate affiliate members. CUAHSI operates the Water Data Center and is affiliated with the CTEMPS facility operated by Oregon State University and University of Nevada Reno, described elsewhere in this Handbook.

WATER DATA CENTER

The CUAHSI WDC was established in 2013 to implement a comprehensive set of water data services using the Hydrologic Information System (HIS), a standards-based services-oriented architecture that supports publishing, discovery, and downloading of time series data collected at fixed points. The HIS consists of three components:

1. **Clients** that permit users to discover and download data. Currently, the most-used client is HydroDesktop, a windows-based program. The WDC will develop additional clients during 2013 – including a web portal – that will be platform-independent and portable to devices such as mobile phones and tablets.
2. **A Metadata Catalog.** The WDC will assume operation and curation of the metadata catalog which brings together data from multiple levels of government, universities, and international entities to enable discovery of water data at the granularity of the time series. The current catalog references nearly 100 different services representing over 20 million time series.
3. **A Server Software Stack** for deployment by users to publish data. The Water Data Center will provide hosting services for users with static data sets. The present server software, HydroServer, is based upon Microsoft SQL Server, but support for other platforms and database engines, such as Linux/MySQL, is planned.

All software is freely available and open source, licensed under the Berkeley Software License and can be downloaded from the WDC website (http://wdc.cuahsi.org). Developers may access source code on Codeplex site at http://www.hydrodesktop.org (Client Software), http://hydrocatalog.codeplex.com/ (Metadata Catalog Services), and http://hydroserver.codeplex.com/ (Server Software Stack).
The CUAHSI WDC provides training and assistance to scientists and students for the use of all components of the services-oriented architecture. Services can be divided into the following categories:

- **Data discovery and access**. HydroDesktop can be used for both education and research. Its current functionality includes some visualization and analysis tools, such as a plug-in for the R open source statistical language. Tutorials, training, and sample lesson plans using HydroDesktop are available at the WDC website and live user support is also provided by WDC. Contact Jon Pollak (jpollak@cuahsi.org) for assistance.

- **Data publication.** The CUAHSI WDC can assist scientists in establishing their own server or provide guidance on how to organize data for hosting on a server at the WDC. For projects where the data collection activities are on-going, we recommend that universities establish their own server. For projects that have ended and there is a static collection of data, the WDC can host such data. The current focus of the WDC is on observational data, but assimilated data products and model output will also be hosted by the WDC.
- **Software development.** The CUAHSI WDC provides a set of service interfaces that can be accessed by both custom programs and within modeling environments such as MATLAB, OHMF and others. In addition, HydroDesktop has a plug-in architecture which may be extended with additional modules. Information on these services is provided on the WDC website.
- **Standards development.** The CUAHSI WDC participates in international standards-setting bodies, including the Open Geospatial Consortium (OGC) and the Global Earth Observing System of Systems (GEOSS).

During 2013, the CUAHSI WDC will assume responsibility for the components of this services-oriented architecture. All services currently operating will be maintained and significant software upgrades will be developed and deployed during this time.

WWW Home page URL: http://www.cuahsi.org

Continental Scientific Drilling Coordination Office (CSDCO)

Scientist in Charge:

Anders Noren, Director
University of Minnesota
Department of Earth Sciences
310 Pillsbury Drive SE
Tel: (612) 624-3298
FAX: (612) 625-3819
E-mail: noren021@umn.edu

Contact Person:

see Scientist in Charge

Facility Description:

The Continental Scientific Drilling Coordination Office (CSDCO) is hosted by the University of Minnesota, and dedicated to providing coordination, leadership, and technical support in subsurface sampling and monitoring on Earth's continents to address topics of critical scientific and societal importance. Through collaboration with the U.S. academic research community and other national and international organizations, the CSDCO coordinates projects and infrastructure developments to enable scientific drilling and coring. Our primary goals are:

- Provide community leadership and support for scientific drilling and coring and associated activities
- Develop plans and budgets for potential scientific drilling and coring projects, and manage active projects
- Develop new physical and cyberinfrastructure to support the scientific community
- Provide a clearinghouse for continental scientific drilling and coring data, procedures, and policies
- Coordinate a world-class outreach, diversity, and education (ODE) program

Together with support from the associated NSF-funded LacCore Facility for operations, core processing and analysis, and sample and data curation and dissemination, the CSDCO provides fully-integrated project support at every stage, from inception to curation.

COMMUNITY LEADERSHIP

The CSDCO fosters collaboration and innovation in the continental scientific drilling community, advancing community priorities and representing the community to funding agencies that support CSD projects, including the International Continental Scientific Drilling Program (ICDP). By engaging the community through multiple avenues and coordinating the process of community science planning at both broad and domain-specific workshops, scientific endeavors are enabled and nurtured.

PROJECT PLANNING, BUDGETING, AND MANAGEMENT

The CSDCO supports scientists in the complex process of project development and budgeting. This begins with understanding the project goals and scope including details such as drilling location(s), lithologies, number and depth of holes, sample type(s) to be generated, site-specific permitting, safety, and logistics, analyses to be performed on samples, management and curation plans for samples and data, etc.

The CSDCO collaborates with scientists to draft a suitable project plan, discussing and matching the most appropriate and cost-effective resources to the project needs. Project budgets are determined by the scope, using bids from drilling contractors, freight forwarders, logistics providers, and other vendors as needed for accurate estimation of costs. Any additional pre-drilling requirements (site surveys, community engagement meetings, equipment modification or development) are identified and plans are made to seek funds to address those needs. After project funds are obtained, cost estimates and quotes are updated and contracts are signed.

The CSDCO provides operational support to drilling and coring projects, funded through collaborative proposals submitted together with the lead scientific proposal. Operational support includes providing off-site project management infrastructure, and providing experienced personnel on-site in the "company rep" role, ensuring that the drilling contractor executes the plan safely and efficiently, supporting drilling engineering, managing samples and data, and coordinating freight and logistics.

PHYSICAL AND CYBERINFRASTRUCTURE DEVELOPMENT

The CSDCO uses its connections to the distributed scientific community to understand the critical needs for new infrastructure development, and to prioritize and focus those needs through coordination of efforts to develop and acquire new physical and cyberinfrastructure. The CSDCO advances field, lab, and sample repository equipment and instrumentation acquisition and development efforts through support for proposals and (if needed) coordination of technical consultations, engineering and feasibility studies, prototyping, and full production of new resources, brokering partnerships with industry and among funding agencies when possible.

The CSDCO is the central coordinating entity for development of cyberinfrastructure to support data management, visualization, registration, and archiving for the continental scientific drilling and coring community. These efforts build on systems developed organically in the community as well as those developed at IODP (Integrated Ocean Drilling Program) and ICDP (International Continental Scientific Drilling Program), utilizing community best practices and standards, and in collaboration with community leaders at ICDP and NSF-funded data facilities.

CLEARINGHOUSE

The CSDCO coordinates with ICDP to develop, maintain, and distribute community-specific best practices documents, standard operating procedures (SOPs), workflows, project performance data, metadata standards, and project-specific initial reports covering goals, major accomplishments, lessons learned, and initial description of cores and other samples.

OUTREACH, DIVERSITY, AND EDUCATION

The CSDCO works for full participation of underrepresented groups, fosters public engagement with science, collaborates with agencies and private industry,enhances workforce development, and expands access to training and infrastructure. Continental scientific drilling and coring projects yield samples from locations near population centers and therefore offer an opportunity for local residents to partner with the project and take ownership in some of its goals. The CSDCO collaborates with project scientists to engage members of the public at the earliest stages of project planning, and to develop community-driven research in parallel with project scientific goals. Stakeholders may include primary and secondary education institutions, nonprofits, state and county agencies, business leaders and representatives, and indigenous peoples and tribal governments.

In addition to community-driven research, the CSDCO coordinates REU activities that utilize the associated LacCore facility; a CSD summer institute for graduate students; an informal training program for local schoolteachers during major core processing parties, to provide perspective on CSD projects and content that can be used in classroom activities; and numerous facility tours, field experiences, and school visits to the facility, and develops and maintains informal education/outreach products such as brochures, YouTube videos, a Facebook page, Twitter feed, etc.

The CSDCO maintains a booth in the exhibit hall at major geoscience conferences and holds an annual CSD community meeting to facilitate communication within the scientific drilling and coring community and across scientific disciplines. This workshop provides a forum for the discussion of projects of varying maturity, from concept through publication, and for discussion of community scientific priorities and infrastructure needs.

GOVERNANCE

The CSDCO governance and management structure is an interface between the scientific community, funding agencies, and the activities of the CSDCO. This structure is designed to ensure close involvement of the research

community in the operation and development of CSDCO activities and infrastructure, to focus scientific talent on common objectives, to encourage broad participation, and to manage effectively the CSDCO programs.

Policy Committee (9 members, 3-year terms). Has full management authority of the affairs of the CSDCO, representing the interests of the research community. Supports development of strategic plans, provides policy decisions and oversight. Communicates at least monthly.

Standing Committees (four committees). The four Standing Committees develop policies and provide detailed oversight of CSDCO operations.

- Science Advisory Panel (9-10 members). Reviews and nurtures proposals and infrastructure development concepts, provides distributed focal points for community input, provides post-project independent review, and communicates at least quarterly.
- Infrastructure Committee (3 standing plus ad hoc members). Prioritizes development of field and lab physical infrastructure, provides safety and environmental assessment, provides post-project independent review, and meets at least once per year, communicating and meeting additionally as needed.
- Informatics Committee (3 standing members). Prioritizes development of cyberinfrastructure, provides oversight on data management policies and activities, fosters new linkages. Meets at least once per year, communicating and meeting additionally as needed.
- Outreach, Diversity, and Education Committee (6 members). Reviews CSDCO operations with respect to outreach, diversity, and education. Reviews applications for student summer internship programs, supports planning and funding of appropriate education and outreach activities, prioritizes activities and goals. Meets at least once per year, communicating and meeting additionally as needed.

The Directors and Policy Committee may appoint special advisory committees and ad hoc working groups for specific tasks. It is the role of all appointed committees to develop recommendations for the Policy Committee, which in turn, evaluates and acts upon such recommendations.

WWW Home page URL: www.csdco.org

AfricaArray

Scientist in Charge:

Andrew Nyblade
Department of Geosciences
Pennsylvania State University
University Park, PA 16802
Tel: (814)863-8341
E-mail: nyblade@psu.edu

Contact Person:

see Scientist in Charge

Facility Description:

AfricaArray (www.africaarray.org) is a multifaceted research and education initiative with broad goals of supporting human capacity building for the geosciences within Africa and the U.S. As part of this initiative, *AfricaArray* has established a network of permanent geophysical observatories across western, eastern and southern Africa that provide seismic, GPS, and weather data to the science community.

The network consists of 51 observatories in 19 countries. Forty-eight observatories are equipped with broadband seismometers and 27 with GPS receivers and automated weather stations. Data are manually downloaded from data loggers at the majority of stations, but real time data transmission via the internet is available for some of the stations, primarily in southern Africa. The data are provided online via the IRIS and UNAVCO data management centers. Information about the seismic equipment and access to the seismic data can be obtained from the IRIS data management center under *AfricaArray*'s network code AF (http://www.iris.edu/mda/AF). Information about the GPS and meteorological equipment and access to the data are available through the UNAVCO data management facility (http://facility.unavco.org/data/data.html) by searching on AfricaArray.

FACILITY OBJECTIVES

The mission of the *AfricaArray* observatory network is to provide seismic, GPS and weather data from the African continent to the community, and to foster the use of the data to build human capacity in geoscience fields in Africa and the U.S. To this end, *AfricaArray*, through a variety of funding sources other than the NSF I&F program, supports a number of educational and outreach programs aimed at supporting undergraduate and graduate students and postdocs in Africa and the U.S.

MANAGEMENT AND GOVERNANCE

AfricaArray was established in 2005 through a partnership of three organizations: the University of the Witwatersrand (Johannesburg, South Africa), the Council for Geoscience (Pretoria, South Africa; formerly known as the South African Geological Survey), and the Pennsylvania State University (University Park, Pa.). These institutions made a wide range of teaching, research, and data acquisition facilities available to launch *AfricaArray*. To reflect these investments, an organizational structure consisting of co-directors from each institution was put in place.

The operation and maintenance of each station in the observatory network is shared between an in-country host organization and the facility PI. Host organizations include universities, geological surveys and meteorological agencies, and they are responsible for providing baseline resources for operating the stations, including technician salaries, travel to the stations for downloading data and performing routine maintenance, and for security. NSF I&F support is used primarily for equipment repair, technician training, and partial support for a network manager. Data are archived at the IRIS and UNAVCO data management centers. Data latency for stations not connected to the internet can be up to several months depending on station servicing schedules.

INFRASTRUCTURE

The observatories are equipped with a variety of instrumentation. Seismic equipment includes broadband seismometers, 24-bit data loggers and GPS clocks. The equipment is housed in a seismic vault with a pier. The GPS equipment includes a Trimble NetR8 receiver and either a choke-ring or Zepher antenna. The automated weather sensor is a Vaisala WXT520 unit. The GPS antenna and weather sensor are mounted on the roof of the observatory building.

WWW Home page URL: http://www.africaarray.org

Scripps Orbit and Permanent Array Center (SOPAC)

Scientists in Charge:

Yehuda Bock (PI)
Jennifer Haase (Co-PI)
Institute of Geophysics and Planetary Physics
9500 Gilman Drive
La Jolla, CA 92093-0225
Tel: (858) 534-5292
E-mail: ybock@ucsd.edu

Contact Persons:

Maria Turingan
Tel: (858) 822-2156
E-mail: mrturingan@ucsd.edu

Melinda Squibb
Tel: (858) 534-8487
E-mail : msquibb@ucsd.edu

Facility Description:

The Scripps Orbit and Permanent Array Center (SOPAC) at the University of California San Diego's Scripps Institution of Oceanography has a 20-year history of supporting precise GPS/GNSS (global and regional) networks for geodetic, geophysical, atmospheric, and natural hazards research. SOPAC routinely collects, archives, and distributes RINEX data and accurate metadata for more than 3000 continuous GPS stations. The consistency and continuity of GNSS analysis and archiving at SOPAC assure high quality standards for a large community of users.

SOPAC maintains a web site, GPS Explorer as part of a NASA-funded project with the Jet Propulsion Laboratory, and web services supported by an Oracle database to provide a hierarchy of data products and a suite of interactive utilities. SOPAC also serves as a Global Data Center and Global Analysis Center for the International GNSS Service (IGS). The utilities include, for example:

- Scripps Epoch Coordinate Tool and Online Resource (SECTOR). Provides user-requested reference station true-of-date coordinates for about 3000 global and regional stations.
- Scripps Coordinate Update Tool (SCOUT). Analyzes uploaded GPS data for the user to determine station coordinates in ITRF for an unknown station.
- Station Code Service – Provides network operators a check on existing 4-character station codes and a means for submitting station metadata through the Site Information Manager (SIM), to encourage adoption of rigorous standards.

Data products include, for example,

- Position/displacement time series of more than 3000 stations, some spanning more than 20 years) for understanding and modeling plate tectonics and deformation with a focus on Western North America, but also in other locations (*e.g.,* New Zealand, Eastern Mediterranean, South Pacific, Greenland).
- Time series model terms including interseismic velocities, coseismic offsets, postseismic decay, non-tectonic offsets and seasonal signatures.

A growing number of researchers in the geodesy and seismology communities are working on real-time GPS/GNSS research. SOPAC provides access to real-time data, metadata and data product streams as part of the READI project, which utilizes a superset of all real-time 1 Hz GPS data available in the western U.S. from 600+ stations. SOPAC operates servers for real-time access to these data collected directly from its own SCIGN stations in southern California and from several other real-time servers including UNAVCO/PBO (the majority of stations), USGS-Pasadena/SCIGN, UC Berkeley/USGS-Menlo Park/BARD, and Pacific Geosciences Centre/WCDA.

SOPAC also provides extensive support to a wide range of non-academic users requiring precise (real-time and post-processed) positioning and reference system data including government agencies, the commercial sector, and local, state, federal, and international agencies (e.g., surveying, GIS, agriculture, intelligent transportation, engineering infrastructure). SOPAC services directly contribute to natural hazards mitigation and early warning systems for earthquakes, volcanoes, tsunamis, short-term weather forecasting and related flooding hazards, and to earthquake engineering research for large structures (e.g., bridges, buildings, dams), all of which have a significant impact on public safety.

SOPAC PERSONNEL

Dr. Yehuda Bock, SOPAC Director, is PI of the project and Dr. Jennifer Haase is co-PI. The group includes a system administrator (Anne Sullivan), a database administrator and programmer/analyst (Melinda Squibb), academic analysts (Peng Fang and Jianghui Geng), project assistant (Maria Turingan), and field engineer (D. Glen Offield). Current graduate students include Diego Melgar, Dara Goldberg and Jessie Saunders.

SOPAC INFRASTRUCTURE

SOPAC maintains an extensive computing environment in support of geodetic processing and archive service:

- 14 high capacity processing systems including a quad-node processing cluster (128 CPU cores) used to compute the measures combination solution and 10 individual processing hosts (24 CPU cores) used for a variety of processing including GAMIT daily and weekly processing, rapid, ultra-rapid and time series products;
- 10 systems dedicated to processing high-rate data, including GPS positioning, accelerometer and meteorological data;
- Archive of continuous GPS data, related data and processing solutions that are available for public access;
- High-speed storage array, configured for high reliability, providing 30 terabytes of online storage capacity for the archive and internal working space, and expandable to 60 terabytes;
- Oracle relational database cluster used to track multiple types of information including site data, historical results, archive holdings and more;
- Dedicated servers providing secure public access to data products including GPS Explorer and the Geophysical Resource Web Services (GRWS), as well as ftp and http access to our extensive archive;
- A dedicated server room served by 2 new Cisco switches providing 1 Gbps network connections to each server and a 10 Gbps uplink to the internet, capable of handling hundreds of high-rate GPS stations as well as public access to our archive.
- High precision GPS/GNSS analysis software including GAMIT, RTD (epoch by epoch real time differential network GPS position), and PPP-ARA precise point positioning with ambiguity resolution and accelerometer integration.

OUTREACH

SOPAC runs the California Spatial Reference Center (CSRC), an outreach facility for surveyors, engineers and GIS professionals. The CSRC maintains the geodetic reference frame for California (California Spatial Reference System) based on the coordinates and motions of over 800 continuous GPS stations in California. The CSRS is tied to the National Spatial Reference System (NSRS) operated by the National Geodetic Survey. SOPAC operates the California Real Time Network (CRTN) that streams 1-Hz GPS/GNSS surveyors through NTRIP-based servers to support kinematic surveying. Users are provided one-free account that allows them access to real-time RTCM3 data – over 300 accounts are currently in use.

WWW Home page URL: http://sopac.ucsd.edu
Archive: http://geoftp01.ucsd.edu/pub
GPS Explorer: http://geoapp.ucsd.edu/; requires username & password
READI Project: http://sopac.ucsd.edu/projects/realtime/READI
CRTN Project: http://sopac.ucsd.edu/projects/realtime/CRTN
CSRC: http://csrc.ucsd.edu/

The Northeast Nation Ion Microprobe Facility (NENIMF)

Scientist in Charge:

Glenn A. Gaetani
Department of Geology and Geophysics
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543
Tel: (508) 289-3724
Lab: (508) 289-3744
FAX: (508) 457-2183
E-mail: ggaetani@whoi.edu

Contact Person:

Brian Monteleone, Analyst & Lab Manager
Department of Geology and Geophysics
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543
Tel: (508) 289-2405
Lab: (508) 289-3441
FAX: (508) 457-2187
E-mail: bmonteleone@whoi.edu

Facility Description:

The Northeast National Ion Microprobe Facility (NENIMF) is a multi-user SIMS facility established at Woods Hole Oceanographic Institution (WHOI) by Nobumichi Shimizu in 1996. The NENIMF is equipped with two SIMS instruments: a Cameca IMS 1280 and a Cameca IMS 3f. The IMS 1280 is a high transmission-high mass resolution SIMS instrument. It is a double focusing mass spectrometer with a large radius magnetic sector (585 mm), and ion optics optimized to attain a mass resolving power (MRP= $M/\Delta M$) of 6000 without significant loss of secondary ion intensity. It is one of only five such instruments in the United States, and one of three that are operated in NSF-supported national SIMS facilities. The Cameca IMS 3f instrument is a double focusing mass spectrometer with a small radius magnetic sector that has been used for a wide spectrum of geochemical studies since 1978. Recently, the IMS 3f has been renovated to include computer control labview-based analytical software, digital control of magnet and stage, and user-friendly data output. This newly improved 3f will be available for use in early 2015.

The analytical capabilities and expertise of the NENIMF are primarily focused in two areas: determination of magmatic volatiles in silicate glasses and analysis of biogenic carbonates as records of climate change and its impacts on marine organisms. Analytical protocols and the requisite standard materials are available for determination of H_2O, CO_2, F, S, and Cl in silicate glasses and of B, Mg, Sr, Ba, and U in carbonates. Emphasis on these areas makes the NENIMF a unique interdisciplinary resource to the geosciences community, with minimal overlap to other SIMS facilities. Despite the lab's emphasis in these areas, the NENIMF is an open facility that actively develops new analytical protocols to meet a wide variety research needs of users. Particular areas of new development have included U/Pb geochronology and measurement of Sulfur, Hydrogen, Boron, and Lead isotopes from rocks from a variety of tectonic settings and within materials subjected to various experimental conditions. Recent technical development work has also focused on the acquisition of high-resolution depth profiles of stable isotopes in a variety of minerals. The NENIMF welcomes interaction with scientists seeking to utilize SIMS to answer a wide variety of questions in the Earth and Ocean Sciences.

For more information about the capabilities of NENIMF and applying to use the facility, please consult our web site (below) and contact Glenn Gaetani or Brian Monteleone (above).

WWW Home page URL: http://www.whoi.edu/page.do?pid=18655