



GUIDE TO MULTI-USER FACILITIES

Instrumentation & Facilities Program
Division of Earth Sciences
National Science Foundation



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 twelve 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 facility 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 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 the 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>), the Digital Library for Earth System Education (<http://www.dlese.org>), Sustainability of Semi-Arid Hydrology and Riparian Areas (<http://www.sahra.arizona.edu>), the Southern California Earthquake Center (<http://www.scec.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 (see Program Solicitation at: <http://www.nsf.gov/pubsys/ods/getpub.cfm?nsf03590>) and the EarthScope Program (solicitation revised annually and available at the EAR website).

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Incorporated Research Institutions for Seismology (IRIS)

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Facility Description:

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 more than one hundred U.S. institutions with more than 40 foreign affiliates. IRIS supports the research needs of Earth scientists in the U.S. and around the world. IRIS consists of four management programs:

PASSCAL

The Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL) provides portable instrumentation and support facilities for temporary deployments in studies of seismic sources and Earth structure. Data loggers developed to PASSCAL specifications form the core of the program. These data loggers are extremely flexible in their ability to respond to a variety of deployment schemes -- mobile arrays for recording of planned explosions; temporary deployments for aftershock studies; longer term deployments for observations of teleseismic events. Over 900 multi-channel recorders, associated sensors and support equipment are available. Individual experiments involving more than 300 PASSCAL instruments have been supported. The instrument center for maintenance of PASSCAL equipment is located at New Mexico Institute of Technology in Socorro, NM. Data from PASSCAL experiments are distributed through the IRIS Data Management Center. As the program moves towards acquisition of the eventual goal of 6000 channels, current emphasis is on supporting field experiments; maintaining equipment; implementing improvements in hardware; and developing software for efficient data collection and initial processing.

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GLOBAL SEISMOGRAPHIC NETWORK

The Global Seismographic Network (GSN) is the focused effort of the U.S. seismological research community to provide a 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 by the IDA project at the University of California, San Diego. IRIS 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 toward its long-term goals, and serves as a fundamental resource in the study of earthquake dynamics and tomographic analyses of the elastic and anelastic structure of the Earth.

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DATA MANAGEMENT SYSTEM

The IRIS Data Management System (DMS) is the primary conduit for data flow within IRIS and to data users. The DMS acts as the archive for all data collected by the IRIS GSN and IRIS PASSCAL programs. The DMS also receives, archives and distributes data from a variety of other data sources, most notably the Federation of Digital Broadband Seismographic Networks (FDSN). All broadband data, from the GSN, PASSCAL and FDSN are available in a seamless fashion from the DMC in SEED format. Active source data are available in SEG-Y format. At the end of September 2003, the IRIS Data Management Center (DMC) had more than 43 terabytes (43,000,000,000,000 bytes) of seismic waveform data in more than 2,000,000 files. The IRIS DMS typically services several tens of thousands of requests for seismic data each year.

The core of the IRIS DMS is the IRIS Data Management Center (DMC) located in Seattle. Other nodes of the system include the IRIS/IDA Data Collection Center at UCSD, the IRIS/USGS DCC at Albuquerque, the DMC Host at the University of Washington, the Waveform Quality Center at Harvard and the Moscow Data Analysis Center in Moscow, Russia.

In addition to its role of archiving and distributing data, the IRIS DMS is responsible for all 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 IRIS DMS has developed novel means of accessing data in near real time through systems such as WILBER (via www.iris.edu), SPYDER developed by the University of Washington and NRTS developed by the University of California at San Diego, and the LISS System developed by the USGS in Albuquerque. These systems provide researchers access to data within minutes of a seismic event of interest. A complete database management system and associated user tools allow researchers to make complex requests for customized subsets of data stored in the IRIS archive.

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EDUCATION AND OUTREACH

The seismological community recognizes the potential for coordinated Education and Outreach (E&O) activities in seismology to contribute significantly to the advancement of national awareness, interest, and understanding of science and mathematics. IRIS E&O 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 E&O staff work 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 range of K-16 teacher workshops, widely distributed teaching modules and associated tools (including seismographs and software for viewing and interpreting seismograms), and an Educational Affiliate membership for undergraduate institutions. Outreach to the general public is enhanced through a distinguished lecture program, museum exhibits, improved access to and use of seismic data via our website, and other informational materials.

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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 the 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. Through special Congressional interest and support, IRIS is working with federal agencies to enhance IRIS facilities into multi-use resources for the international verification regime of a Comprehensive Test Ban Treaty. Many nations are using 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 in making the data from these stations available for use by the National Earthquake Information Center in their location and cataloging of 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 publishes a newsletter twice a year. In addition to the newsletter, IRIS produces other publications available to the scientific and educational communities. To subscribe to the IRIS newsletter please send your name, institution, address, telephone, fax number and e-mail address to:

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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 sending a request to membership@iris.edu.

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

Consortium for Materials Properties Research in Earth Sciences (COMPRES)

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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. 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, promoting novel scientific initiatives through a Grand Challenge program, 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.stonybrook.edu/>).

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 the National Synchrotron Light Source (NSLS, Brookhaven, NY), and the Advanced Light Source (ALS, Lawrence Berkeley National Laboratory). Depending on the size of 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.stonybrook.edu>. Much of the experimental capability involves diamond anvil cells (DAC) or large volume multi-anvil presses (LVP).

NSLS: Facilities include three experimental stations (B2, B3 and C) 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 the P-V-T equation of state, phase transformations, crystal structures, stress state and rheological properties, absorption, reflectance, P and S wave velocities, dilatometry, and kinetics.

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. 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 or less.
- 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 white radiation for 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 2mm in length and 1 mm in diameter.
- 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 port dedicated for DAC research. The capabilities include:

- Far- and mid-IR reflectivity and absorption measurements at multimegabar pressures.
- A Bruker IFS/66v FT-IR spectrometer for the spectral range 10-25,000 cm^{-1} and a Bruker IRscopeII microscope.
- Companion Raman, UV-visible absorption, reflectivity and ruby fluorescence capability with Ar-ion or Ti-sapphire lasers, cryostats, and furnaces.

West Coast Synchrotron Facilities: Facilities for high pressure x-ray and infrared experimentation are available beginning in summer of 2003. Beamline 11.3.1 at the Advanced Light Source will operate up to ~16 keV for high-pressure powder diffraction studies with a focused x-ray beam. ALS beamline 1.4.3 will be equipped for high-pressure infrared studies. Potential users should contact Simon Clark at smclark@lbl.gov. A partial list of the present capabilities include:

- ADX X-ray diffraction on polycrystalline samples using diamond cells, with a high resolution CCD detector.
- Diamond cells for XRD or IR studies at ambient temperature or resistance heating to 1100K.
- Pressure measurements by ruby fluorescence and sample preparation facilities.

Neutron Scattering: A number of facilities for neutron scattering exist within the US (<http://www.crystal.vt.edu/compres/>). COMPRES is actively promoting the use of these facilities for research on earth materials, especially at high pressures and temperatures. COMPRES can assist in utilizing these facilities through the general user programs by defraying expenses and arranging for technical support. COMPRES is also supporting educational initiatives to broaden the user base of earth scientists at neutron sources. Contact Nancy Ross (nross@vt.edu) for further 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 multi-anvil cell assembly development and production, improved laser-heated diamond cells, pressure and temperature calibration, and interfacing Brillouin scattering with x-ray diffraction. Submissions of new Infrastructure Development projects is encouraged. Contact Jim Tyburczy (jim.tyburczy@asu.edu). COMPRES also cultivates and nurtures collaborative scientific projects which 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. Three original projects initiated in 2002 are in the areas of elasticity, rheology, and development of new growth of larger diamonds for high-pressure experiments. For additional information on such collaborative research programs, contact Bob Liebermann (Robert.Liebermann@stonybrook.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: 1) Collaborations with EarthScope, IRIS, the Digital Library for Earth System Education and other organizations to cultivate a network of educators and scientists, 2) Developing and disseminating educational resources, including online information systems for educators and researchers, 3) Utilizing ongoing programs by local school systems to pilot specific programs and to evaluate their effectiveness; 4) Promoting the dissemination and advancement of knowledge through topical workshops. We strongly encourage the participation of the entire Earth science community in these efforts and proposals for new projects. The E&O coordinator is Glenn Richard (garichard@notes.cc.sunysb.edu).

WWW Home page URL: <http://www.compres.stonybrook.edu/>

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Facility Description:

UNAVCO, Inc. is a non-profit membership-governed organization that supports and promotes Earth science by advancing high-precision geodetic and strain techniques such as the Global Positioning System (GPS). UNAVCO, Inc. provides planning and management for community activities. Most of its operational activities are carried out by the UNAVCO Facility. Management of the Facility was transferred from UCAR to UNAVCO, Inc. at the beginning of FY 2004.

The precise positioning provided by GPS has become a powerful tool for studies of diverse Earth processes including plate tectonics, the earthquake cycle, mountain building, volcanism, plate rigidity and intraplate deformation, hydrology, ice dynamics, and sea level change, and atmospheric dynamics, as well as contributing to many education and engineering activities, as summarized in http://www.unavco.org/research_science/brochure/brochure.html.

UNAVCO, Inc. assists investigators in the use of GPS and related technology primarily through the capability and activities of its Facility in Boulder, CO. Many of the investigators assisted are interested in advancing space-based geodesy while others use these techniques as tools to solve geological, geophysical, and glaciological problems. UNAVCO, Inc. therefore seeks to make it possible for investigators interested in monitoring crustal motions, tracking ice sheet flows, or mapping uplifted terraces, to focus on their scientific goals rather than on the GPS technology. A growing group of researchers are more simply interested in using or synthesizing the results of various studies, in many cases conducted by others, for modeling and strain analysis.

To meet these diverse needs, UNAVCO, Inc. provides a focal point for the broad community of Earth scientists interested in either conducting studies with GPS geodesy or using its results. The UNAVCO Facility assists NSF and NASA funded principal investigators with GPS equipment, field engineering, technology development, training, technology transfer, data management, and archiving, depending on specific project needs. A major service provided by the Facility is bulk purchase of GPS and ancillary equipment at significant discounts on behalf of the university research community. The UNAVCO Facility also provides technical and operational support to the permanent GPS stations in NASA's Global GPS network, many of which contribute to the International GPS Service (IGS) global network.

UNAVCO, Inc. works collaboratively with other research institutions in the areas of data processing, technology development, and data archiving. UNAVCO, Inc. supports scientific interchange among investigators doing GPS-related science, both from UNAVCO, Inc. members and from other institutions, via an annual community meeting, scientific working groups, and other forums.

The UNAVCO, Inc. and UNAVCO Facility Web pages provide information about research support including:

1. Data acquisition support includes use of a community pool of high accuracy GPS receivers. Field engineering, training, and technology transfer support is provided for GPS data collection in both campaign style and with continuously operating permanently installed networks of GPS receivers.
2. Data archiving and distribution is supported for campaign and continuous GPS data, via ftp and an archive accessible via a relational database. The archive allows query by data location, date of collection, equipment used, principal investigator, and other "descriptors." A program jointly conducted by the UNAVCO Facility, the Scripps

Institution of Oceanography, and many other participants, is working to implement the GPS Seamless Archive Centers (GSAC). This system provides a “seamless” access to multiple archive centers, allowing users to obtain data without knowledge of the individual archive holdings or data structures.

3. Research toward improved GPS accuracy support is coordinated by the Smithsonian Astrophysical Observatory, with support from MIT and the UNAVCO Facility. Activities include testing and evaluation of new GPS equipment and technology, and development of techniques for measurement and reduction of factors degrading GPS data quality. UNAVCO, Inc. is also promoting the use of GPS to study volcanic processes and synthesis of both a global GPS velocity and strain field that will provide valuable new tools for tectonic studies.

UNAVCO, Inc. is governed by a Board of Directors elected by member institution representatives. The Board works with the GPS research community to promote a broad interdisciplinary research agenda based on applications of GPS technology, to identify investigator needs for infrastructure support, to develop proposals to appropriate sponsors to maintain that infrastructure capability, and to ensure that UNAVCO, Inc. and associated activities provide high quality, cost-effective, and responsive support.

UNAVCO, Inc. is principally organized to support NSF and NASA-funded Earth science investigators and projects but it also provides keystone support for wider interdisciplinary GPS applications at the international level. Many of the GPS tools and techniques developed by the UNAVCO, Inc. community are publicly available via the UNAVCO, Inc. Web site. UNAVCO, Inc. is a principal participant in planning for the proposed EarthScope NSF Major Research Equipment and Facilities Construction (MREFC) project along with the Incorporated Research Institutions for Seismology (IRIS) and Stanford University.

UNAVCO, Inc. welcomes inquiries from prospective users of GPS for either recognized or new applications of this exciting technology.

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

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

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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 Consortium for Advanced Radiation Sources, which is managed by the University of Chicago.

Most 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 both monochromatic and energy-dispersive techniques, including double-sided laser heating apparatus
- X-ray diffraction and imaging in the large-volume press using both monochromatic and energy-dispersive techniques. There is 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
- X-ray absorption spectroscopy including micro-spectroscopy, with beam sizes near 1 μm , and surface studies
- X-ray fluorescence microanalysis
- Inelastic x-ray scattering with $\sim 1\text{eV}$ resolution
- 3-D computed microtomography

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) evaluation of potential waste cleanup protocols, (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 GeoSoilEnviroCARS facility is available to all interested Earth scientists through a web-based proposal system (http://www.aps.anl.gov/user/beamtime/get_beam.html). The GSECARS web page (<http://www.gsecars.org>) contains announcements of proposal deadlines, 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. Over 750 beamtime proposals have been received since implementation of the beamtime proposal system in 1998. Over 410 visiting scientists have conducted experiments on the GSECARS sector since 1997. In

FY2003 there were 89 experiments performed on the undulator beamline and 82 experiments on the bending magnet beamline.

In addition to the experimental stations, GeoSoilEnviroCARS has laboratories for sample preparation and characterization, and 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)

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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 are using the accelerator to measure both man-made and cosmic-ray-produced radioisotopes such as ^{14}C (half-life 5730 years), ^{10}Be (1,500,000 years), ^{26}Al (730,000 years), ^{36}Cl (300,000 years), ^{41}Ca (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 the Earth and planetary sciences. Applications include measuring the exposure time and erosion rate of rocks on the surface of the Earth 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. 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 building on the Purdue campus contains 31,000 sq. ft of floor space with 14 offices and 16 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.

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 300 samples per year and perform AMS measurements on over 3000 samples per year. We continually work to improve AMS methods and develop detection of new nuclides.

PRIME Lab is currently available to the research community for measurements of the nuclides ^{10}Be , ^{14}C , ^{26}Al , ^{36}Cl , and ^{129}I . In addition, we can determine carbon and chloride concentrations using isotope dilution. 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>

NSF – University of Arizona Accelerator Mass Spectrometer (AMS) Laboratory

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Facility Description:

The NSF - University of Arizona Accelerator Mass Spectrometer (AMS) laboratory is a national facility dedicated to radioisotope research. The purpose of the facility is to provide radioisotope measurements for a broad range of scientific and historical studies. The facility is financed by the National Science Foundation and by funds received from user charges.

The AMS laboratory is primarily devoted to radiocarbon measurements. Samples are submitted by scientists from around the world. A typical sample is pretreated, converted to CO₂, and reduced to graphite. The ratio of ¹⁴C/¹³C in the graphite is measured in the accelerator and used to calculate a radiocarbon age. A conventional stable isotope mass spectrometer is available to provide δ¹³C measurements. These δ¹³C measurements will be provided for all samples except some sediments, and this information is used to correct the ¹⁴C ages to δ¹³C of -25 ‰, as by convention, before reporting them.

For samples younger than a few thousand years, the ¹⁴C/¹³C ratio is measured with a standard deviation of about 0.5%. This precision yields an uncertainty in the radiocarbon age of approximately ± 40 years. Published tree-ring calibration curves are used to determine calendar ages. The uncertainty in the calendar age is generally larger than the uncertainty in the radiocarbon age, and depends on the location of the calculated age in the calibration curve. For samples with ages greater than about 11,000 years, only radiocarbon ages are quoted. For special cases, better precision can be achieved by analyzing several targets made from the same material. This improves the standard deviation of the averaged result by a factor of sqrt(n), where n is the number of independent analyses. The best precision obtained to date is 0.2%. The maximum radiocarbon age that can be measured at the facility is about 48,000 years B.P.

The AMS facility is also equipped to provide ¹⁰Be measurements. Beryllium oxide targets are used in the accelerator to measure the ¹⁰Be content of samples. For samples with ratios of ¹⁰Be/⁹Be = 10⁻¹³, ¹⁰Be rates of about 3.5 counts per minute can be obtained.

The laboratory facilities have been expanded with the addition of a second AMS instrument. We expect that this addition will improve the reliability of the operation of the laboratory, and allow the analysis of additional cosmogenic isotopes.

For current sample size requirements and fees, see our web page or contact the laboratory directly.

WWW Home page URL: <http://www.physics.arizona.edu/ams>

Institute for Rock Magnetism (IRM)

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Facility Description:

The Institute for Rock Magnetism (IRM) was established in the fall of 1990 to provide the Earth Science research community with no-cost access to state-of-the-art facilities and technical expertise for magnetic material characterization. Visiting scholars and resident researchers utilize the resources of the IRM to study contemporary topics in rock magnetism, paleomagnetism, and a broad range of interdisciplinary fields such as biomagnetism and paleoclimate records.

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.

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). 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 μ m) 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.

Current in-house projects include magnetic phenomena in nanophase and poorly-ordered materials [e.g., Guyodo et al., *Geophys. Res. Lett.*, 30, 10.1029/2003GL017021, 2003], effects of paleoclimatic and paleoenvironmental change on sediment magnetic properties [e.g., Brachfeld et al., *Earth Planet. Sci. Lett.*, 194, 311-326, 2002], biomineralization of magnetic material [e.g., Frankel & Moskowitz, in *MagnetoScience: Molecules to Materials*, Wiley-VCH, 2003] and phenomena associated with low-temperature magnetic and phase transitions [e.g., Carter-Stiglitz et al., *Geophys. Res. Lett.*, 29, 10.1029/2001GL014197, 2002]. Examples of recent research by Visiting Fellows include investigations of the origin of stable magnetic memory in relatively large multidomain particles, using low-temperature measurements; and studies of climate-driven periodic variations in the physical and chemical characteristics (particle size distribution, mineral composition) of marine sediments, using suites of field- and temperature-dependent magnetic measurements. Undergraduate seniors from small colleges and universities in the upper mid-west carry out senior thesis research under guidance from IRM faculty and staff. Since 1992, five biennial conferences have been held in Santa Fe, NM, organized by IRM to advance new interdisciplinary research utilizing rock-magnetic techniques. A conference organized jointly by the IRM and the European

Community's MAG-NET research consortium was held in Erice, Sicily in 2002, and a sixth Santa Fe conference is planned for the summer of 2004.

Cooperative efforts with magnetics groups from nearby companies (Seagate Technology and Web Research) lead to the productive exchange of ideas and provide fertile ground for the development of new technology.

Interested scientists are encouraged to apply to become Visiting Fellows or Visiting Students. Applications are accepted twice a year for work to be done during the following half year. 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. To help defray travel costs, we offer a limited number of grants for up to \$750 each as seed money to researchers who submit outstanding proposals. (There are no funds available for per diem personal expenses.) Shorter, less formal visits from other researchers are readily arranged through the laboratory manager. There are no fees for use of IRM facilities.

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.geo.umn.edu/orgs/irm/irm.html>

W.M. Keck Foundation Center for Isotope Geochemistry – National Ion Microprobe Facility

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Facility Description:

The principal resource of the W.M. Keck Foundation Center for Isotope Geochemistry is a CAMECA ims 1270 high resolution, high sensitivity ion microprobe. A LEO 1430 VP scanning electron microscope is available for sample characterization in support of ion microprobe analyses. The Division of Earth Sciences of the National Science Foundation provides a portion of the support for the Keck Center to enable us to host external users from the geological and related communities. We seek to provide the user with a world-class instrument that is developed to support applications that both take advantage of its unique capabilities and are at the forefront of scientific investigations.

Two primary application areas have been developed for the ims 1270, a large-radius, triple-focusing mass spectrometer: U-Th-Pb measurements of accessory minerals, and stable isotopic analysis of silicate, carbonate, and oxide minerals. U-Th-Pb analyses are conducted using a primary beam of O⁻ ions that can be focused to spots from 10 to 30 μm on 1" polished thin sections or grain mounts. A slit-lens transfer optical system and the 585 mm radius magnet achieve high secondary ion transmission at the mass resolving power of ~5,000 required for these analyses. Measurements of U-Th-Pb systematics of zircon and monazite yield high Pb sensitivities (up to 20 cps/ppm/Pb/nA) and typical age accuracy of ±2%. Stable isotope measurements of oxygen and carbon in carbonates, silicates and oxides are undertaken using a Cs⁺ primary beam and yield typical precision for δ¹⁸O and δ¹⁷O of 1.0 ‰ for 15 minute analysis times and 15 μm diameter spots. Similar results are obtained for δ¹³C in carbonates. See our web page for more details.

To request utilization of the ion microprobe, contact Dr. Marty Grove or Dr. Kevin McKeegan to discuss feasibility of the project and availability of instrument time. For projects requiring development work, external investigators are expected to collaborate in the investigation with a member of the Center staff. Such collaboration is not required for routine analyses, however, in all cases it is expected that data obtained from the ion microprobe will be written up for publication in a refereed journal in a timely fashion. Investigators currently funded by NSF pay a subsidized user rate of \$100/hour. Non-NSF supported external users pay the full rate of \$250/hour.

WWW Home page URL: <http://oro.ess.ucla.edu/ionprobe/home.html>

Northeast National Ion Microprobe Facility (NENIMF) at Woods Hole Oceanographic Institution

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Facility Description:

The NENIMF was established in 1996 by Nobumichi Shimizu as an outgrowth of the Woods Hole Oceanographic Institution (WHOI) Regional Ion Microprobe Facility, and represents a consortium effort involving WHOI, Massachusetts Institute of Technology (MIT), Brown University, Rensselaer Polytechnic Institute (RPI), Lamont-Doherty Earth Observatory (LDEO) and the American Museum of Natural History (AMNH). The facility is equipped with Cameca IMS 3f and IMS 1270 ion microprobes, and with complementary sample preparation equipment.

The NENIMF consortium members and non-consortium facility users cover a broad range of geochemical research including solar/presolar materials and processes, early Earth evolution, mantle dynamics, crustal processes and evolution, environmental monitoring and experimental geochemistry. Measurements of both the abundances of diverse trace elements (REE, HFSE, LILE) as well as stable and radiogenic isotopes are essential components of this research. Technique developments reflect the broad range of scientific interests of the user base.

The IMS 3f has been used since 1978 for a wide spectrum of geochemical studies, and remains highly effective for in situ trace element and REE analysis of rock-forming minerals and glasses (spatial resolution better than 10 μ m). More recent applications for the IMS 3f include i) measurement of $\delta^{11}\text{B}$ in melt inclusions, and in natural waters (prepared by evaporation) and, ii) measurement of Sr, Mg and Ba in marine biogenic carbonates for paleotemperature reconstructions and other applications.

The IMS 3f continues to be readily accessible to scientists from the United States and beyond. Current user fees for this instrument for geochemical research are \$80/hour. We are currently reevaluating the facility structure, including user fees, and will publicize the results of this reevaluation as soon as possible.

The IMS 1270 is a high transmission-high mass resolution SIMS instrument with a great number of extended capabilities for geochemical analysis. NENIMF applications include in situ Pb isotope measurements in glasses, sulfides and silicate minerals, ii) high precision $^{232}\text{Th}/^{230}\text{Th}$ analyses in Th separates from volcanic rocks, iii) stable Cl isotope analyses of glasses and small aliquot fluid samples, iv) HMRP trace element analyses in sulfide and carbonate minerals, and v) high precision carbon and sulfur isotope analyses..

The IMS 1270 was seriously damaged in a fire on October 22, 2002. We are currently in the process of negotiating replacement/repair of this instrument and are working towards making the IMS 1270 available to the community again as soon as possible.

WWW Home page URL: <http://www.whoi.edu/nenimf/>

High-Resolution X-Ray Tomography Facility

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Facility Description:

The high-resolution computed X-ray tomography facility at the University of Texas at Austin makes state-of-the-art industrial tomographic imaging capabilities available to the scientific community. Our principal focus is on research applications in the earth sciences. The facility combines a custom-designed tomographic scanning system with a digital image-analysis laboratory to provide data analysis and visualization.

High-resolution X-ray CT (computed tomography) is a completely non-destructive technique for visualizing and measuring features in the interior of opaque solid objects, and for obtaining digital 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 few tens of micrometers 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, and organic tissues; quantitative textural analysis of crystalline rocks; porosity/permeability assessment; description of 3-D fracture patterns in aquifer and reservoir rocks; 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 features.

The centerpiece of the facility is a tomographic scanner designed for three modes of operation: high-energy and high-resolution computed tomography; real-time microradiography; and digital radiography. For high-penetration tomography of large and dense objects, a 420 kV X-ray source is employed, with either a solid-state linear array detector, or a high-resolution radiographic line scanner detector. For micro-tomography of smaller objects, a 200 kV microfocal X-ray source with image intensifier is employed.

The facility encourages use by external investigators: in calendar year 1999, more than half of the imaging done by the facility was for outside users. Investigators working on NSF-funded projects receive priority scheduling and a reduction in user fees to 50% of normal rates. 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/>

Facility for Electromagnetic Study of the Continents (EMSOC)

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Facility Description:

The EMSOC facility provides equipment for inductively sensing the electrical conductivity structure of the Earth's interior. Electrical conductivity is related to temperature and the presence and connectivity of fluids or other interstitial conductive material such as graphite that are difficult or impossible to sense by other means.

The facility presently consists of fourteen long period (10-30,000 s) magnetotelluric (MT) systems and 2 wideband (.002 to 500 s) MT systems. Together, these systems are suitable for targets ranging from the near surface (tens of meters) to the upper mantle (~400 km depth). They are owned respectively by the University of Washington (UW), the University of California at Riverside (UCR), and the University of Utah (UU).

The fifteen-channel, wideband MT system of UCR is commercially manufactured and is suitable for either continuous tensor MT profiling (an electromagnetic equivalent of seismic reflection profiling) or simultaneous multi-site MT using GPS synchronization. The second existing wideband system has been developed by UU. While also functioning similarly to the commercial units, the latter addresses additional research situations, such as deployment on ice sheets or radio telemetry, which are not currently possible commercially. This system is currently being rebuilt to allow simultaneous multi-band acquisition, GPS synchronization, and higher bandwidth and telemetry rates. Five additional long-period instruments are to be purchased.

Although the MT equipment is owned by the grantee institutions above, its use is open to the U.S. academic community. Users are expected to pay for expendables (e.g., batteries, wire, electrodes), shipping, insurance and training. Users are required to be trained and to archive data according to the IRIS Data Management System under rules similar to those governing PASSCAL seismic data.

The Facility is governed by the EMSOC Facility Steering Committee (EFSC). This committee presently consists of three representatives from the three grantee institutions and three representatives from other academic institutions. The EFSC sets policy, oversees operations, allocates equipment use through an open application process and organizes training opportunities. All actual equipment use is coordinated by the Scientist-in-Charge to whom inquiries regarding equipment availability should be addressed.

WWW Home page URL: <http://vortex.ucr.edu/emsoc/index.html>

NSF-Supported Center for Airborne Laser Mapping (NCALM)

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Facility Description:

NCALM is an NSF supported Center for Airborne Laser Mapping which supports and promotes application of Airborne Laser Swath Mapping (ALSM) technology in the scientific community. The Center is operated jointly by the Department of Civil & Coastal Engineering, College of Engineering, University of Florida (UF) and the Department of Earth and Planetary Science, University of California-Berkeley (UCB). NCALM uses the ALSM system jointly owned by UF and Florida International University (FIU), based at the UF Geosensing Engineering and Mapping (GEM) Research Center.

The ALSM observations are analyzed both at UF and UCB, and made available to the PIs through an archiving and distribution center at UCB - building upon the Berkeley Seismological Laboratory (BSL) Northern California Earthquake Data Center system. Both the UF and UCB groups contribute to software development that increases the processing speed and data accuracy. NSF supported researchers contact UF during proposal preparation to obtain guidance on cost estimates, scheduling and related issues. Once funded, PIs and their students participate in all phases of the research.

CENTER OBJECTIVES

Primary goals of NCALM are:

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

NCALM MANAGEMENT AND GOVERNANCE

NCALM is managed, overseen and governed by nine Steering Committee (SC) members, including one elected Chair, from universities across the United States. The SC meets twice a year, once in Florida and once at Berkeley (the latter in association with the Annual meeting of the American Geophysical Union). The SC provides guidance and review on the following issues:

1. Analysis scheduling and prioritizing projects,
2. Cost effective management of the Center,
3. Information dissemination,
4. Opportunities and necessities for technological upgrades, and

5. Contact and coordination with major programs (PBO, CUAHSI, Margins, etc) and agencies (NASA, FEMA, etc.)

INFRASTRUCTURE

The state-of-the-art NCALM instrumentation is used to collect data in areas selected through the competitive NSF grant review process. The major component of the system is a laser that emits 33,000 pulses per second. The laser is mounted in a small twin engine (Cessna 337) aircraft and the laser pulses are directed towards the ground by a scanning mirror. Each pulse illuminates an area, or footprint, of about one foot in diameter and the light is scattered back to a sensor in the aircraft. 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 resulting set of latitudes, longitudes and heights of many millions of points on the ground. Research grade ALSM data can be used to produce highly accurate three-dimensional, digital topographical map of a large area of land surface.

OUTREACH

The first two-year NCALM budget includes funding “seed” projects. The fund is used for small demonstration projects for PIs who need ALSM data sets in different areas of research in geo-sciences. The seed funds also provide support for educational and visiting fellowship 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.ufl.edu/>