High Performance Wireless Research and Education Network

# HPWREN

http://hpwren.ucsd.edu

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***Cover photographs.*** From San Diego's Coastline to Remote Mountains: The HPWREN project spans from the San Diego coast to the county's rugged mountains. While the HPWREN backbone node at Mount Soledad overlooks the La Jolla shoreline, the solar-powered HPWREN relay site at the Santa Margarita Ecological Reserve provides a scenic view of the County's northeastern mountains.


The HPWREN project is based on work sponsored by the National Science Foundation and its ANIR division under Grant Number ANI-0087344. The HPWREN project is led by University of California–San Diego researchers at the San Diego Supercomputer Center and the Scripps Institution of Oceanography.


The HPWREN website is located at http://hpwren.ucsd.edu.



Utilizing antennas up to ten-feet in diameter, HPWREN backbone node installations require significant planning and installation efforts.

*Shown here: This HPWREN backbone node site is located on a mountaintop near Fallbrook (California).*

The High Performance Wireless Research and Education Network (HPWREN) team is creating, demonstrating, and evaluating a prototype, high-performance, wide-area, wireless network in San Diego and Riverside counties.

The NSF-funded network includes backbone nodes on UC San Diego and San Diego State University campuses, and several "hard to reach" sites in remote areas.

Not only is HPWREN used for measurement and analysis research, but the network also provides high-speed Internet access to field scientists from several disciplines–such as geophysics, astronomy, ecology–and educational opportunities for rural Native American learning centers and schools.

Additionally, HPWREN provides a testbed for the first responder community to experiment with and demonstrate rapid deployments of networking technologies.

"Over the years of its existence, HPWREN has evolved into a collaborative activity that is both interdisciplinary and multi-institutional in nature.

HPWREN has significantly transcended beyond the initial science and education applications, and also includes crisis management applications for first responders."

**- Hans-Werner Braun, HPWREN principal investigator**

## Broader Impacts of HPWREN

HPWREN influences many scientific disciplines that monitor and sense the environment. A fundamental impact is the field deployment of pioneering wireless networks for sharing real-time data across multiple disciplines ranging from environmental sciences, oceanography, and astronomy to rural education.

HPWREN is a critical testbed for the large-scale sensor network applications in several NSF initiatives, such as:

- Earth sciences (EarthScope);
- Ocean sciences (OOI- Ocean Observatories Initiative);
- Biological sciences (NEON - National Ecological Observatory Network); and
- Civil engineering (NEES - Network for Earthquake Engineering Simulation).

Each of these large scale initiatives aims to collect real-time data from thousands of sensors, and each will require new technologies to process, manage, and communicate real-time multidisciplinary environmental data on regional, national, and global scales. The techniques developed by HPWREN and the applications developed using HPWREN will be used to create the next generation of scientific and environmental monitoring systems.

## Remote Research Uses of HPWREN: Ecology

Recent advances in wireless networking, solar power, and sensor technology allow field scientists to observe the environment on a continuous basis–giving them more data to understand ecological and Earth science processes while also providing a new infrastructure to conduct multidisciplinary research.

One example of such a multidisciplinary wireless sensor network is being developed by an HPWREN collaboration, which has connected San Diego State University's 4,344-acre Santa Margarita Ecological Reserve to the 45 Mbps broadband network. That is, ecologists at the Santa Margarita can now stream sensor data directly from the field to their campus laboratories for analysis.

Water quality and hydrology sensors along the Santa Margarita Watershed allow hydrologists to remotely measure parameters such as water acidity and pressure. Meanwhile network-connected acoustic sensors allow biologists to track animal calls and other wildlife activity such as bat sonar—without even setting foot on the remote ecological reserve.

*A Santa Margarita Ecological Reserve field scientist captures images using a digital camera. Photos are transmitted in near-real-time by connecting the camera to an Ethernet port in a laptop, which functions as a router with a wireless card–connected via a directional antenna to a remote receiver.*

HPWREN-connected cameras at the reserve allow researchers to catch a glimpse of a biologically diverse area with mountain lions roaming, golden eagles nesting, and hummingbirds sipping nectar. These cameras deliver more than three megapixels per image, and are controlled from a remote server across the Internet.

Rolf Baumberger, a biology researcher at the University of Zurich in Switzerland, has been studying the bush monkey flower (*Mimulus aurantiacus*) for almost ten years. Until recently, however, Baumberger was making several trips per year to the Santa Margarita Ecological Reserve—examining the flower's alteration in shape and color during various conditions.

Since Spring 2002, Baumberger has been observing monkey flowers at SMER via a high-resolution, HPWREN-connected, real-time camera.

That is, Baumberger uses an HPWREN-connected camera at the Santa Margarita Ecological Reserve to remotely observe hummingbirds, bees, and moths in the pollination of bush monkey flowers.

Baumberger and other reserve scientists have the capability of sending and receiving data at speeds approaching 45 megabits per second!

"During my remote study via HPWREN, I realized that the evolution of bush monkey flowers is a bit smarter than a biologist might realize.

By comparing two photographs–one taken via an HPWREN-connected camera in May and the other taken in July–one realizes that a single 'monkey' can quickly alter shape and color when the conditions are favorable.

Without the HPWREN-connected camera, this discovery would not have been possible."

**- Rolf Baumberger, Biology researcher**

*The primary benefit of the remote reserve's high-speed connectivity includes the availability for researchers like Baumberger to employ high-bandwidth instruments such as imaging systems used to measure and monitor ecological and environmental systems as well as to extend the number and range of conventional remote sensing devices in the terrestrial and aquatic domains.*

*Related Link: http://hpwren.ucsd.edu/research.html#ecology*

## Remote Research Uses of HPWREN: Structural Engineering

Home to the world's first outdoor shake table and the largest shake table in the United States, Camp Elliot is located about eight miles east of the UCSD campus. The facility is specifically used by university structural engineering field researchers as a seismic test facility and is linked to the 2.4 GHz portion of HPWREN.

Camp Elliot utilizes their HPWREN connectivity to send and receive large data files that depict the real-time response of large and full-scale structural specimens tested under seismic and blast loading using the shake table and blast simulator.

*In addition to this 40-inch grid antenna, the Camp Elliot installation includes an Internet-accessible real-time video camera.*

*The video camera allows researchers at this remote site to share their ongoing progress and findings with Caltrans, NEES, and TSWG participants.*

This research is sponsored by multiple sources, including the California Department of Transportation (Caltrans), which funds the soil-foundation-structure interaction studies being conducted at the Camp Elliot field laboratory. Additionally, the National Science Foundation's George E. Brown Network for Earthquake Engineering Simulation (NEES) sponsors the Large High Performance Outdoor Shake Table (LHPOST), which measures 25 feet by 40 feet and allows researchers to examine real-time seismic activity on full-scale structures. Meanwhile the Technical Support Working Group (TSWG), which is part of the U.S. Defense Department, sponsors the Explosive Loading Laboratory at Camp Elliot.

"One of the primary components of the NEES program is the ability to tele-participate and conduct experimentation at various equipment sites in real-time.

Our research at the Camp Elliot site will eventually require one gigabit-per-second networking capabilities, and this HPWREN connection is our first step in getting there."

**- Lelli Van Den Einde, NEES coordinator**

*Related Link:*
*http://hpwren.ucsd.edu/news/020809.html*

## Remote Research Uses of HPWREN: Geoscience

Implementing real-time access to earthquake sensors in the remote east San Diego desert is a challenge, however, this access is no longer impossible - thanks to the advancements in wireless technology. The HPWREN project is currently working to expand and improve existing wireless links in remote seismic field locations to ensure that the sensors are adequately configured to withstand a catastrophic seismic event.

Led by HPWREN co-PI and geophysicist Frank Vernon, the HPWREN team provided two southern California research sites with a broadband network link and an interface to real-time strainmeter data. That is, scientists from around the world can now access real-time long-base strainmeter data recorded at the Piñon Flat Observatory and Durmid Hill sites, which are both managed by the Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics (IGPP) at the Scripps Institution of Oceanography (SIO).

Additionally, HPWREN researchers wrote and implemented software that utilizes SIO's IGPP's existing seismic sensor network to distribute real-time data to client computers. Real-time distribution of seismic data is now available via HPWREN Multicast Quake, or Mquake.

Specifically, Mquake provides date, time, location, magnitude, and additional details regarding seismic activity that occurs within a seismic sensor network affiliated with the Scripps Institution of Oceanography's Institute of Geophysics and Planetary Physics (IGPP). The prototype software makes multi-cast, real-time distribution possible for parametric information from individual sensors, as well as summary data - providing analyzed results after the determination of location and magnitude of seismic activity. The data is then transferred to many machines simultaneously via the IP multicast overlay called MBONE; however, with less network efficiency, the data can also be transferred into a non-multicast environment.

The primary goal of the HPWREN-developed Mquake is to provide notification prior to actual shockwave arrival at the client machine, as well as analyzed information within a minute or so following an event.

## Remote Research Uses of HPWREN: Astronomy

More than 50 years have passed since astronomers first started using the Palomar Observatory's 48-inch Samuel Oschin telescope to study the night sky. Known throughout the world as the meter-class-aperture telescope with the largest field of view, one of the Oschin's most recent "claims to fame" is its link to HPWREN's 45 Mbps backbone.

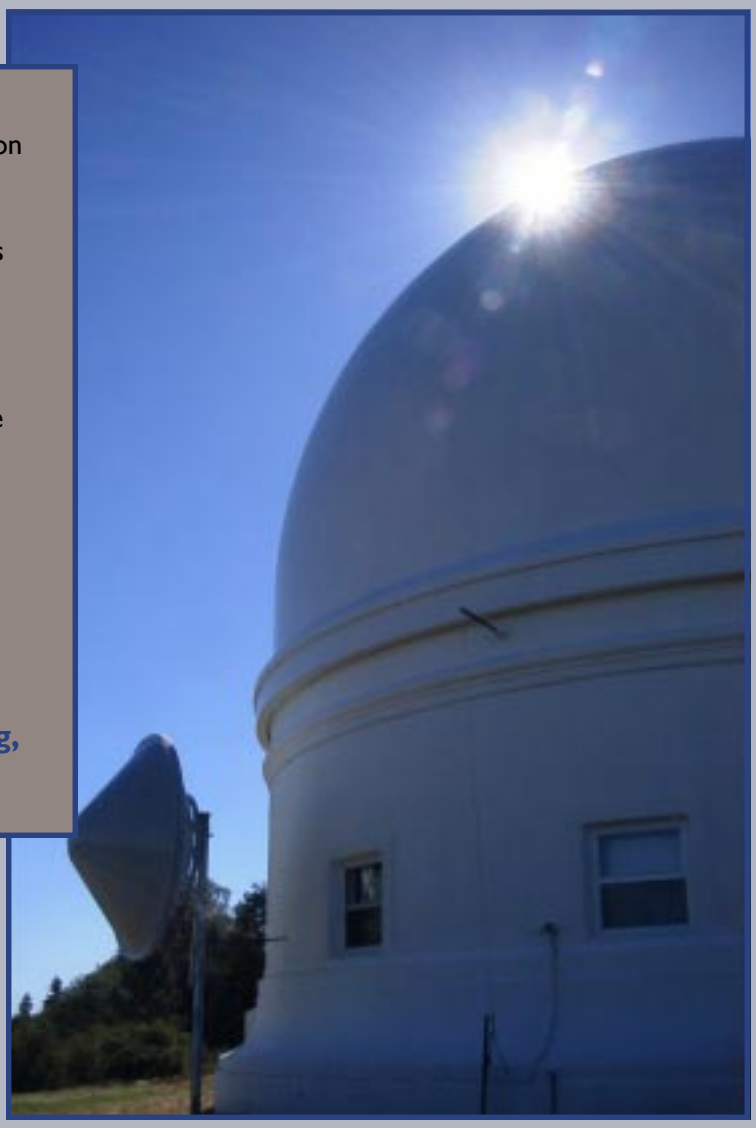
Coupled with the Oschin's sophisticated 161-megapixel digital camera, the high-speed network connection allows researchers to transmit real-time images directly from the observatory to worldwide laboratories. The images are primarily used for near-Earth asteroid research and supernova detection.

For instance, the Nearby Supernova Factory is one project that utilizes the HPWREN connection at Palomar. Specifically, the researchers are looking at nearby supernovae and studying them in detail so that they can be used as cosmological distance indicators. Astrophysicist Greg Aldering and colleagues with the Nearby Supernova Factory then use their findings to measure distances to galaxies that are tens of billions of light years from Earth.

"The cause of the Universe's expansion is currently unknown, however, some think that it is related to Einstein's famous Cosmological Constant and is commonly called 'dark energy'.

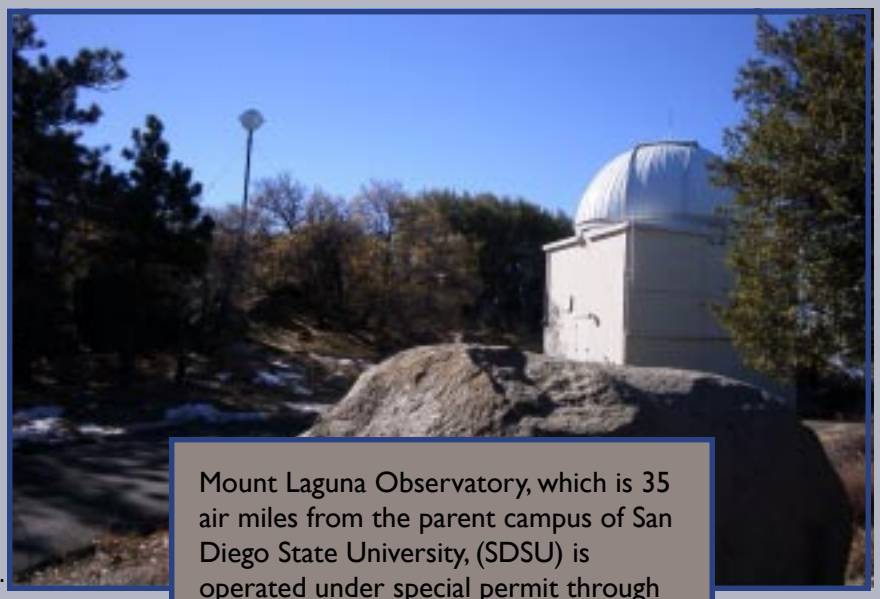
To measure the rate change of the universe's expansion due to 'dark energy', we must understand how the brightness of supernovae changes when their input ingredients change. This requires that we discover exploding supernovae as soon as possible–hence the HPWREN real-time connectivity is highly crucial to our research efforts."

**- Greg Aldering, Astrophysicist**



Aldering and his fellow scientists, who recently reported that their supernova project has discovered an unprecedented 34 new supernovae in its first year (2002), continue their work to understand the cause of the Universe's expansion.

Astronomers at Mount Laguna Observatory were among the first to benefit from HPWREN. Previously, hundreds of digital images obtained per night were transported to the San Diego State University campus on digital audio tapes. Images are now quickly sent to campus via HPWREN, and often displayed the next day in classes.

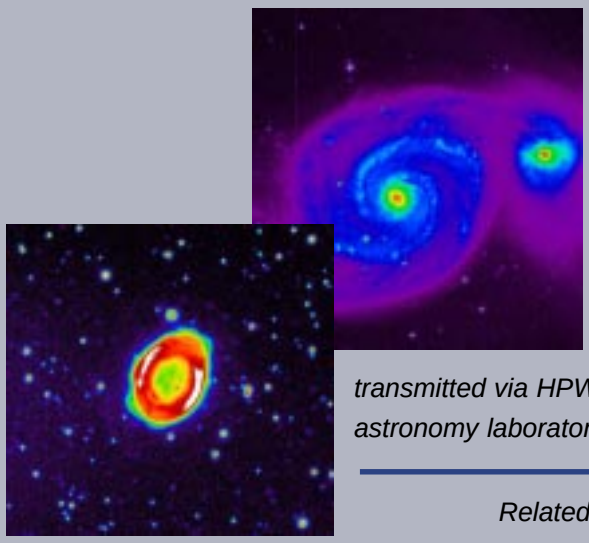


Mount Laguna Observatory, which is 35 air miles from the parent campus of San Diego State University, (SDSU) is operated under special permit through the United States Department of Agriculture Forest Service (USFS). Partner institutions include the University of Illinois Urbana-Champaign and the University of Kansas.

Research telescopes of 16-, 24-, and 40-inch apertures are outfitted with electronic instrumentation. The 21-inch Buller Telescope is used for visual observations by SDSU undergraduate students and with the USFS for the Summer Visitor's Program.

HPWREN has brought new opportunities to the observatory. For example, a remotely operated 10-inch telescope is currently under construction so that persons with disabilities can more easily access and observe the night sky. The HPWREN-connected telescope will also be used by college students at SDSU, which is frequently cloudy.

Additionally, NSF recently funded the three-year Project ULTRA (Ultra-Lightweight Technology for Research in Astronomy) to build a 40-inch telescope with lightweight carbon graphite composites.



Project ULTRA, a consortium of SDSU, University of Kansas, Dartmouth University, and Composite Mirror Applications (Tucson), will encompass an HPWREN-connected telescope that will allow astronomers to remotely conduct research from their campuses.

*Images such as these (left: ring nebula; right: whirlpool galaxy) are now easily transmitted via HPWREN from the Mount Laguna Observatory to astronomy laboratories and classrooms at San Diego State University.*

*Related Link: http://hpwren.ucsd.edu/research.html#astronomy*

## Remote Research Uses of HPWREN: Oceanography

Scientists from the Scripps Institution of Oceanography (SIO) Integrative Oceanography Division (IOD) and Woods Hole Oceanographic Institution (WHOI) conducted a two-week pilot study in Fall 2002 using 802.11b technology to help them examine surf zone water motions in real-time. With assistance from the HPWREN team, several SIO and WHOI scientists deployed two in-situ current and wave measuring stations in shallow water at Black's Beach. These stations connect to an autonomous data acquisition system on the beach which telemeters the data in real-time, via a wireless Ethernet bridge on Scripps Pier, directly to IOD and WHOI laboratories for analysis.

> "The real-time data that are now streamed from the beach to our labs allow researchers to better understand beach erosion and nearshore circulation."
>
> **- Jerome Wanetick**
> **SIO computer scientist**

Additional such HPWREN-involved initiatives include the San Diego Coastal Monitoring and Observing System, a partnership of research scientists, public health officials, policy makers and natural resource managers. Specifically, the system is designed to collect real-time measurements of key oceanographic parameters that will enhance our understanding of local water quality issues in southern California.

The backbone of the system is an array of high-resolution Coastal Ocean Dynamics Radars (CODARs) connected by HPWREN and designed to provide a spatial map of the local ocean surface currents in real-time. The data from the CODAR array are complemented by a number of in-water monitoring systems measuring temperature and water quality parameters.

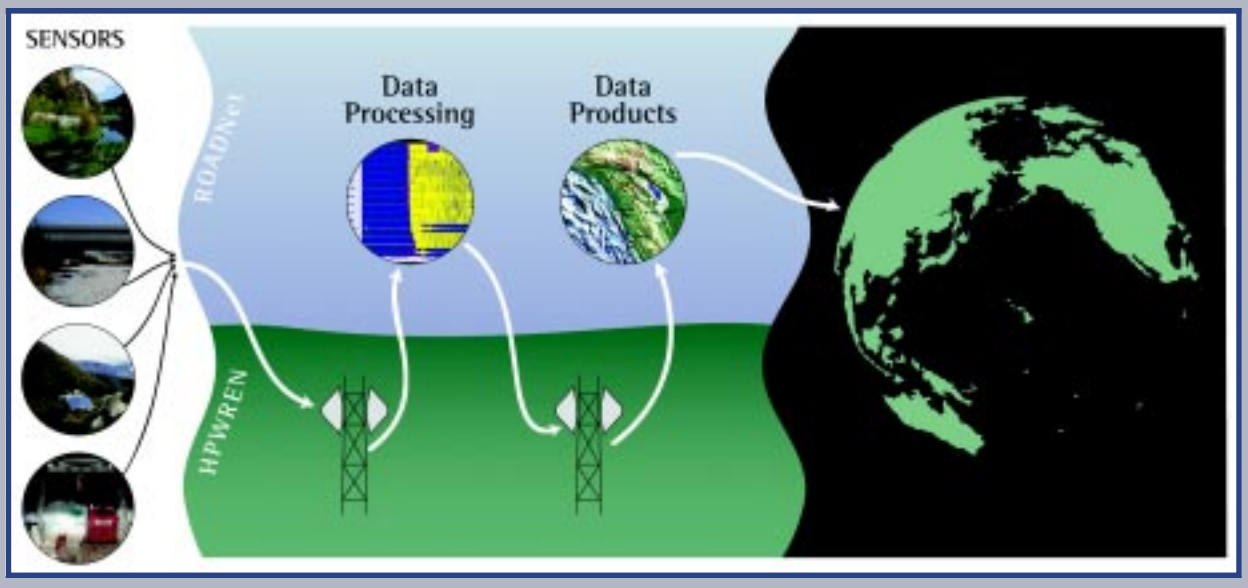
With funding from the California Clean Beaches Initiative, SIO is also establishing a Coastal Monitoring and Observing System in the South Bay region of San Diego encompassing Point Loma to the U.S.–Mexico Border and waters offshore to distances of approximately 30 kilometers. The funds have been provided to conduct real-time measurements of key oceanographic parameters relevant to understanding the coastal transport mechanisms present in this region and their relevance to local water quality issues. These real-time measurements will be made possible via HPWREN connectivity.

The immediate attention of this program is directed toward the city of Imperial Beach which experiences a significant number of beach closures as a result of high concentrations of indicator bacteria. It is recognized that the city's local beach problems requires examination on a framework of regional scales.

## Real-Time Sensor Networks

HPWREN provides access to many different types of sensors which monitor the coastal, ocean, riparian, and geophysical phenomena and ecosystems in southern California. Turning these HPWREN-connected environmental data into information and knowledge is the goal of the NSF-funded Real-time Observatories Applications, and Data management Network (ROADNet) project.

Specifically, ROADNet is enhancing the capacity to monitor and respond to changes in the environment by developing an integrated and transparent information management system that delivers seismic, oceanographic, hydrological, ecological, and physical data to a variety of end users in real-time. ROADNet scientists are also developing the software tools to make these data available in real-time to a variety of end-users, including researchers, policymakers, natural resource managers, educators and students.




The sensor network connectivity created by HPWREN provides a testbed that ROADNet can use to demonstrate the requirements and utility of collecting and streaming environmental sensor data in real-time. ROADNet seamlessly integrates multidisciplinary data sets (e.g. earthquake, ocean current, hydrometeorological, and ecological) and advances our understanding and management of coastal, ocean, riparian, and terrestrial geophysical phenomena and ecosystems in southern California.

*This image of a red-tailed hawk was collected via an HPWREN-connected motion-detect camera at the Santa Margarita Ecological Reserve.*

*Related Link:*
*http://stat.hpwren.ucsd.edu/cameras*

## HPWREN and the Digital Divide: Native American Learning Centers

In an effort to help bridge the "digital divide" in rural communities, the HPWREN team has been working toward delivering high-speed Internet connectivity to several remote Native American learning centers in San Diego county. In addition, as a collaborative activity, HPWREN researchers are teaching Native Americans to ensure that the community's members are able to understand, maintain, and evolve the network themselves.

Specifically, HPWREN researchers are working with San Diego's Southern California Tribal Chairman's Association to utilize HPWREN experiences, to build out their own Tribal Digital Village Network (TDVNet). TDVNet has been funded by the Hewlett Packard Corporation as a grant to the San Diego tribes.

*The HPWREN team works alongside La Jolla Native American tribal members to connect a learning center to the high-speed Internet.*

Originally part of HPWREN, the TDV network has since been transformed to tribally owned technology. Armed with knowledge and expertise gained from HPWREN, TDVNet expanded the wireless communications network across and within their reservations, with a goal of an eventual self-sustaining utility among the tribes.

*Related Links:*
*http://hpwren.ucsd.edu/news/030510.html*
*http://hpwren.ucsd.edu/news/021029.html*
*http://hpwren.ucsd.edu/news/020325.html*

"This technology and expertise transfer was facilitated by in-kind replacements of the equipment back to HPWREN, and assuming TDVNet ownership of what had been deployed earlier. This transfer of equipment ownership also included educating TDVNet staff with the expertise that they need to design, build, configure, and operate a high performance wireless data network."

**- Hans-Werner Braun,**
**HPWREN principal investigator**

In addition to the TDVNet collaboration, the HPWREN team also has a partnership with the Santa Rosa Native American reservation, which is located in southeastern Riverside county. In exchange for linking the Santa Rosa Native American education facilities to HPWREN, the NSF-funded research project was granted access to the tribe's land and communications facilities atop Toro Peak.

As part of the agreement between the tribe and researchers, HPWREN connected tribal facilities to the high-speed network, while the mountaintop relay supports various research projects. For instance, the relay site allows HPWREN to reach remote seismic sensors in the Anza Borrego desert, an ecological reserve in Boyd Deep Canyon, and the Kings Stormwater Bridge near Salton Sea.

*The solar-powered relay for the Santa Rosa reservation HPWREN installation includes weather sensors, which measure climate conditions such as temperature, humidity, precipitation, and barometric pressure.*

*HPWREN-collected weather data is available at http://stat.hpwren.ucsd.edu/Weather/.*

*Related Link:*
*http://hpwren.ucsd.edu/news/030414.html*

## HPWREN and the Digital Divide: Distance Learning

Over the past three years of the HPWREN project, the researchers have been both directly and indirectly involved with distance learning via the network.

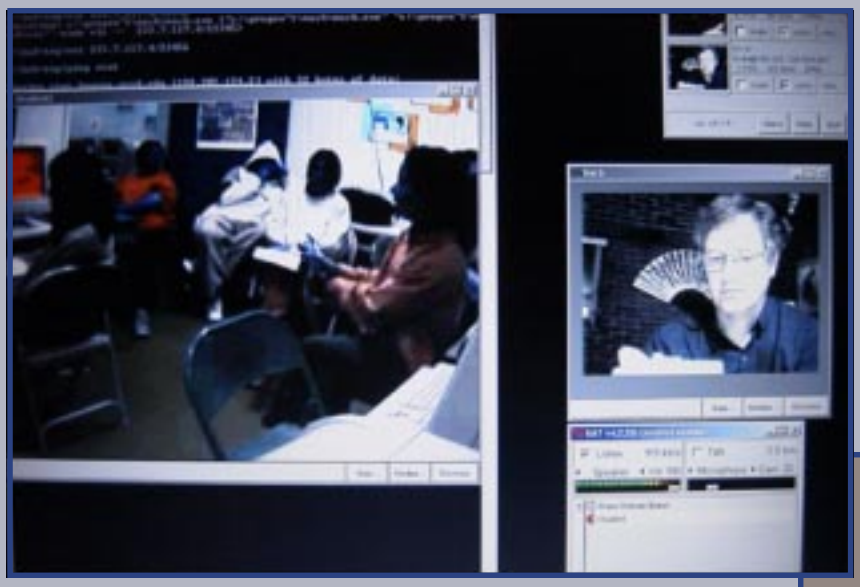
For instance, in Fall 2000, the HPWREN team worked with Palomar College and the Southern California Tribal Chairmen's Association Tribal Digital Village Network to offer a Computer Science and Information Systems course for local Native American reservations.

The course was primarily taught in traditional classroom style at the Pala Learning Center for Pala, La Jolla, Rincon, and San Pasqual tribal members.

The HPWREN team and Palomar students also experimented with multicast technology via HPWREN.

The multicast experiments included the use of vic, a multicast video tool, and rat, an audio tool. Meanwhile, Blackboard was the browser interface used for all class lecture presentations, assignments, and on-line discussions.

While Palomar College provided instruction funds and administrative support, the Tribal Digital Village Network project provided the students with computer equipment and textbooks for the course.



*HPWREN researchers provided a distance lecture via the network and a hands-on laboratory for one of several Native American Learning Center courses offered over the past three years.*

The HPWREN team provided broadband connectivity, instruction, curricula, and technical support for the course.

Participants in the course ranged from Native American high school students to reservation community members.

HPWREN distance learning programs have included a wide array of activities.

In addition to efforts made by HPWREN researchers, UCSD math students also used the high-speed network to serve as online tutors for Pala Learning Center middle school students.

In addition to distance learning activities with rural Native American learning centers, the HPWREN team has also participated with the California State Parks Distance Interpretation Program in their efforts to facilitate remote interactive presentations via a broadband connection.

In Summer 2003 HPWREN researchers recently worked with California State Parks to allow park rangers, educators, and administrators from around the country to pay a “remote” visit to the Anza-Borrego State Park. That is, attendees of two different southern California conferences examined fossilized oyster beds in the remote Fish Creek - while sitting in urban conference rooms approximately 100 miles away.

*The HPWREN 45 Megabits-per-second connectivity for the remote interactive presentations was achieved by using a four-foot antenna on a tripod at Fish Creek.*

*This antenna pointed to an HPWREN backbone site on Mount Laguna. From there, the link shoots to the Cuyamaca mountains, onto Mount Woodson, and finally to the San Diego Supercomputer Center at UCSD.*

*Additionally, a yagi antenna was used to create a local multi-hop wireless environment within the Anza-Borrego location. This local set-up allowed connectivity for both the Fish Creek fossilized oyster beds and the nearby Wind Caves.*

“The high-speed wireless link provided by HPWREN can provide students in California with access to an extraordinary park resource that school buses simply can’t get to,” said Alan Friedman, Chief Information Officer for the California Department of Parks and Recreation in Sacramento. L. Louise Jee, GIS specialist at the Anza-Borrego State Park head quarters adds that “the possibilities of remote wildlife monitoring in this large park no longer seem so impossible to dream about.”

*Related Links:*
*http://hpwren.ucsd.edu/news/030430.html and http://hpwren.ucsd.edu/news/030331.html*

## First Responder Uses of HPWREN

While the initial HPWREN phase focused on science and education applications, early collaborations with local agencies at network deployment sites served as a catalyst for further work involving first responders and HPWREN researchers–with distinct applicabilities to homeland security activities.

For example, in August 2001, local agencies teamed with HPWREN researchers for a crisis management exercise, which emulated a truck hauling hazardous chemicals spilling into an urban environment, causing a poisonous plume to penetrate the area. “This exercise allowed us to evaluate an Internet-based data sharing scheme, where multiple agencies could view tailored perspectives of the same incident in real-time,” says Steve Murray of SPAWAR Systems Center’s San Diego’s Crisis/ Consequence Management Initiative team, who participated in the activity.

Additional exercises encompassed HPWREN researchers connecting the San Diego County Sheriff’s Department as well as the San Diego Air Attack Base of the California Department of Forestry and Fire Protection. These activities are enabling various joint research and technology demonstrations.

“While the HPWREN connection allows for technology demonstrations, experiments, and exercises, we also hope that enhanced access to university researchers enables us to find advanced technologies to respond to incidents and emergencies,” says Chris Hinshaw, Assistant Manager of the San Diego County Sheriff’s Department’s Wireless Communications Office. “Real-time information from deployed sensors, such as being shown with the HPWREN-connected seismology and ecology sites, is becoming more and more critical in our current environment.”

*Experimental connections to the San Diego Sheriff’s Department and the California Department of Forestry and Fire Protection*

*Related Links:*
*http://hpwren.ucsd.edu/news/030707.html*
*http://hpwren.ucsd.edu/news/030716.html*

## Crisis Management Uses of HPWREN

On the afternoon of July 16, 2003, lightning ignited the Coyote Wildfire in northeastern San Diego County and more than 18,000 acres were lost by the time the fire was contained on July 23. Thanks to the HPWREN team, the firefighters at the remote operations site were provided with data connectivity for the week-long incident. This wireless high-speed data link was established via the HPWREN backbone node in only eight hours and allowed first responders to update wildfire status reports, images, and weather information in real-time.

"Technology such as this provides CDF with a means for the command and control functions to better communicate information to the field units. The same will also work in reverse with the field units relaying real time intelligence to the regional command and control decision makers," says Jim Garrett, California Department of Forestry and Fire Protection (CDF) Emergency Command Center Chief.


*Layout for an HPWREN ad-hoc connection to an actual large-scale fire incident in southern California*

Other experiments under way in the incident management arena include HPWREN-connected cameras mounted onto CDF airplanes.

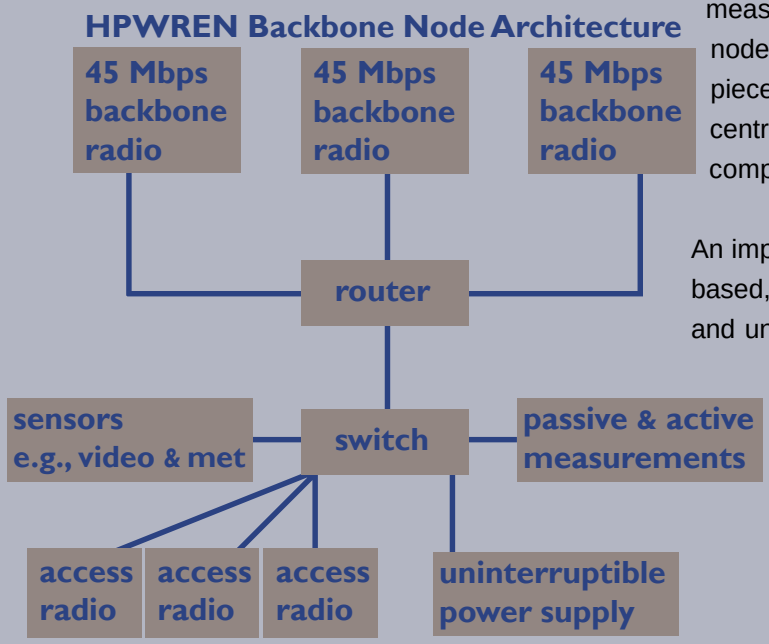
*Related Links:*
*http://hpwren.ucsd.edu/news/030725.html*
*http://hpwren.ucsd.edu/Tech/*

"The dissemination of information and incident intelligence up and down the command and control chain of command is more important now than it ever has been in the past. The connectivity provided to CDF for the Coyote Fire was a real-life exercise which clearly demonstrated how valuable and useful the wireless technology provided by the HPWREN team is to our agency."

**- Jim Garrett,**
**CDF Fire Chief**

## Network Measurement and Analysis

From its very early stages, HPWREN researchers have incorporated an array of network monitoring capabilities - often utilizing findings from research conducted by the National Laboratory for Applied Network Research (http://moat.nlanr.net). Primary HPWREN monitoring includes the use of dedicated measurement machines at both backbone nodes and several access points, various pieces of measurement software, and a centralized statistics collection and analysis computer.

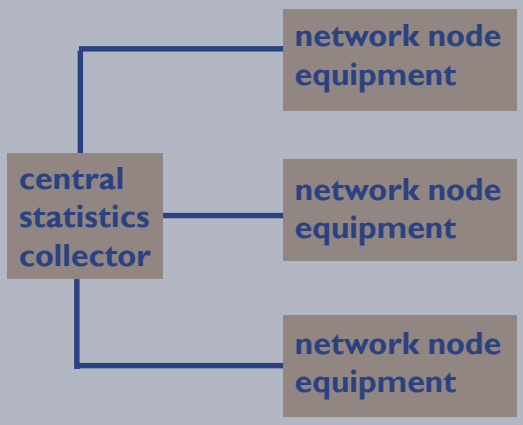



*The HPWREN backbone node architecture includes various opportunities for network measurements as well as a dedicated computer for active and passive performance assessments.*

An important source of data is SNMP/MIB based, and includes radios, routers, switches, and uninterruptable power supplies.

For example, the backbone radio MIB data is auto-processed into a performance summary that is automatically sent to network engineers on a daily basis.

Automated reachability tests from the central server result in alarms being mailed or staff paged when network problems occur.




*A centralized server collects measurement data from the HPWREN backbone nodes.*

Additionally, regular inter-nodal throughput tests, utilizing the NLANR DAST group's IPERF program (http://dast.nlanr.net/Projects/Iperf), result in a daily matrixed summary of throughputs across HPWREN backbone nodes.

Netflow data is collected from the router at the interface to the larger Internet. This latter interface is also being utilized by a machine for automated detection of denial of service attacks.

In addition, the central statistics server houses data from HPWREN-connected sensors, such and weather stations and cameras. The HPWREN statistics data is available at http://stat.hpwren.ucsd.edu.

## HPWREN Connectivity Enables Sensors on Coronado Bridge

In summer 2002, the HPWREN team participated in an activity that demonstrated ad-hoc and temporary multi-media installations of seismic and visual instrumentation at the Coronado Bridge. The activity provided wireless IP access, using off-the-shelf 802.11b technology, from the bridge to the University of California–San Diego campus, where multi-agency and multi-institutional participants examined and discussed the feasibility of a permanent networked monitoring system of this type.

The Coronado Bridge demonstration was the first major step in testing the feasibility and understanding the values of a remote monitoring system, and was conducted after several local and federal government agencies expressed an interest in working with UCSD in developing and deploying multi-functional sensor networks on the bridge for the purpose of seismic/infrastructure monitoring and crisis management of the bridge. In addition, such instrumentation will be usable for security surveillance of the nearby Navy piers and waterways as a means of directly addressing principal homeland security and defense needs.

"Those attending the demonstration were unanimously impressed and expressed interest in what they saw as potentially valuable for their agencies," says Frieder Seible, School of Engineering Dean. "Plans continue for the narrowing of focus to produce an end product that serves the specific needs of the various involved agencies as well as providing meaningful research parameters for UCSD."

HPWREN

http://hpwren.ucsd.edu

The High Performance Wireless Research and Education Network
is a National Science Foundation research project.