



2004 Annual Report



Incorporated Research Institutions for Seismology



National Science Foundation  
4201 Wilson Boulevard  
Arlington, Virginia 22230

### IRIS Consortium Members.

This past year has been both very exciting and very challenging for EAR and the IRIS Consortium. The successful launch of EarthScope and the USArray facility has brought additional responsibilities and management challenges for EAR and IRIS. Moreover, an additional requirement in our Cooperative Agreement this year was an NSF review of IRIS management. This review was undertaken in April 2004 by a special emphasis panel and was designed to guide the *Instrumentation & Facilities Program* in its recommendation to the National Science Board to renew or recompetite the management of the IRIS facilities. At your Annual Workshop in Tucson, I described this process and was able to report on some of the findings of the review panel. One quote from this report says it all: "By all standards and measures, IRIS has been and continues to be a spectacular success story." The panel concluded that IRIS is characterized by both exceptional management and an exceptional degree of community involvement in all strategic planning and program execution.

Your success clearly lies in the strong involvement of the scientific community at all levels of IRIS facility management and consortium governance. Because of your successes, the consortium management model is now being emulated by other EAR organizations. I am very grateful to all of you who have encouraged and mentored other communities as they have organized along similar lines. Thank you for sharing your 20 years of experience!

So, what does the future hold for IRIS? Yes, budgets are tight but we must all continue to innovate. I am certain that the IRIS consortium has identified new and exciting opportunities to engage the community, especially in the international arena where IRIS has always had very strong connections. I look forward to receiving your next five-year proposal and to learning about the new science opportunities that will be enabled by IRIS!

David D. Lambert, Ph.D.  
Director, Instrumentation & Facilities Program  
Division of Earth Sciences



# IRIS

## 2004 Annual Report

IRIS is a university research consortium dedicated to monitoring the Earth and exploring its interior through the collection and distribution of geophysical data. IRIS programs contribute to scholarly research, education, earthquake hazard mitigation, and the international verification regime for the Comprehensive Nuclear Test-Ban Treaty. IRIS operates through Cooperative Agreements with the National Science Foundation under the Division of Earth Science's Instrumentation and Facilities Program and the EarthScope Program. Funding is provided by the National Science Foundation, other federal agencies, universities, and private foundations. All IRIS programs are carried out in close coordination with the US Geological Survey and many international partners.

# The Year in Review

The year 2004 – our 20th year as a Consortium - has been one of significant growth and change for IRIS. As shown in the later sections of this report, the IRIS core programs, with solid support from the EAR Instrumentation and Facilities Program at NSF, continue to provide data and services that underlie much of modern research in seismology in the US and internationally. The GSN has stabilized at more than 130 stations, most of which now provide data in real time. To ensure the long-term survival of the network, a new generation of instrumentation is under development and plans are underway to streamline and enhance routine operations. PASSCAL instruments continue to be used in variety of national and international programs and a new generation of instruments has become available with support from DOE. The Data Management System continues to efficiently collect, manage and distribute data from the growing archive. Increasing effort is being applied to providing software tools to support the effective use of these data and encourage data exchange with other networks. The Education and Outreach Program has had great success with outreach through museum displays and collaboration with the Seismological Society of America on a Distinguished Lecturer series. The IRIS Intern and Educational Affiliate programs have proven to be very successful in engaging undergraduate students and encouraging them to consider careers in Earth Science.

EarthScope is underway. IRIS, in collaboration with UNAVCO Inc, Stanford University and USGS, has embarked on a major initiative to establish a new and exciting array of observational facilities for exploration of the structure and dynamics of North America. The IRIS core programs provide the solid foundation from which we are able to build the integrated systems of USArray (Backbone Network, Transportable Array and Flexible Array) as part of the EarthScope facility being funded through the NSF Major Research Equipment and Facility Construction account.

The Annual Workshop in June provided an opportunity to celebrate the 20th anniversary of the creation of IRIS in 1984. In addition to the usual review of current IRIS activities and discussion of future opportunities, many of those involved in the birth of the consortium shared their recollections of the early history of IRIS and helped to review the accomplishments of our programs over the past two decades.

At the special Board meeting at the June Workshop, important modifications to the IRIS Bylaws were adopted that streamline the structure of the Consortium to allow it to better serve the membership, NSF, and other funding agencies. In the coming year, the new IRIS Board of Directors will continue to take important actions on behalf of the members of the Consortium. The most significant of these will be the development and submission of a

proposal to the National Science Foundation for the next five years of IRIS activities. All members are encouraged to take advantage of the opportunities available to participate in the planning and development of the proposal.

One of the strengths of IRIS has been the depth and breadth of community participation in the governance and management of our programs. An essential ingredient in our success has been the dedication and responsibility that the many committee members bring to the important tasks of advising and guiding the activities and evolution of the Consortium. To current and past members we extend our sincere thanks - and we look forward to engaging a new generation in the future success of the Consortium.

## Executive Committee and Officers

Göran Ekström (Chair)	Harvard University
Thomas Owens (Vice Chair)	University of South Carolina
Andrew Nyblade (Secretary)	Pennsylvania State University
Susan Beck	University of Arizona
Greg Beroza	Stanford University
Arthur Lerner-Lam	Columbia University
Kate Miller	University of Texas, El Paso
Brian Stump	Southern Methodist University
Candy Shin	IRIS Treasurer
David W. Simpson	IRIS President

## Planning Committee

Arthur Lerner-Lam (Chair)	Columbia University
Göran Ekström	Harvard University
Thomas Jordan	University of Southern California
Alan Levander	Rice University
Anne Meltzer	Lehigh University
Michael Wyession	Washington University, St Louis
David W. Simpson	IRIS President
Position Not Filled	IRIS Director of Planning

## Coordination Committee

Thomas Owens (Chair)	University of South Carolina, ExCom
Rick Aster	New Mexico Tech, E&O
David James	Carnegie Institution of Washington, PASSCAL
Thorne Lay	University of California, Santa Cruz, GSN
Guust Nolet	Princeton University, DMS
Brian Stump	Southern Methodist University, ExCom
Timothy Ahern	IRIS DMS
Rhett Butler	IRIS GSN
James Fowler	IRIS PASSCAL
Shane Ingate	IRIS Director of Operations
Candy Shin	IRIS Treasurer
David Simpson	IRIS President
John Taber	IRIS E&O

The IRIS management structure is an interface between the scientific community, funding agencies, and the programs of IRIS. The structure is designed to focus scientific talent on common objectives, to encourage broad participation, and to efficiently manage IRIS programs.

IRIS is governed by a Board of Directors elected by representatives from each member institution. The Board of Directors appoints members to the Planning Committee, the Program Coordination Committee, the USArray Advisory Committee, and the four Standing Committees that provide oversight of the Global Seismographic Network (GSN), the Program of Array Seismic Studies of the Continental Lithosphere (PASSCAL), the Data Management System (DMS), and the Education and Outreach Program (E&O). In addition, special advisory committees and ad hoc working groups are convened for special tasks. It is the role of the Standing Committees and the advisory subcommittees to develop recommendations for the Board of Directors.

Consortium

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Maryland Geological Survey  
Gerald R. Baum

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Hanyang University, Republic of Korea  
So Gu Kim

Institute of Geophysics, Switzerland • Domenico Giardini

Academia Sinica, Institute of Earth Sciences, Taiwan  
Bor-Shouh Huang

National Central University, Taiwan  
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Istanbul Technical University, Turkey  
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Kandilli Observatory, Bogazici University, Turkey  
Nurcon Ozel

Tubitak-Marmara Research Centre, Turkey  
M. Namik Yalcin

\* New members are displayed in bold.



# GSN

global seismographic network

The Global Seismographic Network is a permanent network of state of the art seismological and geophysical sensors connected by available telecommunications to serve the scientific research and monitoring requirements of our national and international community. All GSN data are freely and openly available to anyone via the Internet. Installed to provide broad, uniform global coverage of the Earth, 137 GSN stations are now sited from the South Pole to Siberia and from the Amazon basin to islands in the Indian Ocean, in cooperation with over 100 host organizations and seismic networks in 59 countries worldwide. The GSN coordinates closely with other international Networks through the Federation of Digital Broadband Seismograph Networks (FDSN), of which the IRIS is a founding member.

The GSN is operated and maintained through the USGS Albuquerque Seismological Laboratory and through the University of California at San Diego IRIS/IDA group. Ten GSN Affiliated stations and arrays contribute to the Network, which are operated and maintained independently. In collaboration with the U.S. National Earthquake Information Center, the GSN and NEIC are the principal global source of data and information for earthquake locations, earthquake hazard mitigation, and earthquake emergency response. In collaboration with U.S. Tsunami Warning Centers, the GSN provides essential data for tsunami warning response.

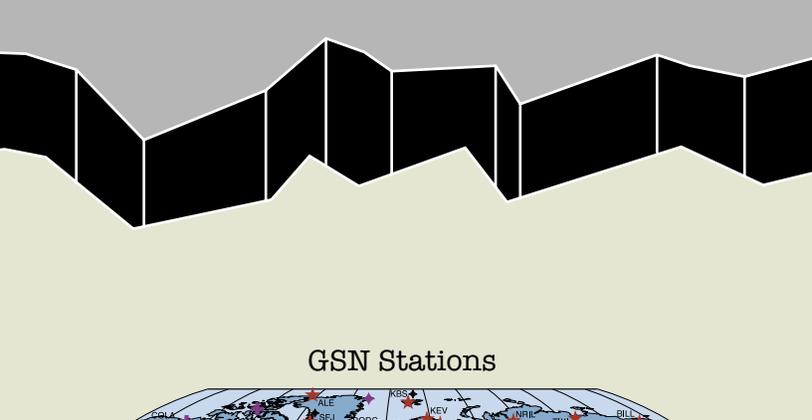
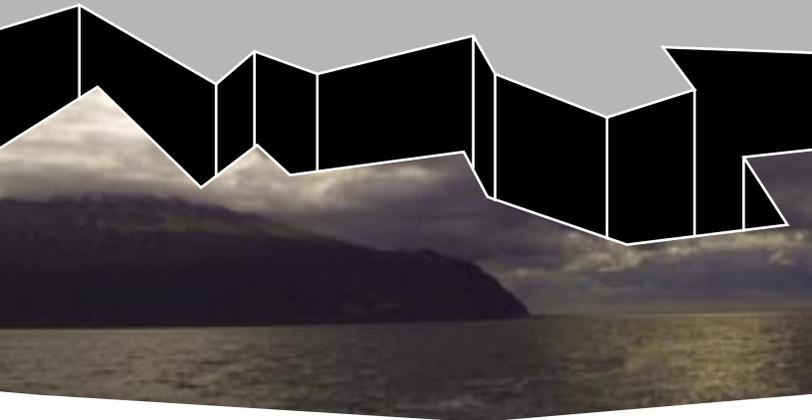
The GSN grew by four stations in 2004. New stations were installed on Funafuti and Raoul Island in the South Pacific, Diego Garcia in the Indian Ocean, and Tristan da Cunha in the South Atlantic. All of the new installations are in seismic vaults on very remote islands. The Funafuti and Raoul installations are cooperative with Japan's National Research Institute for Earth Science and Disaster Prevention. The Tristan da Cunha site is a joint station with the French GEOSCOPE Network, and the installation was done in cooperation with the Comprehensive Nuclear Test Ban Treaty Organization, which also installed seismic equipment on the island. Work is in progress by our Australian colleagues in completing a joint seismic station on Macquarie Island between New Zealand and Antarctic, where GSN seismometers were installed this year.

Continuous, real time telemetry of all GSN data is a fundamental goal. The GSN continues to create opportunities to extend new telecommunications capabilities to our stations. We are in transition from air mailed media, dial up telephone, and slow speed Internet access to broadband VSAT satellite links and high speed Internet. In 2004, 86% of the GSN is now on-line via Internet and VSAT links. Real-time access is available to all GSN stations in the United States.

Eleven new telemetry circuits were established in 2004. The IRIS/IDA group has arranged for Internet connectivity to our new GSN station on Diego Garcia, and our site in Erimo Japan. VSAT systems provide the majority of new telecommunications circuits for the GSN.

The GSN is working closely with the International Monitoring System (IMS) for the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) to share data from more than 50 GSN sites designated for participation in the IMS. Twenty GSN sites are now linked directly to the CTBTO International Data Centre via their global communication infrastructure (GCI) being established for secure communication. This satellite infrastructure is shared with the GSN, enabling remote operations, maintenance, and quality control for the IMS, and providing real-time GSN data access for the scientific community. Nine





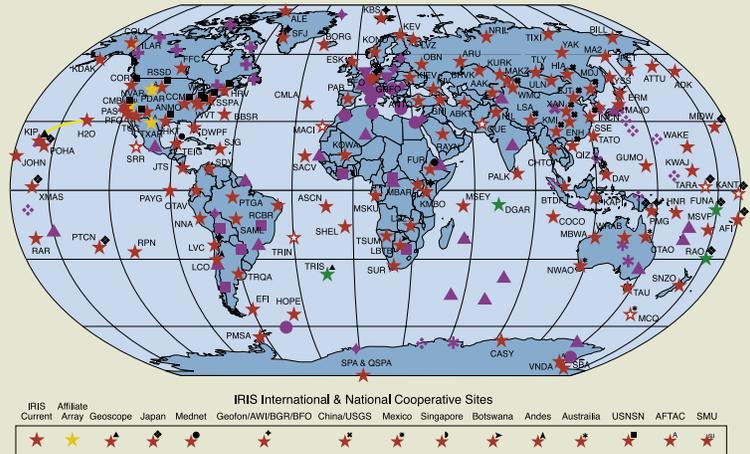
new, shared VSAT links have been established this year, opening real-time access to GSN sites in Western Samoa, Solomon Islands, Namibia, Tristan da Cunha and Raoul Island, and providing for enhanced access to Kodiak Island, Easter Island, Kyrgyzia, and South Africa. Eighteen GSN sites now have access to shared GCI telemetry.

In the Pacific, the GSN continues coordinating directly with the National Weather Service (NWS) to bring GSN data directly to the Oahu hub at the Pacific Tsunami Warning Center, where it is then forwarded to the Internet. VSAT systems are currently in place at five sites in the Pacific: Johnston, Midway, Wake, Easter, and Pitcairn Islands. NWS is funding the satellite space segment costs for GSN data access. The Oahu hub is also being cooperatively used by UNAVCO/NASA for GPS telecommunication from Easter Island, and by the Pitcairn Islanders for their Internet access.

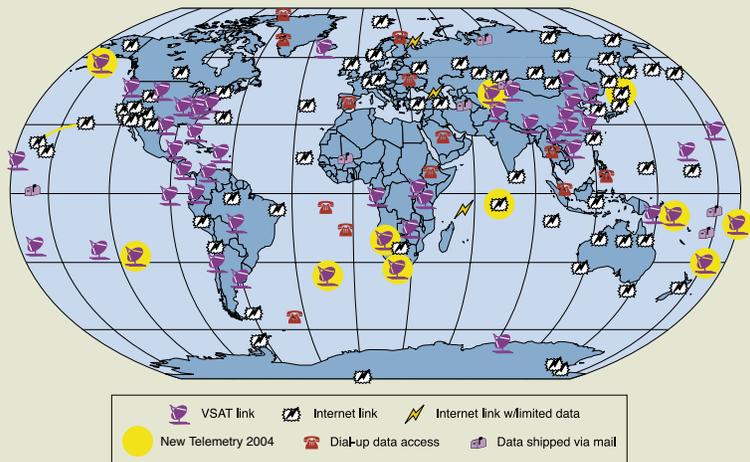
Many GSN sites have evolved into geophysical observatories. An extended suite of geophysical instrumentation makes use of GSN logistical and telemetry infrastructure, including GPS, gravimeters, magnetometers, microbarographs, and meteorological sensors. The 40 microbarographs installed globally at GSN sites are the largest open data source of its kind. The GSN continues its close cooperation with the GPS community with co-located instrumentation at 17 sites and additional shared telemetry infrastructure in Africa and Siberia.

The nineteen GSN stations in the United States are part of the USGS Advanced National Seismic System (ANSS) Backbone. Under joint ANSS and GSN funding in 2004, site preparations were completed for new Backbone stations in Texas, Tennessee, and Montana. The USArray Backbone team at ASL completed seismometer upgrades at eight Backbone stations in Georgia, Arkansas, Texas, Virginia, Washington, Colorado, Utah, and Arizona to further enhance the Backbone this year.

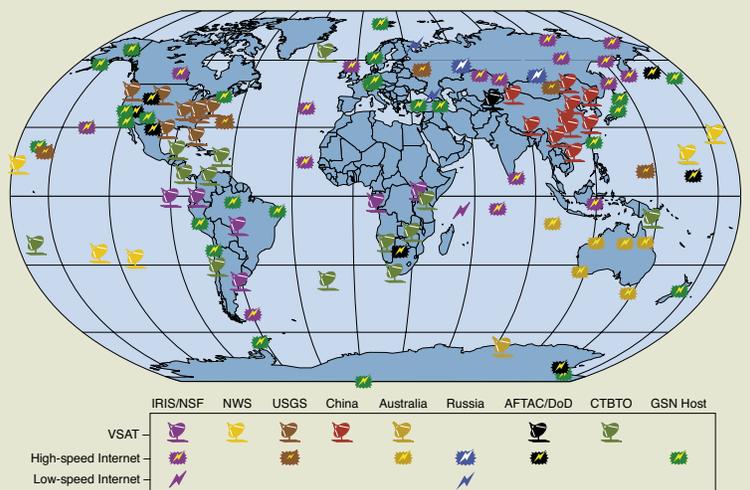
## GSN Stations



## GSN Communications



## GSN Telemetry



### Standing Committee

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Karen Fischer	Brown University
Gabi Laske	University of California, San Diego
Bill Leith	US Geological Survey, Reston
Jeffrey Park	Yale University
Mike Ritzwoller	University of Colorado
Jeroen Tromp	California Institute of Technology
Lianxing Wen	State University of New York, Stony Brook
Rhett Butler	GSN Program Manager

# Raoul Island GSN Installation

By ASL/HTSI Field Engineer Ted Kromer



In September 2004, the most recent Global Seismological Network station, Raoul Island (RAO), was installed by a team of two field engineers from the US Geological Survey's Albuquerque Seismological Laboratory (ASL). ASL's Honeywell Technology Solutions, Inc. (HTSI) field engineers Mark Sharratt and Ted Kromer visited the remote island, the largest of the Kermadec Islands, situated directly above the boundary of the Australian and Pacific Plates. Raoul has been host to many who have tried to settle the island, but has been a New Zealand meteorological and seismological station for many years. Now operated by the Department of Conservation, Raoul Island is New Zealand's largest marine reserve. The island is inhabited by a handful of meteorological staff and volunteer conservationists.



The seismological station installation, a coordinated effort between IRIS, the U.S. Geological Survey, and the Comprehensive Test Ban Treaty Organization, was designed to provide continuous real time telemetry of data for the CTBTO and the GSN. The ASL field engineering team, along with a CTBTO VSAT engineer, deployed as a team to perform the seismological station installation. Access to the Island required deployment by means of an ocean capable vessel for the three day voyage, sometimes confronting twenty foot swells. The New Zealand registered boat, Braveheart, a former Japanese-owned research vessel, was chartered to transport the team to the island, *intending* to return three weeks later for the return voyage.

The actual seismological station site, chosen via a site survey performed in 1997, is located six kilometers from the Raoul Caldera. Though the caldera has had no eruptions since 1964, tremors and small earthquakes can be felt on a daily basis. Installing a seismological station at such a remote location, where there were no commercial stores, and only minimal facilities existed, required that every conceivable piece of hardware be brought with the installation team. Offloading the equipment from the transport ship required transferring personnel and equipment onto smaller craft for hauling to the base site. Because there is no dock at Raoul, equipment had to be hoisted from small inflatable boats by a hand operated boom and powered winch. Arriving passengers on inflatable boats had to jump onto a rock when the boat was at the crest of a wave, and quickly scramble up the rocks before the next wave comes to sweep them into the ocean.



The living facilities on Raoul, constructed sometime in the 1940's, are separated into two different sections. The Hostel is where the island staff reside, and hosts the kitchen and the Annex, where the volunteers and visitors bunk. Each person is responsible for preparing his or her own food, with the exception of dinner, and cleaning of the facilities. Dinner is prepared by two persons who have been scheduled to be the cooks for that night.



Once the installation team had settled and equipment had been inventoried, the team began station installation activities. The station is comprised of an STS-2 broadband seismometer, an STS-1 vertical very broadband seismometer, and an FBA-23 accelerometer, housed in a surface vault constructed by the island staff a year previous to the arrival of the installation team.

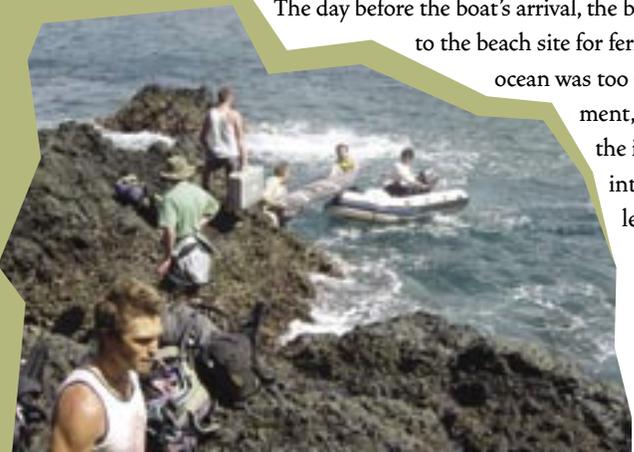
Fighting frequent rain storms and windy days, the installation team was able to erect the 2.4 meter satellite dish the first day and install the seismic station in just four days. Installation of the STS-1 vertical seismometer stretched over five more days due to the instrument's sensitivity to the slightest wind, temperature fluctuations, and rain showers.

In cooperation with the CTBTO's International Monitoring System, the data can be accessed through the GCI link that was installed during the same visit by ASL and Hughes Network Service personnel (HNS).

Upon completion of the station installation, the field personnel had to wait for the returning ship to return them to New Zealand. Unfortunately, a change in plans occurred due to issues on Pitcairn Island, canceling their return reservation. Department of Conservation Program Manager Mike Ambrose was able to secure another ship in the vicinity that could extract the engineers, but it would be an additional three weeks before the ship would actually arrive at Raoul. And even then, the ship was bound for the Kingdom of Tonga, not New Zealand, where they had return airline tickets. As IRIS and the Department of Conservation's agreement was to provide round trip transportation to Raoul (from New Zealand), the Department of Conservation obtained return airline tickets for the field engineers from Tonga to New Zealand.

During the three week delay, frequent hikes around the island and cleaning of the Hostel became the highlight of the day. As each week passed, the fourteen island volunteers were also nearing the end of their project, and were also waiting to leave the island after finishing four months of hard work. Each day there would be reports of a delay of the boat. After a few weeks, wondering if Raoul Island would end up with seventeen permanent inhabitants, news came that the ship's arrival was near.

The day before the boat's arrival, the bags were packed and spirits were greatly lifted. Again, all equipment was hand trucked to the beach site for ferrying out to the main ship by way of a small rubber dinghy. Unfortunately, this day, the ocean was too rough, so the ship 'Evohe' deployed to the other side of the island, requiring all equipment, baggage, and personnel to move down a narrow trail, another two miles. Getting off the island followed the same reverse process of arrival, only this time jumping from a rock into a small dinghy. Once all persons and their luggage were loaded, the boat was off, leaving behind the four island staff to complete the rest of their twelve month stay. Less than one hour out, Raoul Island disappeared below the horizon as well as the fourteen volunteers, who disappeared below decks feeling ill, as the waves grew to the now routine 20 foot swells.



# PASSCAL

program for the array seismic studies  
of the continental lithosphere

PASSCAL has supported almost 70 experiments this year. The broadband instrument pool has grown to almost 400 instruments, but the waiting time for experiments continues to be over two years. The limitation on broadband instrumentation continues to be the shortage of sensors. PASSCAL has continued an aggressive policy of broadband sensor acquisition, but the demand continues to outrun availability. Even though the number of broadband experiments has not grown, the total number of instruments requested has increased, and we expect this to continue.

The active source instrument pool of single channel “Texan” instruments contains over 800 instruments. These instruments along with approximately 250 units from European pools represent the total number of instruments available for university conducted long–offset reflection/refraction experiments. The use of these instruments has increased significantly over the last year. The instruments have been in the field constantly since the beginning of the year. This has put a strain on the pool in that we have not had time to do any preventive maintenance and instrument repairs cannot be performed in all field locations.

To help address the problem of increasing broadband demand and the effects of aging on the current instrument pool, Congress appropriated \$9,500,000 for the PASSCAL program spread over the last three fiscal years. The funding, provided through DOE’s Nonproliferation and National Security Research and Development Account, has not only allowed the replacement of the older instruments but also for the development of a new generation telemetered array that will consist of 25 broadband stations. The telemetry equipment for the array is currently deployed as part of a short period array in Parkfield, CA. As a result of this DOE funding, we have been able to acquire approximately 400 new data recorders. When this year’s funding is available, we will be able to purchase approximately 200 new units. This will enable us to “retire” all of the original instruments.

The new dataloggers have been in the field now for over a year. They are lower power, lighter weight, more reliable and have better timing than the older units. The ability to network these units together over an IP network will prove to be extremely useful as satellite, cell phones and other communications systems adopt the IP protocol and become more widespread. These new capabilities are being used in US as part of the Transportable Array system in EarthScope.

The major software developments continue to be centered around the new instrumentation. While we have developed the basic capability to archive the data from the new instrumentation we are now looking at improving the ability to service the instruments in the field, the quick look capabilities and the ability to troubleshoot the data. In addition to the development of user software, we are also developing automatic testing software to make it easier to test and verify the operations of the instruments in the lab and before they are sent to the field.



## EarthScope

In support of the EarthScope program PASSCAL is involved with the Flexible Array and the Transportable Array. The Flexible Array is a set of seismic equipment similar to that in the PASSCAL pool. PIs submit proposals to a special panel to do experiments to supplement or enhance the Transportable Array. PASSCAL supports these experiments in a manner similar to those we have supported through the regular pool. This support is administered by the Array Operations Facility housed in a new wing of the PASSCAL Instrument Center provided by New Mexico Tech in Socorro.

This year we received 40 new broadband and 40 short period stations for the EarthScope Flexible Array. Prototypes of the new “Texan” are due in December and production units will be received early next year. This year there were 3 funded Flexible Array Experiments that were supported in the fall. We expect more experiments to be funded next year and by the end of next year the instrument pool should have 80 broadbands, 80 short period instruments and over 600 “Texans”.

The EarthScope Transportable Array is an array of 400 broadband stations deployed on a 70 km grid. The initial deployment of the array has started on the west coast and will stretch from the Mexican border to the Canadian border. It will be approximately 1000 km wide. The array will be deployed over the next three years. Once the array is deployed the western most stations will be picked up and moved to the eastern side. Each station will remain in place approximately two years and by moving 200 stations a year, the array will move across the US in approximately 12 years.

The support for the Transportable Array involves the purchasing and final assembly of the station equipment, station siting, permitting, construction and installation. This year was spent finalizing the station design, studying alternative communication methods and developing station construction and installation techniques. By the end of the year we will have approximately 70 stations operating. Of these approximately 60 will be cooperative stations operated by the California regional networks and the rest will be the prototype stations installed in a manner similar to what will be done in the future. The goal is to have all 400 stations operational at the end of three more years.

### Standing Committee

David James (Chair)	Carnegie Institution of Washington
John Collins	Woods Hole Oceanographic Institution
Matthew Fouch	Arizona State University
John Hole	Virginia Polytechnic Institute
Camelia Knapp	University of South Carolina
Steven Roecker	Rensselaer Polytechnic Institute
Anne Sheehan	University of Colorado
William Stevenson	US Geological Survey, Denver
William Walter	Lawrence Livermore National Laboratory
Colin Zelt	Rice University
James Fowler	PASSCAL Program Manager



# Passcal Seismographs Record Anatahan Eruption, Northern Mariana Islands

**Douglas Wiens**

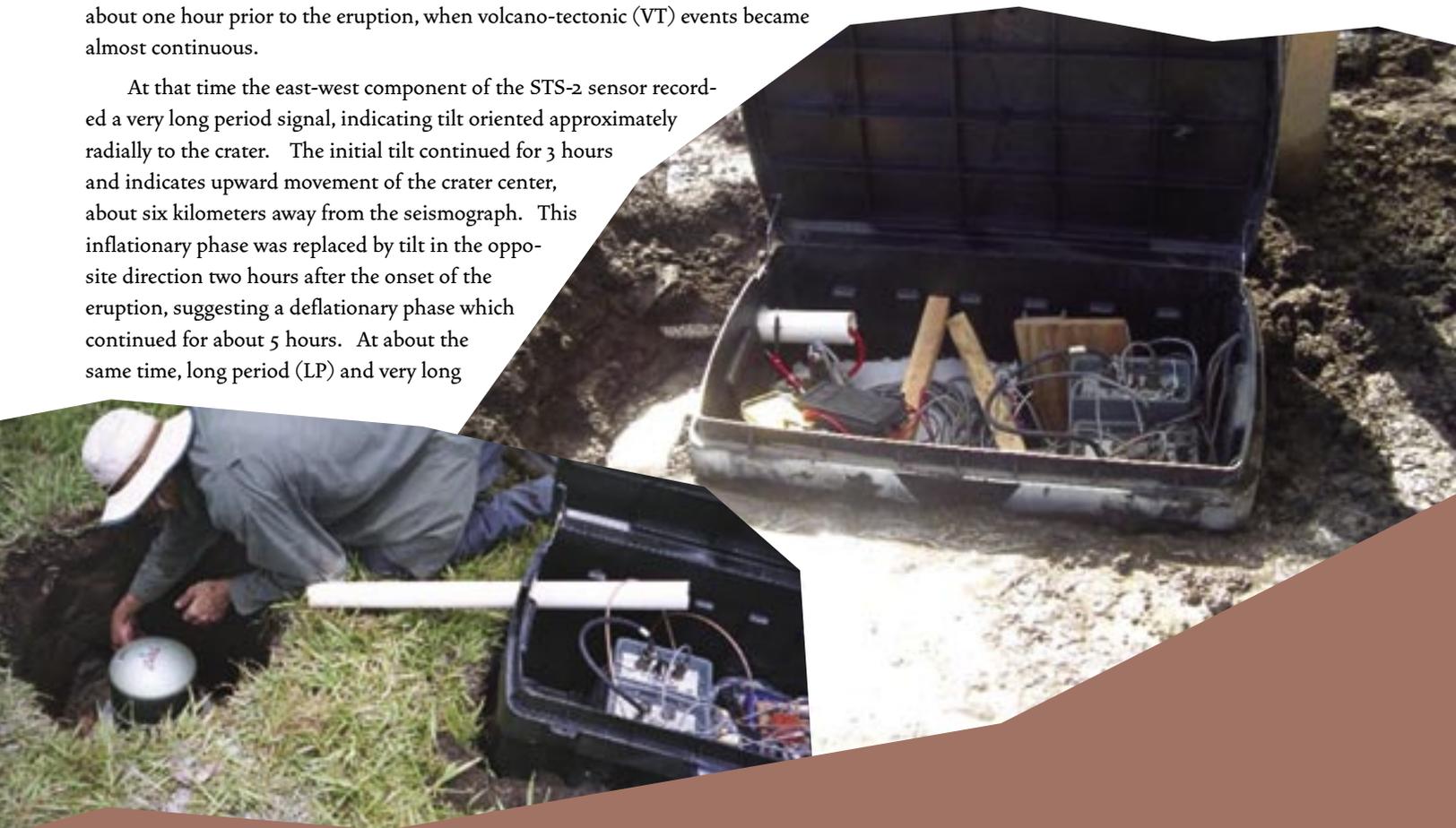
**Department of Earth and Planetary Sciences, Washington University, St. Louis, MO**

Anatahan volcano erupted for the first time in recorded history at about 7:30 GMT on May 10, 2003, covering the island of Anatahan in the Commonwealth of the Northern Mariana Islands (CNMI) with ash. Although the island is only intermittently inhabited and no one was on the island at the time, this eruption disrupted air travel along major routes and resulted in the closing of the Saipan International Airport for several days. The eruption was fortuitously recorded by a PASSCAL broadband seismograph installed just 4 days previously as part of the Mariana Subduction Factory Imaging Experiment, an NSF-funded joint US-Japanese deployment of 20 land seismographs and 58 ocean bottom seismographs with the goal of imaging the magma production regions within the upper mantle beneath the Mariana arc and backarc.

At the time of the eruption, the field team from Washington University, Scripps Institute of Oceanography, and the Saipan Emergency Management Office (EMO) was nearby aboard the small ship *Super Emerald*, and observed a great cloud of ash and steam extending to ten kilometers in altitude. The field team's observations represent the first visual report of the eruption. Part of the field team returned to the island 11 days later, during a lull in the eruption, and found the seismograph still operating although covered with several inches of ash. After refurbishment, the seismograph and others on nearby islands continued to operate throughout the rest of the eruption sequence, which continued into 2004. The US Geological Survey and Saipan EMO have now installed several telemetered seismographs to monitor any continuing activity.

The fortuitous timing of the deployment and eruption offers an unusual opportunity to study the initial eruption of a dormant volcano with a nearby broadband seismograph. Since the island was uninhabited, the first part of the sequence must be reconstructed from the seismic records and satellite photos. Very little precursory seismicity was recorded until 5 hours prior to the eruption, which is estimated at 7:30 GMT on May 10 by the Volcanic Ash Advisory Council (VAAC). Seismicity then increased until about one hour prior to the eruption, when volcano-tectonic (VT) events became almost continuous.

At that time the east-west component of the STS-2 sensor recorded a very long period signal, indicating tilt oriented approximately radially to the crater. The initial tilt continued for 3 hours and indicates upward movement of the crater center, about six kilometers away from the seismograph. This inflationary phase was replaced by tilt in the opposite direction two hours after the onset of the eruption, suggesting a deflationary phase which continued for about 5 hours. At about the same time, long period (LP) and very long

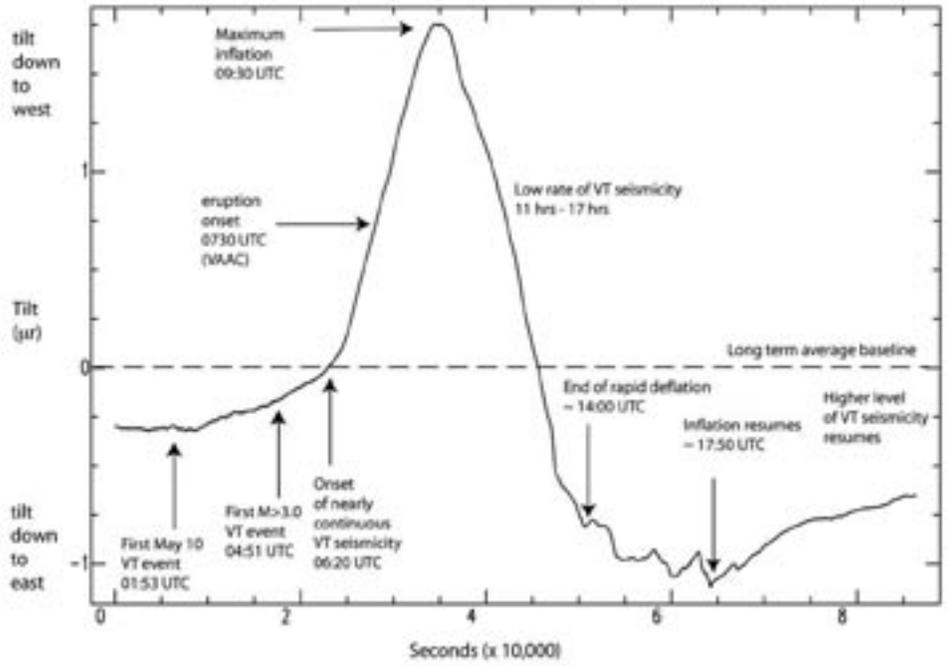


period (VLP) events and harmonic tremor commenced. The initial eruption is thought to represent the sudden release of a large vapor phase atop the column of magma, with more magmatic activity later in the eruption sequence.

The Anatahan eruption also demonstrates the usefulness of broadband seismographs in volcano recording. These results show that under some circumstances, useful tilt signals can be deconvolved from portable broadband instrumentation, even at periods well outside the nominal passband of the instrument. The broadband sensor also recorded many very long period events (VLP) that would not have been detected using conventional short period sensors.

**Reference:**

Pozgay, S. R. A. White, D. A. Wiens, P. J. Shore, A. W. Sauter, and J. L. Kaipat, *Seismicity and tilt associated with the 2003 Anatahan eruption*, *J. Vol. Geoth. Res.*, in press, 2004.



# DMS

data management system

The IRIS DMS is at the core of the largest seismological data system in the world. The DMS is comprised of collection nodes, including the USGS Albuquerque Seismic Laboratory and the UCSD International Deployment of Accelerometers Program, as well as the IRIS DMC in Seattle, WA, a back-up archive in Boulder, CO, and operational links to other seismological data centers around the world.



A satellite dish at GSN station MBAR (Mbarara, Uganda) transmits data in real time to the IDA collection center.

## Data Collection Centers

The system includes nodes at ASL and the UCSD IDA Center, which together collect over 10 Gigabytes of data per day from the Global Seismic Network and the Advanced National Seismic System. During 2004, these two facilities were responsible for capturing a total of more than 5 Terabytes of seismic data from a wide variety of satellite and landline transmission facilities, as well as data tapes that are physically transported from some of the most remote GSN stations. During 2004 the DMS collection nodes implemented quality control procedures on the real time data, to supplement quality control of the tape data. In addition to checking the quality and completeness of the data, and the collection centers distribute the best available near-real-time data to users that include the USGS National Earthquake Information Center and NOAA's Pacific and Alaska Tsunami Warning Centers. Data distributed from both ASL and IDA were indispensable for responding rapidly to the great Sumatra earthquake on December 26.

## The DMC Archive

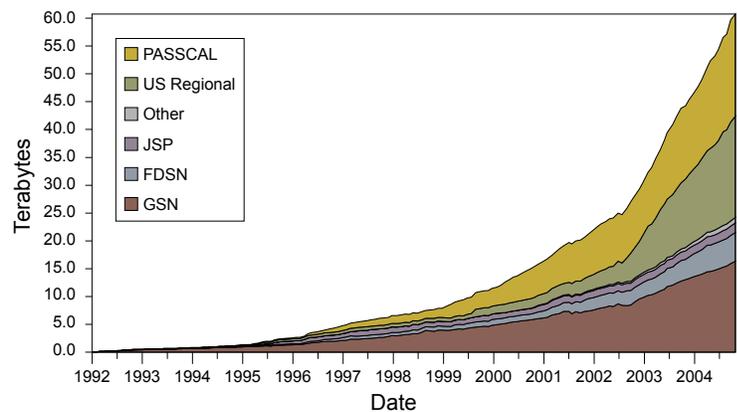
The IRIS DMC's archive is the largest archive of seismological data in the world. Through the support of the National Science Foundation, the data at the DMC are openly available at no cost to anyone in the world.. At the end of September 2003 we had 43.8 terabytes of data available. One year later the IRIS DMC archive has grown to 60 terabytes (see Figure 1), a 37 percent increase in size in just the past year.

During 2004 we have completely migrated all data at the DMC to a new storage media. The current 9940B media consists of small form factor tape cartridges, each capable of holding 200 gigabytes of data. The Powderhorn robot, that forms the heart of our system, has the capacity to store 6000 tapes making the total capacity of our mass storage system 1.2 petabytes.

Data from the IRIS GSN, the IRIS PASSCAL program and US Regional Networks now contribute roughly equal amounts of data to the archive, roughly 16 to 18 terabytes in size each. Data from regional networks are now being received at a rate of about 6 terabytes per year and this represents the largest source of data, by type, now entering the IRIS DMC.

Strong motion data from the Factor Building on the UCLA campus is not entering the DMC and this represents the first strong motion data from a structure is being managed at the IRIS DMC. These data are available as the permanent network with network code FC.

Dual Sorted Archive as of 10-30-2004



The IRIS DMC Archive. The IRIS DMC Archive now contains over 60 terabytes of data in two sort orders. We have roughly equal amounts of data from the IRIS GSN, IRIS PASSCAL and US Regional networks.

## Distributing Data to Users

In addition to providing a complete archive and quality controlled data for researchers, the DMS also provides near-real-time seismic data directly from the DCCs to agencies that require it for life-critical missions, such as warning of tsunamis and responding to earthquake disasters. Following significant earthquakes during 2005, such as near Parkfield, CA on September 28, dozens of users retrieved data from the DMC with delays of no more than a few seconds in many cases and rarely more than tens of minutes. Of the fifty-six permanent networks that were contributing data to the DMS by the end of 2005, forty-two were sending them in real time. The DMC's Buffer of Uniform (BUD) interfaces with Antelope, Earthworm, LISS and SEEDlink systems and makes data it collects from them available to users through a wide variety of client applications that include VASE, jWEED, F2M and SOD, each of which was improved during 2005. VASE's powerful features include requests for data into the future for both continuous waveforms and event-related segments. Completely rewritten in Java, jWEED extends the popular WEED tool for e-mailing requests to allow direct access to any of the DMC data repositories. F2M, developed by Ken Creager and his team at the U. of Washington, imports data directly to MatLab while the variant F2MatSEIS, developed by Chris Young and Darren Hart of Sandia National Labs imports the data into MatSEIS. The new version of SOD from Tom Owens and his team at U. of South Carolina give users a more flexible and configurable tool for creating standing orders for data.

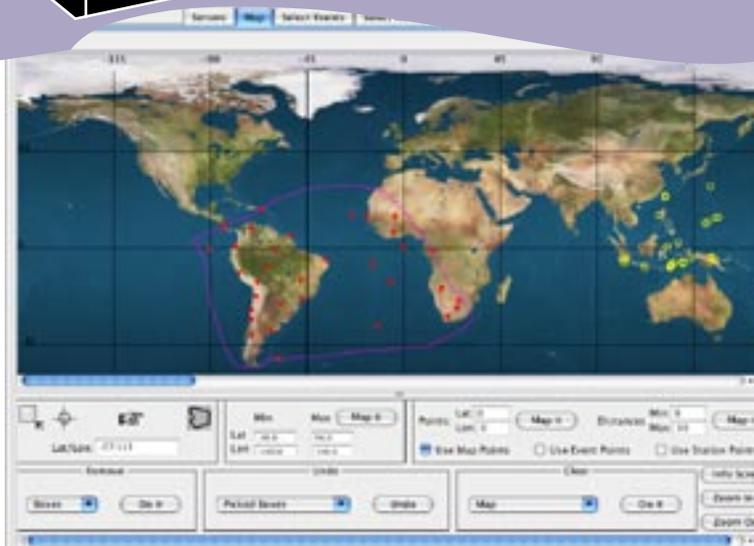
## Seamless Access to Distributed Data

One of the more exciting new capabilities this past year is the realization of seamless access to distributed data centers. Since the DHI approach effectively provides a well defined Application Programming Interface (API) to data center services, any data center that supports the DHI can be accessed by a DHI client in exactly the same manner.

The jWEED and VASE tools have been developed so as to leverage this characteristic, and in the future other DHI clients, will be modified to support seamless access to data archived at distributed centers. Over the past year, IRIS has worked with UC Berkeley and Caltech to install DHI services at their data centers. In addition to the current set of DHI enabled centers of IRIS, NCEDC, SCEDC, and USC we anticipate adding DHI services at ORFEUS, U. Nevada Reno and the NEIC and ISC during the next year or two.

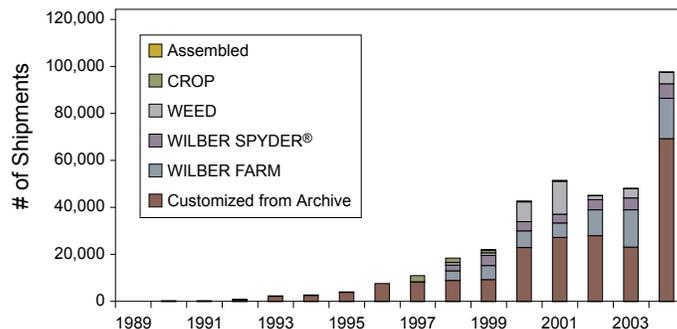
DHI adds to the existing capabilities of NetDC, which provides access to data distributed across Geoscope, MedNET, Canadian National Network, and ORFEUS data centers, as well as the DHZ enabled centers.

The rich suite of data request tools that the IRIS DMC supports is intended to help users easily generate data requests. During calendar year 2004 we serviced about 95,000 customized data requests.



jWEED Map Based Request Generation. A new version of WEED, written in java, became available this year. Users can identify regions on a map that contain event and/or station locations, add additional constraints on the events, stations, or event-station relationships and generate requests for data using NetDC, Breq\_fast, or receive waveforms directly on-line through the Data Handling Interface.

Shipments from the DMC  
Projected as of 10-31-2004



Shipments from the IRIS DMC. During 2004 the number of customized shipments from the DMC increased by nearly a factor of 2 to 95,000. Most of the customized shipments came directly from the large tape-based mass storage system.

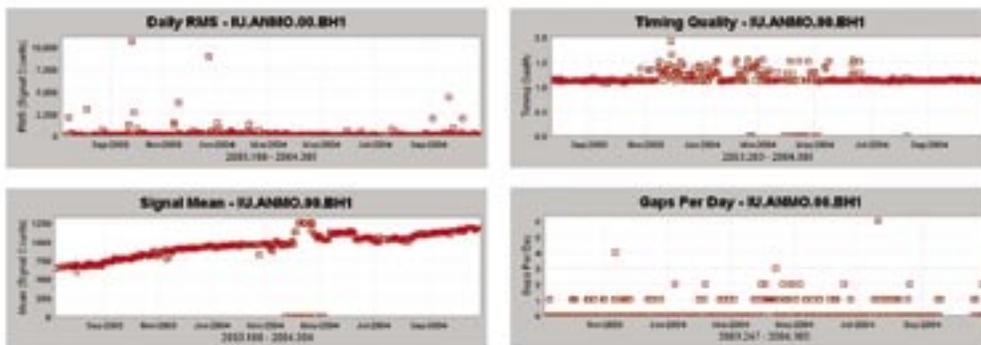
### Standing Committee

Guust Nolet (Chair)	Princeton University
Douglas Dodge	Lawrence Livermore National Laboratory
Edward Garnero	Arizona State University
Daniel McNamara	US Geological Survey, Golden
David Okaya	University of Southern California
Ann Trehu	University of Oregon
Suzan van der Lee	Northwest University
Douglas Wiens	Washington University, St Louis
Timothy Ahern	DMS Program Manager

# Putting C'EYE'cles on Real Time Data: Quality Assurance within the QUACK Framework

Most of the data the IRIS DMC now manages is received electronically and in real time! Since traditional data review no longer takes place before the data are made available to the research community, Dr. Bruce Weertman, of the IRIS DMC, has developed the QUality Assurance Control Kit (QUACK). QUACK has matured to the point where automated quality assurance is now being applied to most data received by the DMC for data management.

QUACK is a framework that coordinates the execution of QA Modules at the IRIS DMC. The framework controls when QA modules are executed, how the modules access specific channels of time series data and also manages the resulting QA measurements in Oracle or DMC



Parameters measured by QUACK include: Daily RMS Values, Signal Mean, Timing Quality, Gaps per day, and NEIC Power Density Functions.

At the present time these QUACK parameters are being measured on data from roughly 800 stations and more than 4000 channels of data. While limited to data entering the real time systems at the DMC, we anticipate extending QUACK to data in the archive in the future. Two independent QUACK systems are currently being operated at the DMC, 1) for data from USArray and 2) from all other data the DMC receives in the real time BUD system.

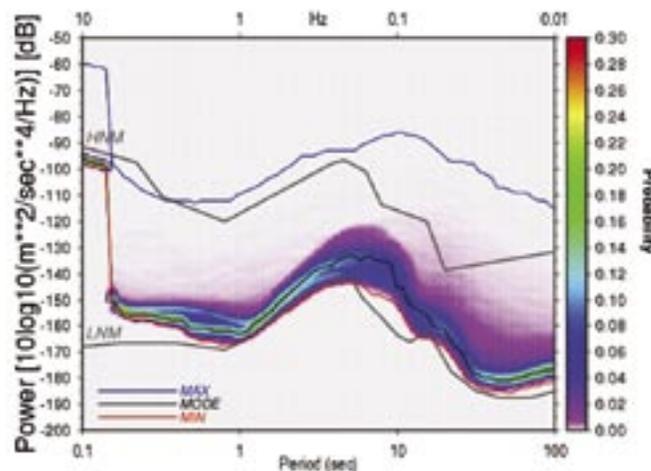
Currently under development is the development of a QUACK alarming system. When measured values of the QUACK plug-ins fall outside preset limits then an email, page or other notification mechanism will be transmitted to the appropriate operations personnel and corrective action will take place.

It is our intention to store most of these parameters in the Oracle Database Management System and to allow users to access these parameters in a variety of flexible ways. We anticipate being able to make requests for data that possess specific QUACK attributes.

The ultimate goal of the QUACK system is to provide automated methods of reviewing data quality without significantly adding to the number of data analysts looking at the data directly. With QUACK the analysts can focus their attention to only those data that have problems identified with them.

The modules can be thought of as plug-ins that are managed by the framework and invoked as required to evaluate different aspects of time series data. In general, when a new characteristic of time series data needs to be measured for quality assurance reasons, a new plug-in will be developed and incorporated into the QUACK system.

At the present time the number of algorithms being applied to time series data number approximately 10 and are shown in the figure on the adjoining



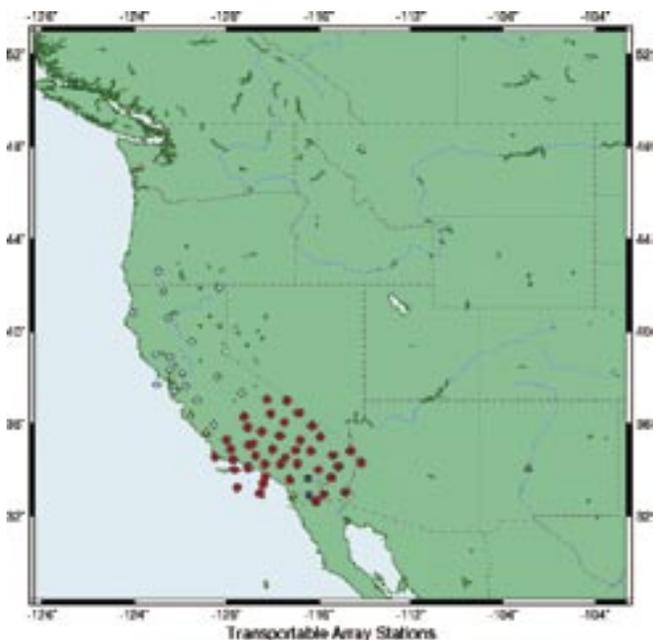
## USArray and the DMC

USArray operations are now in full swing at the IRIS DMC in Seattle. Over the past year, the DMC has been gearing up for the arrival of the new data streams. Two SunFire 880's were acquired and setup as the primary and backup servers for USArray data management. Internet connectivity and analysis software has been installed. New personnel have been hired, including Lonny Jones hired as a Systems Administrator for USArray operations and facilities, and Chad Trabant as the Lead Data Control Analyst. Linus Kamb became the USArray Software Engineer. The DMC also acquired additional space within the building and USArray personnel moved in to the remodeled area in October.



As of October 2004 the DMC is collecting data from 65 Transportable Array sites and 13 Permanent Array/Backbone sites. The DMC ingests approximately 1 gigabyte of seismic data daily from these 78 sites. In addition to the 6 USArray operated stations, the Transportable Array is composed of 2 stations from the ANZA Regional Network, 17 stations from the Berkeley Digital Seismograph Network and 40 stations from the Caltech Regional Seismic Network.

All incoming USArray data streams are processed by the DMC's automated Quality Assurance Framework (QUACK), which applies a variety of Quality Control (QC) procedures. In addition to basic QC parameters such as data gaps and signal RMS, QUACK also makes measurements such as percent of signal above the high noise model and a probability density function analysis of power spectral density. All of the results produced by QUACK are available from the DMC website. A data control analyst reviews the automated QC results taking action when necessary.



All Transportable and Permanent Array data and metadata are available through the traditional DMC delivery mechanisms. Like other real-time data received at the DMC, USArray data are managed in a Buffer of Uniform Data (BUD) structure. These data are available via the Data Handling Interface (DHI) or as real-time data streams via the LISS or SeedLink protocols. AutoDRM capabilities also provide access to the data in the BUD for those that prefer that mechanism.

The DMC's Virtual Network concept has been applied to USArray data. This concept is particularly useful for USArray data as the station sets are commonly composed of stations from more than one traditional network. Virtual networks are defined for the Transportable Array: \_\_US-TA, Permanent Array/Backbone: \_\_US-BB and all USArray stations: \_\_US-ALL. Many of the data query and request tools at the DMC support virtual networks as selection criteria.

Software development in support of USArray efforts continues with development of the IRIS Station Information System nearing completion. Once complete, it will enable Network and Station operators to supply the DMC with detailed station information including field logs, hardware configurations, and data problem reports, in a consistent and standard format.

This will, in turn, allow the DMC to provide that information to the end-users of the data. We are also working in collaboration with the community and other organizations on the design and development of the USArray data products distribution system to provide a standard and uniform access mechanism for all USArray data products.

# E&O

*education and outreach*

The Education and Outreach (E&O) program is committed to using seismology and the unique resources of the IRIS Consortium to make significant and lasting contributions to science education, science literacy and the general public's understanding of the Earth. The E&O program has continued its development and dissemination of a well-rounded suite of educational activities designed to impact a spectrum of learners, ranging from 5th grade students to adults.

These powerful learning experiences transpire in a variety of educational settings ranging from self-exploration in front of one's own computer, to the excitement and awe of an interactive museum exhibit hall, a major public lecture, or in-depth exploration of the Earth's interior in a formal classroom.

The efforts of the IRIS E&O program during the past year have been largely focused on the consolidation, refinement, and enhancement of ongoing core activities, and considerably expanded their impact. The museum program highlights these efforts, with 16 million people potentially impacted by the IRIS/USGS museum displays, many of them in the Hall of Planet Earth at the American Museum of Natural History (AMNH). Our evaluation of our AMNH and Smithsonian Institution National Museum of Natural History displays this year showed that the displays are very popular in both museums, with audiences particularly interested in the presentation of near real-time seismic data. We developed a smaller, more flexible version of the museum display this year for small museums, science centers and visitor centers. Served via a web the display is customizable by each museum and touch screens provide an interactive experience.

Another program aimed at general audiences is the IRIS/SSA Distinguished Lecture Series. This was the second year of the series, and our two speakers presented a total of twelve lectures at major museums and universities throughout the country to audiences of up to 400 people. We also sponsored a "Music of Earthquakes" presentation at the National Association of Science Teachers annual meeting.

The E&O Program continues to refine its highly effective, one-day professional development experience designed to support the background and curricular needs of formal educators. Leveraging the expertise of members, IRIS delivers content such as: plate tectonics, propagation of seismic waves, seismographs, earthquake locations, and Earth's interior structure. In addition, a new, focused workshop was offered this year to teachers who use ASI seismographs in their classroom that they received through the IRIS seismographs in schools program. There are now more than 90 such seismographs in use by schools around the US.



At the core of the IRIS professional development model is the philosophy that improvements in the level of teacher use of such material can be achieved by increasing teacher comfort in the classroom. Specifically, we seek to increase teacher comfort in the classroom by providing professional development which:

- Increases an educator's knowledge of scientific content,
- Provides educators with a variety of high-quality, scientifically accurate activities to deliver content to students,
- Provides educators with inquiry-based learning experiences,
- Provides direct contact with IRIS research and E&O individuals

The short and long-term assessment of the workshops continues to provide critical decision-making data and documents the impact the program has on educators. Using this information as a guide IRIS will continue to monitor and alter its curricular resources and implementation style in an effort to maximize this impact.

The Educational Affiliate Membership has increased IRIS' impact among undergraduate faculty. The objective of this membership category is to cultivate a base of non-research colleges and universities committed to excellence in undergraduate geoscience education through the co-development of E&O activities designed to address their needs. The first such activity to be developed is a sabbatical experience designed to give Educational Affiliate member faculty a chance to interact with seismologists at IRIS institutions.

The E&O web pages remain a primary means of dissemination of information and resources. The Seismic Monitor is the most popular IRIS Web page and we continue to add new material. One such product is an online interactive exercise called the "Earthquake Simulator" which was developed in response to the TV mini-series "10.5". A lesson plan and resources were developed to accompany the Earthquake Simulator and the lesson plan was trialed in a classroom. The Global Earthquake Explorer (GEE) software and associated instructional materials continue to be improved and expanded through collaboration with University of South Carolina and the Digital Library for Earth System Education (DLESE). GEE will be a key to educational access to the seismic data sets that are at the heart of IRIS.

Additional audiences are reached via collaboration with other regional and other national geoscience programs. For example, 15,000 copies of the "Exploring the Earth" poster were provided this year for AGI's Earth Science Week packets. We also leverage our resources by providing materials for workshops organized by other organizations, with ten such workshops in 2004. We are a partner in the Electronic Encyclopedia of Earthquakes project led by the Southern California Earthquake Center (SCEC) and are working closely with EarthScope and the Network for Earthquake Engineering Simulation (NEES) to help establish their Education and Outreach programs. The success of the E&O program is directly attributable to those who have volunteered their time and energy, especially members of the E&O Standing Committee.



#### Standing Committee

Richard Aster (Chair)	New Mexico Tech
Kathy Ellins	University of Texas, Austin
Alan Kafka	Boston College
Steven Semken	Arizona State University
Seth Stein	Northwest University
Lisa Wald	US Geological Survey, Golden
Aaron Velasco	University of Texas, El Paso
John Taber	E&O Program Manager

# Building the Future of the Consortium: The IRIS Undergraduate Internship Program

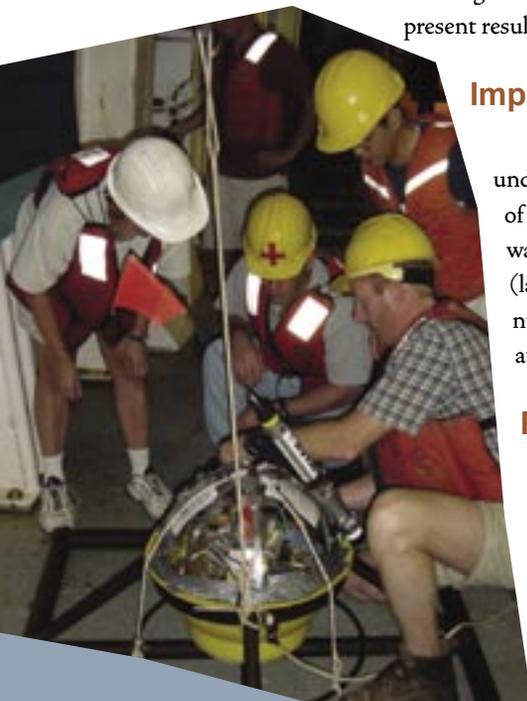
From a wind whipped tent on the slopes of a volcano in the Aleutian Arc to a quiet afternoon in the lab, debugging code in front of a UNIX station; from the rolling decks of the Maurice Ewing located off the coast of South America to the buzz of a poster session in the Moscone Convention Center, IRIS Undergraduate Interns are conducting geophysical research and explaining their results at large professional conferences. Throughout this process they are also gaining insights into the field of geophysics as a potential career path through intense interactions with leading researchers... a path that over 83% of program's alumni ultimately pursue.

Since its inception in 1998, The IRIS Undergraduate Internship Program has been providing students with engaging 8 to 10 week opportunities like these through partnerships with the universities of the IRIS consortium and the USGS. The primary goal of this program is to provide students with research opportunities early in their educational careers, in an effort to encourage more students, representing a more diverse population, to choose careers in Earth science and seismology. A secondary goal of the program is to help the schools in the consortium attract well-prepared, outstanding students for graduate studies in the Earth science.

Research projects, proposed by members of the IRIS community may involve the deployment of seismic instruments in the field (within the US or internationally), and/or analyses of seismic data in a lab setting (for example investigations of Earth structure, earthquake sources, seismic hazards). Each project provides students with ample opportunities to:

- conduct research with state of the art geophysical data and leading researchers at IRIS institutions
- develop an understanding of scientific inquiry, including designing and conducting scientific investigations, defending scientific arguments, and preparing publications
- gather, manage, and convey information, using various skills, strategies, resources, and
- learn, use, and evaluate technologies for the collection and study of geophysical data

To bring closure to the summer, interns and their hosts collaborate to develop and submit an abstract of their summer's work to a national scientific meeting. Thus, each internship culminates in the stimulating atmosphere of a professional meeting, where interns present results from their summer work.



## Impact

The seven-year-old IRIS Undergraduate Internship Program has successfully placed twenty-nine undergraduate students at seventeen different IRIS member institutions plus the USGS; with a range of two to nine students placed per year. To measure the impact of the program a survey of all alumni was conducted in early 2004. The results found that over 83% of the alumni pursue advanced degrees (largely PhDs) in a range of geoscience fields, with the majority in seismology or geophysics and smaller numbers in geological sciences, petrology, geochemistry, and mineral physics. 43% of these students attend graduate school at the institution where they spent their internship.

## Participant Perceptions

In addition to monitoring the long-range impacts of the program on the interns' career choices, the evaluation effort of the program provides regular quantitative and qualitative perception data. The collection of both intern and host perceptions allows the internship program to be introspective, identifying areas for improvements, and drive the future enhancements of the program with data from previous experiences.

Statements		Mean Response (n=9)	Standard Deviation
<i>Instructions: For each statement select one of the following: 5 = Strongly Agree; 4 = Agree; 3 = Undecided; 2 = Disagree; 1 = Strongly Disagree</i>			
Intern Perceptions	My work this summer contributed in a meaningful way, to the overall success of the host PI's research project.	4.4	0.73
	I can easily apply the information/skills I learned during the internship to my future career goals.	4.7	0.50
	As a result of this internship I will seek a career in a field of earth science or seismology.	4.2	0.97
	Overall this internship was one of the best learning experiences I have ever had.	4.7	0.50
Host Perceptions	The internship selection committee provided me with a well-qualified undergraduate to work with for the summer.	4.9	0.35
	My intern's work this summer contributed in a meaningful way to the overall success of my research project.	4.3	0.71
	Overall this internship was beneficial and a worthwhile use of my time.	4.3	0.89
	As a result of this internship I would like to submit a proposal to host another IRIS Undergraduate Intern in the future.	4.4	0.74



Self-reported perception data from the 2003 hosts and interns.

## Profiling Interns

The IRIS Undergraduate Internship Program serves a wide variety of students, from a diversity of backgrounds. 65% of IRIS interns attend IRIS institutions, though students that attend non-IRIS institutions submit nearly 50% of the total number of applications. 47% of interns are female, with recent internship classes having female to male ratios as high as 3:1. While the academic majors of the interns varies, nearly half of the students are engineering or physics students (see figure 1). 62% of the interns are juniors and all are strong students with a mean grade point average of 3.6. Surveys of the 2003 and 2004 internship classes (n=13) revealed that of 15% of interns identify themselves as African American, 7% Asian, and 7% Hispanic or Latino.



## Continuously Improving the Program

While the program has been tremendously successful to date, beginning in 2005, the IRIS Undergraduate Internship Program plans to implement several key improvements developed as a result of annual host and intern feedback. These improvements will:

- increase interns' opportunities to interact, share and learn from and with other IRIS Undergraduate Interns through a week long orientation, and through a variety of telecommunications
- provide interns with clearly stated goals for their internship, through a redesign of the host proposal process, and
- increase each intern's ability to monitor his or her progress towards these stated goals through skills training and the use of web based technology.

For further information on the 2005 program, to see details of past research projects, or to see where the internship alumni are now, please visit <http://www.iris.edu/about/ENO/internship.htm>

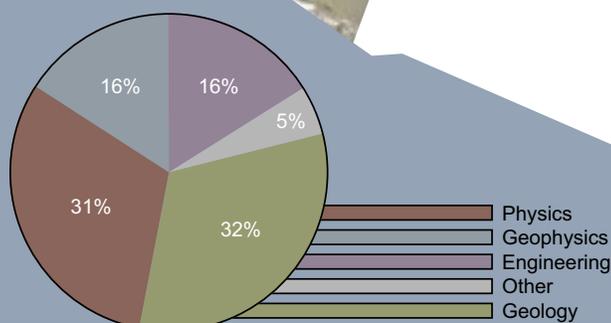


Figure 1: Declared majors of interns including dual majors.



## Activities and Publications

In addition to program oversight and administration, the Consortium also serves the role of an ongoing forum for exchanging ideas, setting community priorities, and fostering cooperation. To enhance this role, IRIS engages the broader community through the use of publications and workshops. Our publications, which are widely distributed without charge, are organized around topical issues that highlight emerging opportunities for seismology. The annual workshop is used to assess the state of the science, introduce programs, and provide training. Through a student grant program, young scientists attend the workshop at little or no cost, and become introduced to the programs and services of the Consortium. As a Consortium, IRIS also serves as a representative for the Geoscience community. IRIS staff and Committee members serve on White House Committees, State Department Advisory Boards, US Geological Survey panels, and testify before Congress. Such broad interactions raise the profile of Geosciences and provide a direct societal return from the federal investment in IRIS.

### Meetings and Publications Subcommittee

Gary Pavlis (Chair)	Indiana University
Richard Aster	New Mexico Tech
David James	Carnegie Institution of Washington
Thorne Lay	University of California, Santa Cruz
Guust Nolet	Princeton University
Gregory van der Vink	IRIS Director of Planning

### 2001 IRIS Annual Workshop, June 10–12, 2004

The Sixteenth Annual IRIS Workshop, held at Westward Look Resort in Tucson Arizona June 10-12 2004, was a celebration of the 20th Anniversary of the Consortium and an exploration of new roads ahead. In addition to the traditional workshop elements, a special meeting of the Consortium's Board of Directors was held at which the members unanimously adopted significant modifications to the Consortium By Laws. These changes simplify the structure of the organization and provide for an elected Board of nine members to represent the member institutions in carrying out the activities of the Corporation.

Science themes at the Workshop included: "Multi-band experiments" (combining passive and active source; short-period and broad-band); Inter-disciplinary studies in the western US during the first "Bigfoot-print" of USArray; "Cyber-seismology: the role of seismologists in Information Technology"; and "The Future Global Seismographic Network -Whither or Wither?" Special sessions on the theme of "IRIS: Then and Future" explored each of the core programs in the context of the 20th Anniversary. A barbeque on the final evening was the venue of revealing reminiscences from some the IRIS founding members on the early days of the Consortium.

Through the Education and Outreach Program, IRIS develops and distributes posters about seismology. The posters are featured at various scientific and educational meetings, and can be found on classroom walls around the world. IRIS has developed a series of "one-pagers" to attract the attention of students, educators, decision makers, and the general public. The one-pagers provide succinct explanations of basic seismological concepts, and are available in hard-copy and on the web in both English and Spanish.



# Financial Overview

The Incorporated Research Institutions for Seismology (the IRIS Consortium) is a 501 (c)(3) non-profit consortium of research institutions founded in 1984 to develop scientific facilities, distribute data, and promote research. IRIS is incorporated in the State of Delaware.

## GSN

The Global Seismographic Network is operated in partnership with the US Geological Survey. Funding from NSF for the GSN supports the installation and upgrade of new stations, and the operation and maintenance of stations of the IDA Network at University of California, San Diego and other stations not funded directly within the budget of the USGS. Operation and maintenance of USGS/GSN stations is funded directly through the USGS budget. Subawards include the University of California, San Diego, the University of California, Berkeley, the California Institute of Technology, Columbia University, University of Hawaii, Albuquerque Seismological Laboratory, Synapse Science Center, Moscow, Woods Hole Oceanographic Institution, Montana Tech, University of Texas at Austin, and Texas Tech University.

## PASSCAL

Funding for PASSCAL is used to purchase new instruments, support the Instrument Center at the New Mexico Institute of Mining and Technology, train scientists to use the instruments, and provide technical support for instruments in the field. Subawards include the New Mexico Institute of Mining and Technology, the University of California, San Diego, and University of Texas at El Paso.

## DMS

Funding for the Data Management System supports data collection, data archiving, data distribution, communication links, software development, data evaluation, and web interface systems. Subawards include the University of Washington, Harvard University, the University of California, San Diego, Columbia University, Synapse Science Center, Moscow, University of South Carolina, and Institute for Geophysical Research, Kazakstan.

## Education and Outreach

Funding for the Education and Outreach program is used to support teacher and faculty workshops, undergraduate internships, the production of hard-copy, video and web-based educational materials, a distinguished lecturer series, educational seismographs, and the development of museum displays. Subawards are issued to IRIS institutions for software and classroom material development, summer internship support and support of educational seismology networks.

## Indirect Expenses

Costs include corporate administration and business staff salaries; audit, human resources and legal services; headquarters office expenses; insurance; and corporate travel costs.

## Other Activities

Other activities include IRIS workshops, publications and special projects such as KNET.

## IRIS Budgets

Core program budgets* (July 1, 2004 – June 30, 2005)		Earthscope awards** (Oct. 1, 2004 – Sept. 30, 2005)	
	<i>FY2005</i>		
GSN	3,444,761	Permanent backbone	2,077,021
PASSCAL	3,506,617	Transportable/Flexible Arrays	11,240,363
DMS	3,400,514	Data management	751,622
E&O	650,164	Siting Outreach	64,600
Other	523,942	Other	55,202
		Earthscope Office	1,451,656
Indirect Costs	1,299,529	Indirect Costs	1,419,084
<b>Total</b>	<b>12,825,527</b>	<b>Total</b>	<b>17,059,548*</b>

\* Budgets are for core IRIS programs from the NSF Earth Sciences Division Instrumentation & Facilities Program, and does not include additional funding from other sources, such as NSF Ocean Sciences, DOE, CTBTO, SCEC, JPL, etc.

\*\* Includes budgets for USArray MRE & O&M, and the Earthscope Office Cooperative Agreements.

The consolidated financial statements of IRIS and IRIS Ocean Cable, Incorporated, and the Auditor's Report are available from the IRIS business office upon request.

### Budget and Finance Subcommittee

Susan Beck (Chair)	University of Arizona
Arthur Lerner-Lam	Columbia University
Brian Stump	Southern Methodist University
Candy Shin	Director of Finance & Administration

# USArray & EarthScope

With funding from the National Science Foundation's Major Research Equipment and Facility Construction account, EarthScope got underway in 2004. To establish the extensive facilities that will form the core observational systems of EarthScope, IRIS, UNAVCO Inc., Stanford University and the U.S. Geological Survey have joined in partnership to establish USArray, the Plate Boundary Observatory (PBO) and the San Andreas Fault Observatory at Depth (SAFOD). The role of IRIS is to install, maintain and distribute data from the Backbone, Transportable and Flexible Arrays that, in concert with existing national and regional networks, will provide seismological coverage of the US at a variety of nested scales. The following articles describe the activities of the various groups that are working with IRIS to establish the USArray facilities.



National Science Foundation  
4201 Wilson Boulevard  
Arlington, Virginia 22230

## *Members of the IRIS Consortium.*

*Years of visionary leadership and community effort on the part of IRIS contributed greatly to the creation of EarthScope, an Earth science program to explore the 4-dimensional structure of the North American continent. EarthScope has now successfully completed its first year and IRIS has risen to the challenges admirably. The USArray is off to a very strong start. Through the USArray, its other strong programs, and the exceptionally strong involvement and support of the scientific community, IRIS will continue to play a leadership role.*

*The challenges ahead are great. As a participant in the first EAR MREFC project, IRIS has undertaken a "construction" program that is unprecedented in solid Earth sciences – and receives an unprecedented level of scrutiny from NSF, the U.S. government, and the Earth science community. But it is IRIS that has this role for a reason: 20 years of success. Thank you IRIS for providing a strong foundation for the building of EarthScope. Thank you IRIS for providing a template for community driven science, education, and outreach. Most of all, thank you IRIS for forsaking complacency to take on new and daunting challenges.*

*Kaye Shedlock  
EarthScope Program Director  
Division of Earth Science*

### **USArray Advisory Committee**

Adam Dziewonski (Chair)	Harvard University
Michael Bostock	University of British Columbia
Michael Gurnis	California Institute of Technology
Rainer Kind	Geo Forschungs Zentrum - Potsdam
James Knapp	University of South Carolina
Terry Plank	Boston University
George Thompson	Stanford University

# USArray Array Operations Facility

**Rick Aster and Bruce Beaudoin (PASSCAL Instrument Center and USArray Array Operations Facility, New Mexico Tech)**

**Jim Fowler, Bob Busby, and Marcos Alvarez (IRIS)**

The USArray Array Operations Facility (AOF) provides core hardware and field support for USArray activities under the direction of IRIS. During 2004, burgeoning AOF staff and activities were housed within the PASSCAL Instrument Center at the New Mexico Institute of Mining and Technology (NMT) in Socorro, New Mexico. In late 2004 AOF staff will migrate into an integrated PASCAL instrument center annex. The annex was specifically designed by PASSCAL and IRIS staff to optimize USArray operations, and construction was funded and overseen by NMT. The 11,500-square-foot annex includes computer, and hardware laboratories, 18 additional offices, and four meeting areas, as well as direct access to a 20,000-square-foot warehouse/shipping facility shared with the PASSCAL program. AOF, PASSCAL Program, and New Mexico Tech welcomed nine new employees during 2004. NMT has additionally officially designated an adjoining field test site specifically for long-term IRIS station development, which now includes the operational USArray site Y22C (below).



AOF Annex under construction (mid-October, 2004).

## Strengthening the Backbone of the USArray

As a part of the Earthscope facility, IRIS is playing a key role in the implementation of the USArray portion of this NSF MREFC program. The USArray, along with the Plate Boundary Observatory (PBO) and the San Andreas Fault Observatory at Depth (SAFOD) is designed to provide a powerful downward looking “tellus” scope for observing the structure and processes of the Earth beneath North America.

The USArray will consist of three major elements: the Transportable Array (a moving 400 element array with 70 km station spacing and an aperture of ~1400 km), the Flexible Array (pool of portable instrumentation to provide even higher resolution studies in areas of interest), and a Permanent Array. Otherwise known as the ANSS Backbone Network, the Permanent Array takes advantage of the existing permanent seismic observatories of the USGS National Seismic Network (NSN) along with the stations from the GSN located in the United States to form a foundation of long-term high-quality seismic observations of the continental US and Alaska. The Earthscope program is currently funding the augmentation of these existing networks to fill in some of the gaps as well as upgrade some of the existing network to support a uniform permanent network with a station spacing of ~300km. This work is strongly tied to the USGS Advanced National Seismic System (ANSS) as they fill in the remainder of the stations required for this uniform network and provide the existing network stations to be upgraded by Earthscope.

In February of 2004, an agreement was signed between IRIS and the USGS to install and upgrade a portion of the ANSS Backbone network in support of the USArray Permanent Array portion of the Earthscope MREFC. With this agreement, work began at the Albuquerque Seismological Laboratory on 39 stations of this network located in the continental United States and Alaska. Four of these stations are existing arrays operated as part of the International Monitoring System and the United States Atomic Energy Detection System that will contribute data to the Backbone network. The remaining 35 stations are either existing NSN stations (21) or new stations to be installed with Earthscope funds (14). The augmentation funds will be used to upgrade the quality of the 14 existing NSN-type installations by providing new instrumentation (Quanterra Q330 DAS, Streckeisen STS-2 and Kinemetrics Episensor ground motion transducers, and upgraded power systems) as well as an upgrade to the seismic vaults as necessary. In addition, 12 new NSN stations will be installed with this instrumentation. These funds will also be used to upgrade seven of the existing NSN stations following the design goals of the GSN. This will provide deeper vaults or boreholes for seismometer emplacements creating a lower long period noise environment, additional seismometers to take advantage of the quieter sites, and microbarographs. Two brand new GSN-type stations will also be created (Southeastern Alaska, and at the EROS Data Center in South Dakota).



USArray Transportable Array site Y22C and test equipment on “seismometer hill” adjacent to the AOF on the NMT campus.



Status of the Backbone as of 1 October, 2004. Green section of pie charts show the amount of work completed at each station. Full green circles are completed and certified and available at the DMC via the \_USBB virtual network code. Pies with gold sections are partially complete and sending data under the virtual network code. Yellow pie sections are station upgrades in progress (from a previously existing NSN site) and white background are new stations.



Lynn Simmons of the USGS tells students at Wishkah Valley School about the contribution of their station to the USArray.

## The USArray's Flexible Array

The Flexible Array (FA) is a planned pool of about 200 broadband, 200 short-period, and 2000 high-frequency instruments that can be deployed using flexible source-receiver geometries. These portable instruments will permit high-density, short-term observations of key targets within the footprint of the larger Transportable Array using both natural and active sources. Three FA experiments were started during 2004, including two near the San Andreas Fault Observatory at Depth (SAFOD).

Yong-Gong Li and John Vidale used 70 short-period autonomous stations to characterize low-velocity damaged structure of the San Andreas fault near the SAFOD drilling using fault-zone trapped waves. Their observations show the existence of a low-velocity waveguide on the SAF that likely extends to seismogenic depths, they interpret as a remnant of repeated damage due to large earthquakes near Parkfield, CA.

"PASO TRES", run by Steve Roecker and Cliff Thurber consists of 12 short-period passive sensors in a real-time telemetered network deployed around SAFOD. Their goal is high-precision even location of target events near the drill hole, to better define the region of penetration for SAFOD.

Along with seismic instrumentation, the Backbone will also coordinate with the Magneto-telluric community with 10 collocated sites (siting to be determined) and with the Geodetic community (UNAVCO) with 16 collocated GPS observatories. The first GPS monument went in this summer at the Albuquerque Seismological Laboratory with the assistance of UNAVCO and ASL personnel.

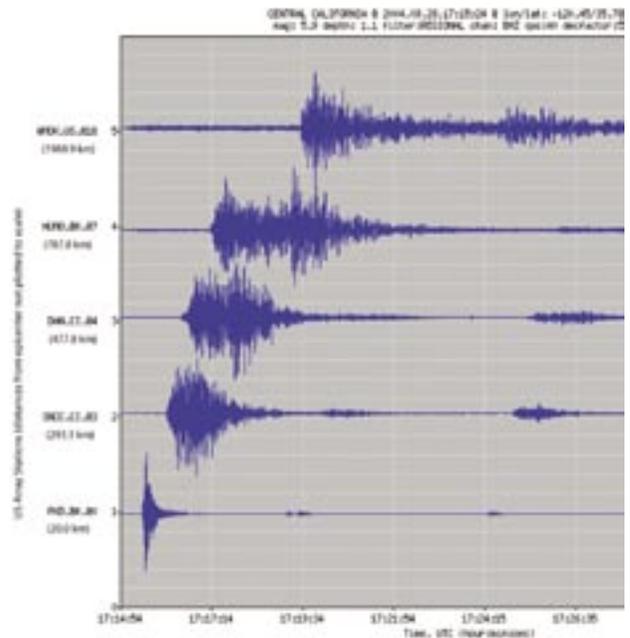
With completion expected in September 2006, the Backbone effort continues the successful and fruitful relationship between the USGS and IRIS in the installation of high quality seismic systems throughout the United States and the world, providing data to the seismic community, and supporting the overall Earthscope program.

## Bigfoot: The USArray's Transportable Array

The Transportable Array (TA) is comprised of 400 stations that will be deployed with a station spacing of about 70 km, advancing across the country in a roll-along fashion. Seismic data are now available from over 60 TA stations, mostly in California. Detailed site surveys have been completed for additional stations that are planned to be installed in early 2005.

The first TA station to be located at a school was installed in September at Wishkah Valley School near Aberdeen Washington. Students watched the installation and talked to seismologists about the EarthScope project, and later viewed data from their station on the DMC website.

The magnitude 5.9 earthquake near Parkfield, California on September 28th was recorded by 62 TA stations at distances from 20 km to 2000 km from the epicenter.



TA records from the Parkfield earthquake show how signals change as they propagate through the earth. Numerous TA stations will make it possible to discern more about both the earthquakes that generate the signals and the earth structure that controls propagation.



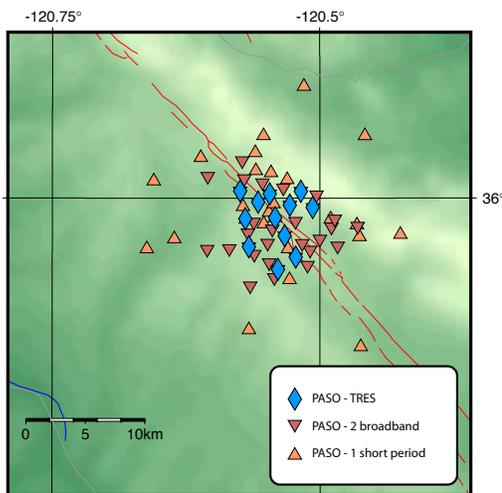
In September, Simon Klemperer and Elizabeth Miller used about 975 single-channel Texans and a cabled spread of R-130s to acquire a 250-km long refraction/reflection seismic profile in northwestern Nevada, across the northernmost Basin and Range province. By exploring Moho topography and crustal structure, they plan to test an hypothesis that the lower crust beneath northern Nevada has flowed south to central Nevada during predominantly east-west extension, equalizing the crustal thickness and balancing the elevations across the region.



## Array Network Facility

*Frank Vernon, Jennifer Eakins, Robert Newman*

The Array Network Facility (ANF) is one of the critical elements required to make the USArray component of the NSF Earthscope projects a success. The ANF role is to guarantee that data telemetered or recovered from USArray Transportable Array (TA) and telemetered Flexible Array (FA) stations are delivered promptly to the IRIS Data Management Center (DMC) for archiving and distribution to users. The ANF provides quality control for all data and ensures that the proper calibration and metadata are always up to date and available. There are many types of monitoring which need to be accomplished including seismic data quality, IP (Internet Protocol) network communications, and higher level data communications. The ANF interacts closely with the Array Operations Facility (AOF) and the TA Field Operations providing immediate feedback on station data quality.

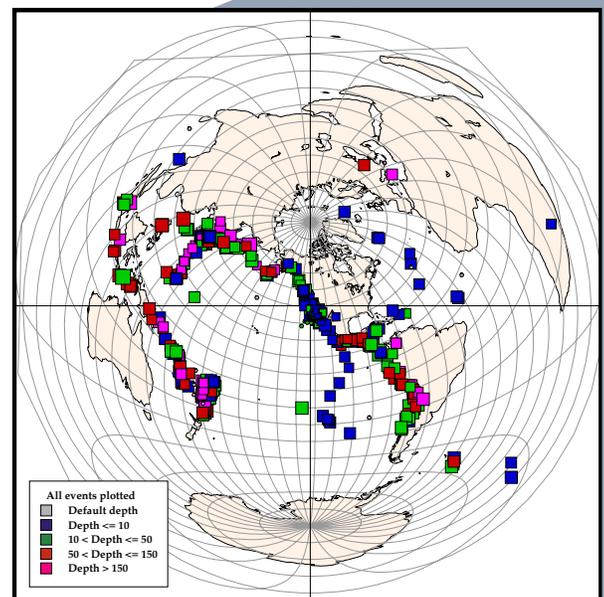


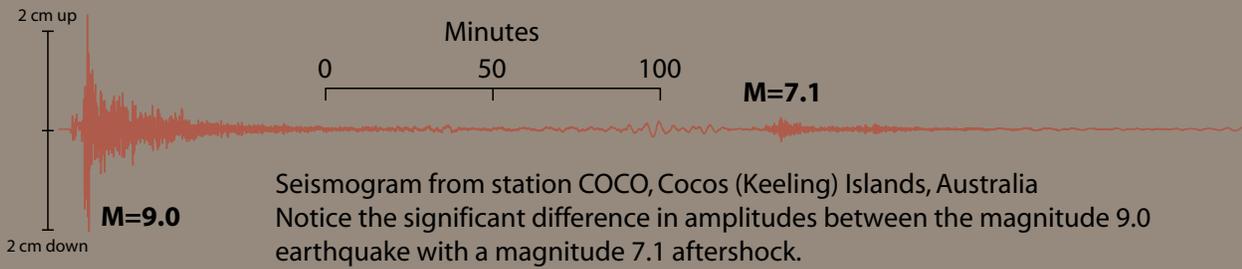
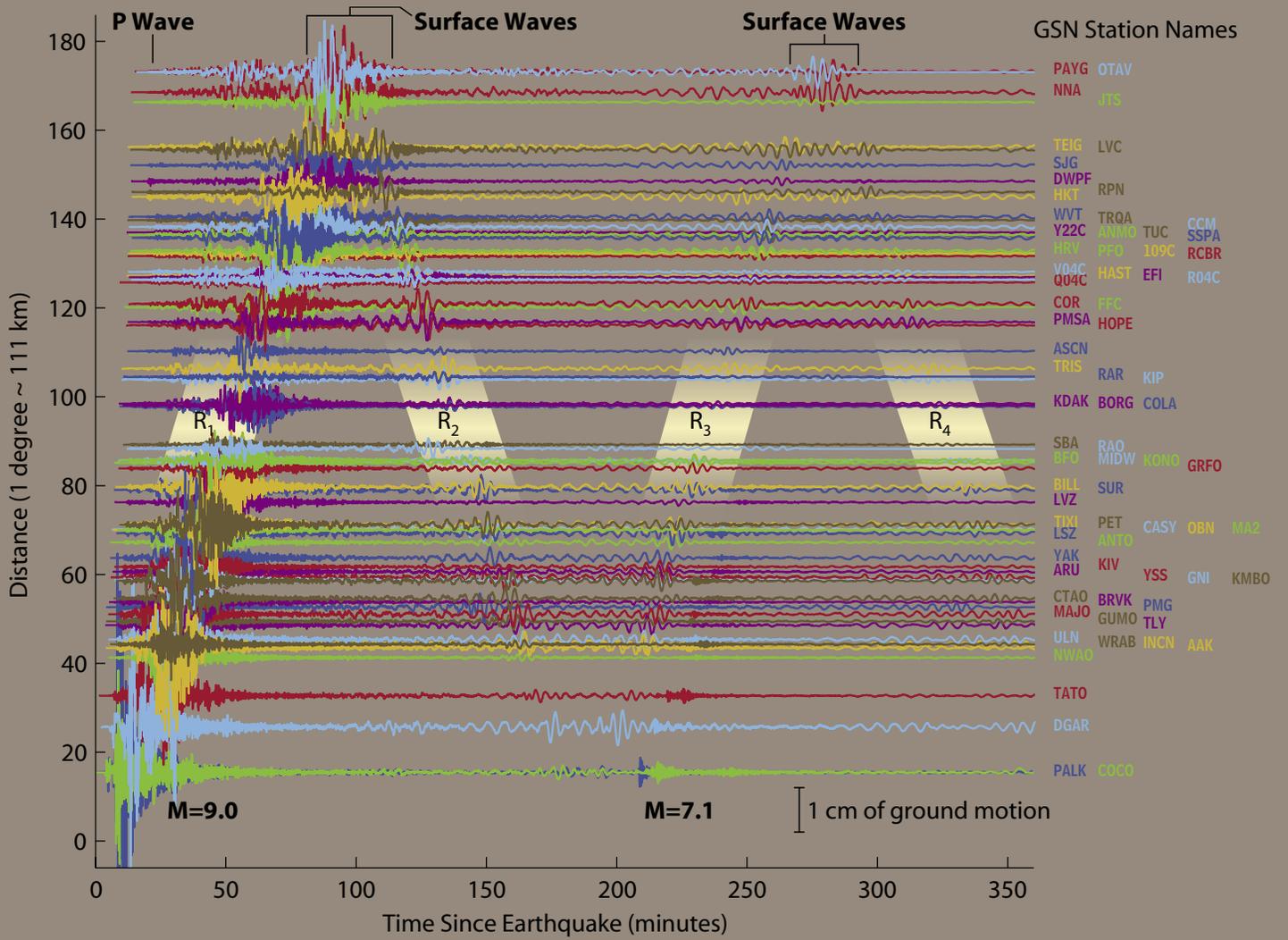
The ANF is a major undertaking considering that when USArray hits its stride there will be 400 TA stations and up to 200 FA stations telemetering data in real-time, bigger than any existing digital telemetry network. The parameters that need to be checked or monitored at each station include timing, channel orientation and polarities, gain and transfer functions, noise levels, mass positions, and environmental and instrument state-of-health information. The best way to check channel timing, orientations, and gains are to calculate locations and magnitudes from earthquakes recorded across the network and to compare these results to the relevant regional,

national, or global catalog. Making noise measurements and station calibrations on a routine basis along with monitoring environmental conditions and instrument state-of-health make another class of quality control measurements. Data review and event location when coupled with routine and systematic noise and calibration measurements will yield the highest quality data. The various state-of-health parameters are accessible through online real-time data-mining tools that allow researchers to quickly appraise the data quality of USArray stations and also access the data collected. Other 'restricted access' online tools have been developed to assist field engineers in determining and reporting data quality problems. These tools also act as searchable archives so field engineers can quickly locate information concerning specific USArray stations.

The ANF became operational in the Spring of 2004 and USArray immediately started observing local, regional, and teleseismic events. The ANF is currently receiving real-time data from selected stations of the Southern California Seismic Network, the UC Berkeley Broadband Network, and the ANZA Network. These regional network stations are included with newly installed TA network stations and passed through automatic triggering algorithms. To date, over 1700 earthquakes have been observed and more than 44,000 arrivals have been picked on the TA.

Events recorded by USArray Transportable Array stations (as of 11/12/2004)





Seismogram from station COCO, Cocos (Keeling) Islands, Australia  
 Notice the significant difference in amplitudes between the magnitude 9.0 earthquake with a magnitude 7.1 aftershock.



# The Great Sumatra Earthquake of December 2004

The December 26 2004 Sumatra earthquake was the largest event since the 1964 MW = 9.2 Anchorage, Alaska earthquake. This is the first earthquake of this size to occur since the broadband seismometers with digital recording have become widespread. Its moment release was eight times that of the previous largest event, the MW = 8.4 Peru earthquake of June 23, 2001.

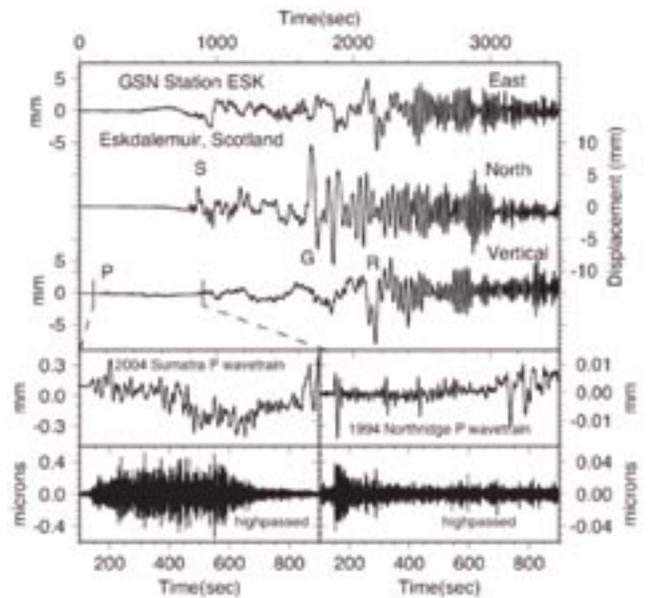
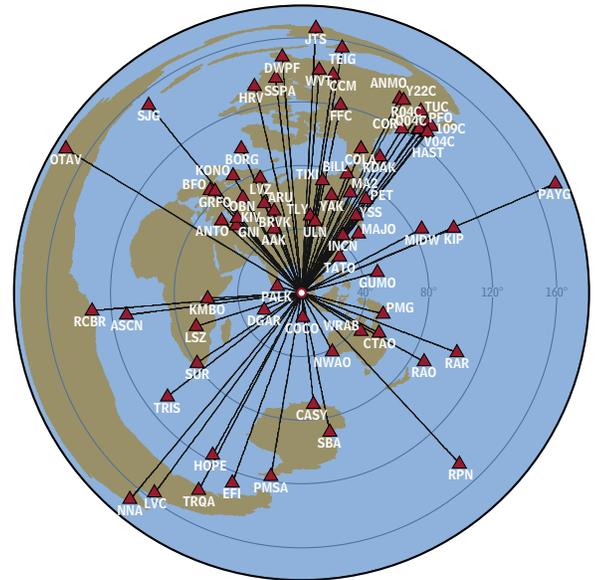
Rupture continued for approximately seven minutes, extending northwestward along the Sunda Trench for roughly 1200 km to the Andaman Islands. Displacement occurred across the shallow-dipping thrust fault and may have exceeded 20 m in some areas, totaling to a moment magnitude of 9.0. The seafloor displacement generated a massive tsunami that swept ashore with 10 m amplitude in northern Sumatra and expanded across the Indian Ocean and Andaman Sea, striking Sri Lanka and Thailand within two hours of the rupture. Confirmed deaths along the coastlines of eleven Indian Ocean nations exceed 220,000, marking this as one of the most lethal natural disasters in human history.

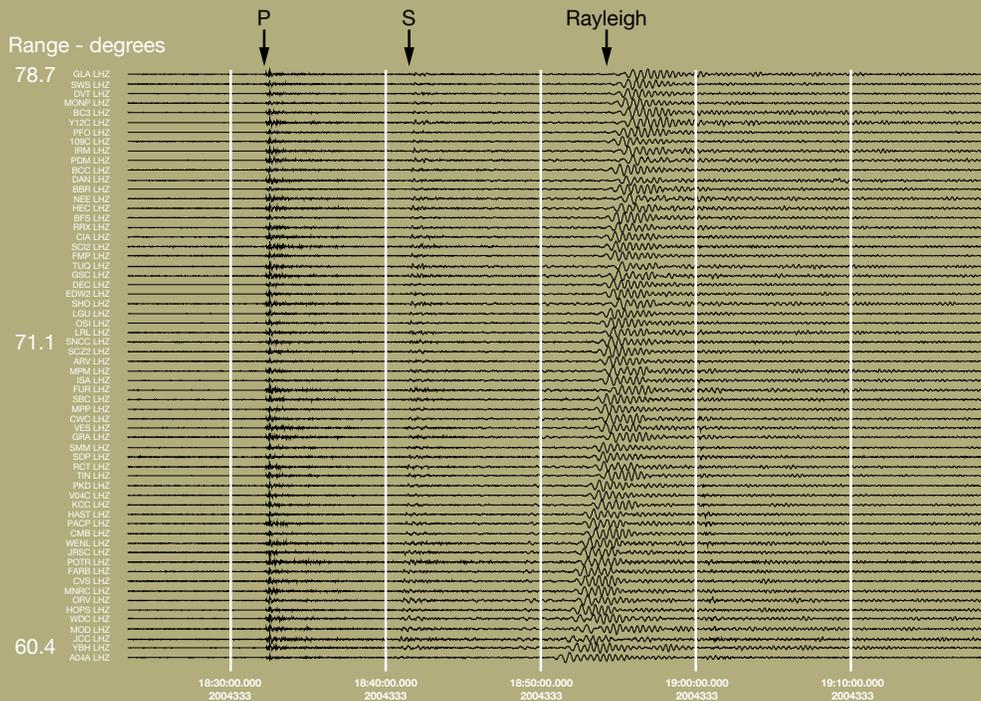
Sensors of extraordinary bandwidth and dynamic range were needed to capture this giant earthquake fully. Fortunately, many such stations have been deployed in the past few decades, including the 137 high dynamic range, broadband stations Global Seismographic Network (GSN) around the world. An original design goal for the GSN was to record with high fidelity all seismic motions for earthquakes anywhere in the world with magnitudes as large as 9.0. The Sumatra earthquake was the first such test of the GSN.

With continuous telemetry of signals from the global GSN stations, a variety of near real-time processing procedures are enabled for all earthquakes. This includes automatic event detection from the first-arriving seismic waves by earthquake monitoring operations such as those of the USGS National Earthquake Information Center and the NOAA Pacific Tsunami Warning Center. The records are used to estimate seismic magnitude and invert for fault orientation and slip direction. The high pass filtered version of the P wave de-emphasizes secondary surface reflections, and suggests ~400 s of primary rupture. Rapid quantification of the earthquake source is useful for tsunami warning and emergency response.

Near-real-time modeling of distributed rupture would be a useful augmentation to existing tsunami hazard assessment procedures. If rupture had progressed southeast along the Indonesian plate boundary rather than northwest, Banda Aceh and Thailand's beaches might have been spared devastation, but heavy damage would be expected along the southern Sumatran coast. Analysis of the P wave motion at GSN stations show that rupture propagated toward the northwest, with patches of underthrust slip as much as 20 m and duration of more than 400 seconds. These analyses were completed several weeks after the event, but they were based on data that were available within minutes.

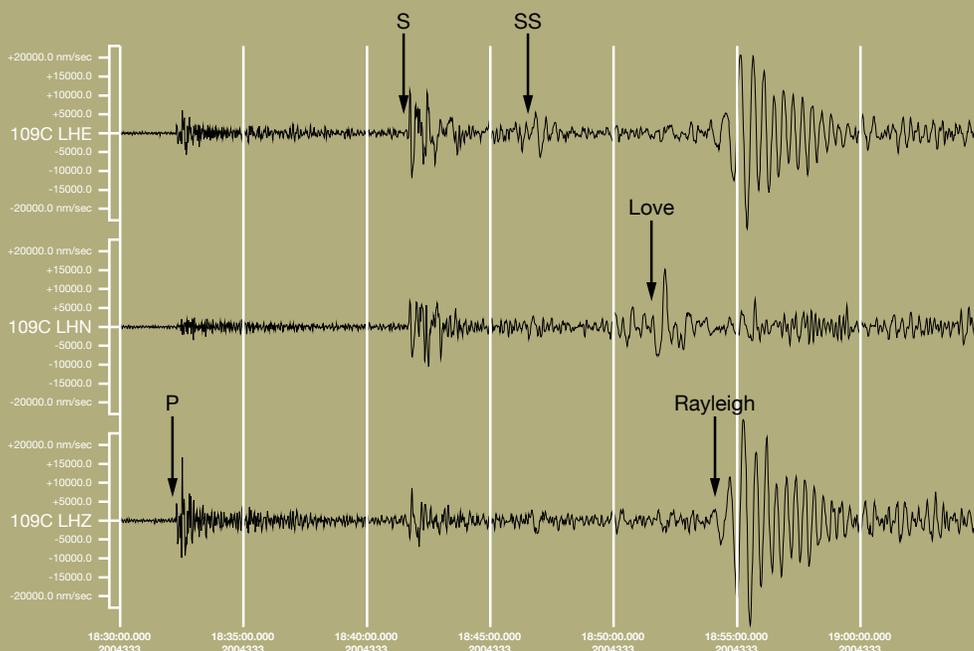
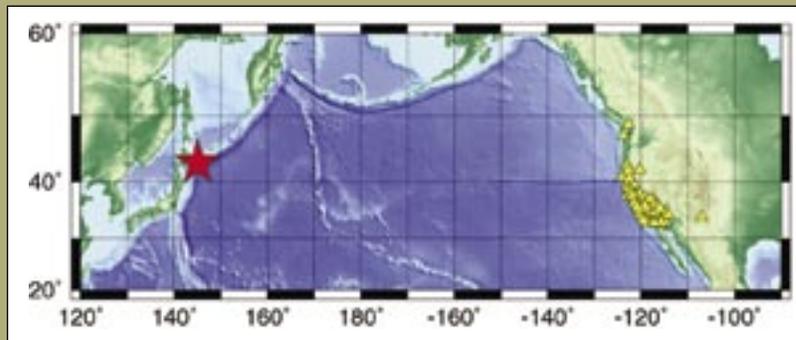
**Global Seismographic Network Stations**





A shallow magnitude 7 earthquake in Japan on November 29, 2004 recorded on the initial stations of the USArray Transportable Array. Most of these 62 stations are in California and are operated by Berkeley, CalTech and UCSD as part of the California Integrated Seismic Network (CISN). The CISN stations, upgraded where necessary, were selected to form the core of the Transportable Array grid in California. Additional stations are being added in California to complete the coverage with nominal 70 km spacing between sites, Selection and installation of stations is also proceeding in the Pacific Northwest.

USArray Vertical Components  
November 29, 2004 • Hokkaido, Japan  
Mb(QED) = 7.0 • Lat = 43.00 • Lon = 145.09 • Depth = 43.8 km



Three components of the Japanese earthquake recorded on USArray station 109C. This is one of the new USArray stations installed at Camp Elliot on UCSD property near San Diego, CA. Since the event is approximately due west of the station, the components are naturally polarized, with the Love wave appearing mainly on the NS (tangential) component and the Rayleigh wave on the vertical and EW (radial) components.

USArray Transportable Station 109C  
November 29, 2004 • Hokkaido, Japan  
Mb(QED) = 7.0 • Lat = 43.00 • Lon = 145.09 • Depth = 43.8 km

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