Dynamic Data Flow in Real Time

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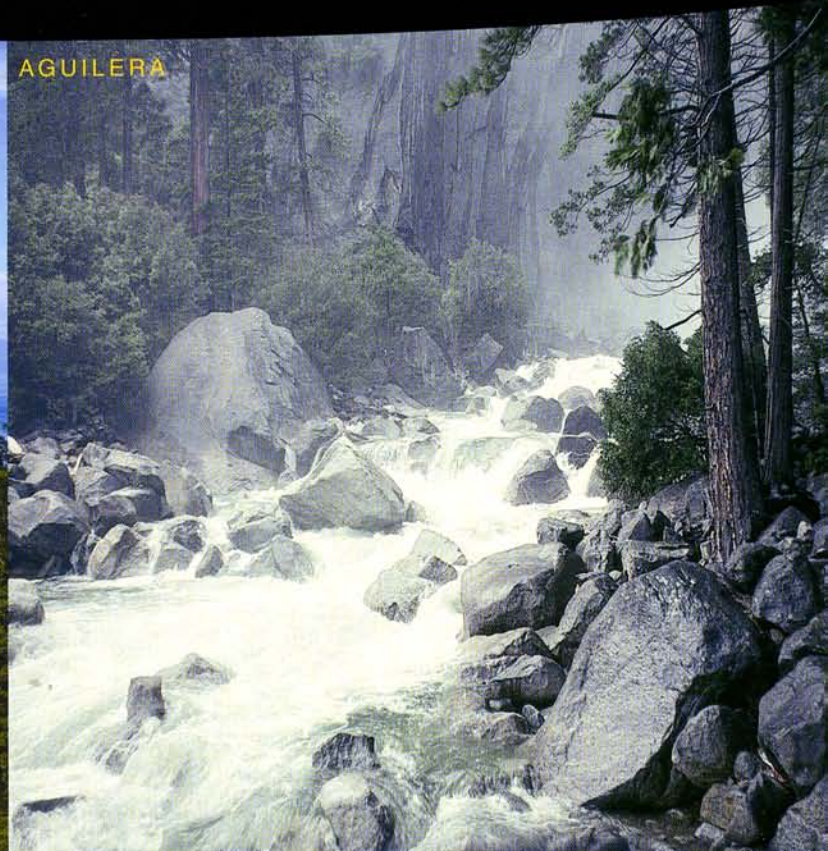


ROADNet researchers deliver uniquely packaged data to a host of users

IT'S OUT THERE, somewhere between acres of charred wild land and the isolation of the high seas. You can't see or hear it, but a new avenue of science has emerged—one that is both powerful and dynamic.

With new advances in technology and computer networking, scientists at the Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics at Scripps Institution of Oceanography are developing innovative ways to manipulate information for uses across a multitude of scientific disciplines. Benefiting from this new science are not only members of the scientific community but also resource managers, policy makers, and members of the general public. All of these users are obtaining information from a varied landscape of environmental settings: the remains of the San Diego Cedar Fire, a Los Angeles lifeguard station, the waters off New Zealand, and the placid streams of the Sierra Nevada Mountains.

New environmental monitoring instruments in remote locations are creating rivers of data on beach conditions, water levels, earthquakes, and status of fires that require advanced information processing and wireless transmission to Scripps Institution of Oceanography and other research centers.

An emerging player in this new science is the Real-time Observatories, Applications, and Data management Network, or ROADNet. Walking the boundary between computer science, wireless networking, and Earth sci-

ences, ROADNet scientists are creating new ways to manipulate and package scientific data.

"There are a lot of new and exciting developments being made on ways of acquiring, accessing, and distributing scientific data sets in real time that have never been done before," said Frank Vernon, a lead investigator of the project and its major driving force.

MEETING THE CHALLENGE OF GRAND EARTH OBSERVATIONS

Today's scientists are devising bold new strategies for monitoring and understanding important earth processes. For example:

- Scientists with the Southern California Coastal Ocean Observing System (SCCOOS) are using science and technology in a unique way to characterize coastal areas. With a host of instrumentation and sensors, SCCOOS will generate volumes of valuable data about the southern California coastal environment. (*See "A Current Affair" on p. 22.*)
- The EarthScope initiative is using an array of 400 transportable, autonomous seismic stations to investigate the structure of the North American continent and processes responsible for earthquakes and volcanoes. Deployed on a uniform grid that will systematically cover the United States, this array also will generate volumes of raw scientific information.
- In the near future, the Ocean Research Interactive Observatory Networks (ORION) will dot the world's oceans with futuristic-looking spar buoys and cabled systems closer to shore that will continu-

Above, *A GPS ground station for earthquake research near downtown Los Angeles provides one of the varied sources of information used in ROADNet.* **Below,** *Scripps Geophysicist Frank Vernon and a seismic instrument array at Garner Valley, California.*

ally produce data about ocean and seafloor conditions. Here, yet again, a wealth of information waits on the horizon.

Such projects illustrate new capabilities for science in which sensitive instruments that monitor Earth processes supply scientists with data streams from varied settings. But how do they get a handle on these streams that fast become rushing rivers of information?

Enter ROADNet.

Vernon, an earthquake specialist by training, had worked for years using wireless technology to collect data about ground movement from seismological

ROADNet technician Steve Foley carries a meteorlogical station assembled on an aluminum pole out to the end of Scripps Pier where he and technician Todd Hansen mount it on the roof of the pier shack.

instruments set up in remote areas such as southern California's Anza Borrego Desert.

Along with John Orcutt, Scripps Institution deputy director for research, and Hans-Werner Braun, Arcot Rajasekar, and Bertram Ludäscher of the UCSD San Diego Supercomputer Center, Vernon recognized an opportunity to develop a project in which

Opposite page, *Frank Vernon and T-Rex, a ground-shaking truck, at the Network for Earthquake Engineering Simulation field station in Garner Valley.* **Left,** *Dust rises up as T-Rex shakes the ground with 65,000 pounds of force to simulate an earthquake.* **Below,** *T-Rex and an instrument van are operated by the University of Texas at Austin.*

enormous amounts of data could be effectively managed.

ROADNet, while a scientific program, isn't a single project addressing a specific need, like SCCOOS or ORION. While it depends on sensors, wired and wireless networking, as well as computers, the project isn't a specific set of equipment, such as EarthScope's seismometer array.

Rather, ROADNet processes information from sensors and wireless networks in a completely innovative way.

In one regard, ROADNet is a hidden level of software and processing power situated between the field sensors and the researchers studying the data at their laboratory computers. In technospeak it is known as "middleware." As Orcutt puts it, ROADNet doesn't intrude on the data-gathering functions, but rather sits on top of it.

"So it has the advantage of being very useful but not obtrusive," he said.

Part of ROADNet's effectiveness stems from technological advances such as UCSD's High Performance Wireless Research and Education Network (HPWREN) that allow information to be transmitted wirelessly from remote sites. Also key are data loggers, which process the data, whether it be an earthquake signal or a weather gauge reading, and code it with a time stamp, thus giving scientists the ability to study trends evolving over time.

From the start, ROADNet's developers proposed not only to record data, but also to process, translate, and put it into a common format—or "interface"—so that different sets of sensors could be cross-referenced. The system, they proposed, could do all of this virtually as it was unfolding in "real time."

Immediately after launching ROADNet four years ago, the project's developers knew that they had something useful and powerful on their hands.

ROADNet was an instant hit.

THE END GAME

An example of ROADNet's usefulness is demonstrated by analysis of environmental data collected during the devastating fires that raged across San Diego County in fall 2003.

With ROADNet's processing capabilities and data from environmental sensors accessed via HPWREN, Vernon was able to plot the conditions that led to the destruction, including plummeting humidity, which led to the dry conditions for the fires to start, and a rise in wind speed, which allowed them to dangerously proliferate.

Vernon's firsthand experience throughout the event—his

HIGH-SEAS COMMUNICATION CHANGES THE COURSE OF OCEANOGRAPHY

WHEN JOHN ORCUTT'S SEAGOING DAYS began in the 1970s, high-frequency radio was the common form of communication from oceanographic vessels.

Patching conversations through a radio operator was less than ideal, but at the time it was the standard technology available.

Today, thanks largely to a new program called HiSeasNet that uses ROADNet (the Real-time Observatories, Applications, and Data management Network) "middleware," scientists at sea are armed with uniquely powerful communication capabilities. Internet access, video conferencing, and other advances through HiSeasNet are changing the way oceanography is conducted at sea.

For years Orcutt, deputy director of research at Scripps, and Jon Berger, a Scripps research geophysicist and lead scientist of HiSeasNet, had searched for a way to bring satellite communication capabilities to oceanographic research vessels. They looked to commercial businesses to provide satellite communication for the academic research fleet, but found an empty market. Out of that gap HiSeasNet was launched.

First installed on the Scripps research vessel *Roger Revelle*, HiSeasNet communication capabilities became a valued component of the seagoing operation.

With Internet access, ship crews gained the ability to make phone calls and send e-mail messages to land to check on the status of supply shipments. The science party could instantly transmit detailed images taken during research expeditions to their land-based colleagues.

Above left, *A dome on the Scripps R/V Roger Revelle houses an antennae that provides a powerful communication link.* **Above,** *The hub antenna for HiSeasNet is located on the roof of the San Diego Supercomputer Center at UCSD, providing direct Internet connection for ships at sea.*

According to Berger, the technology leads to enormous economic benefits, not only in immediate lower communication costs, but also in savings by keeping some of the research team on shore. Land-based scientists, engineers, and others can now provide their expertise at sea "virtually" via the Internet and videoconferencing.

"It's expensive to send people to sea, and a lot of people aren't free to leave for two months," Berger said. "Now they have the option of streaming data back to the home institution. The scientists on land can look at it and respond to the ship instantly."

The HiSeasNet capability recently benefited educational initiatives when two National Oceanic and Atmospheric Administration teachers at sea corresponded with their students on land. Scripps geophysicist Neal Driscoll recently used the system to videoconference with classrooms in San Diego from a research expedition near Papua, New Guinea.

The National Science Foundation finds HiSeasNet so productive that it recently granted Scripps more than $1 million to install similar systems on research vessels from Scripps and other institutions. In the near future, nine research vessels will be similarly equipped to communicate from research sites throughout the world's oceans.

"The difference between a few decades ago and now is just huge," Orcutt said. "Being on the Internet, video conferencing, and having the capability to do things like bring real-time photographs off the seafloor from remotely operated vehicles is an unprecedented capability. "I believe it is changing the way we do oceanography."

home in San Diego's Scripps Ranch burned in the fires—gave him new insight into the value of sensors situated in the midst of an environmental disaster.

"During the early stages of the fire a neighbor of mine was told through 911 that there was no danger to Scripps Ranch," Vernon said. "At the same time, he and I could look out the window and see a wall of flames approaching."

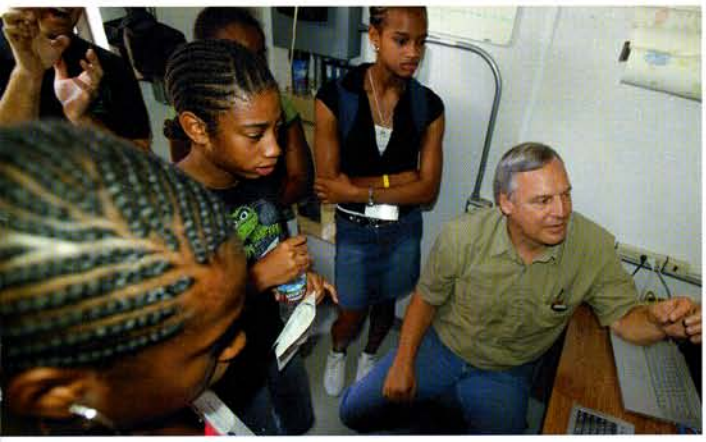
Scientists with ROADNet and HPWREN are now working to increase the scope and timeliness of monitoring sensors such as video cameras that will give fire and emergency response coordinators a clearer picture of environmental and fire conditions as they unfold.

"In addition to the video capability, HPWREN can provide the Internet connectivity capability that enables responders to manage an emergency command post," said Braun, the HPWREN principal investigator and San Diego Supercomputer Center research scientist.

Another key feature of ROADNet is its ability to work with a varied mix of sensors and settings. It is currently being used to speed information from ships far out at sea.

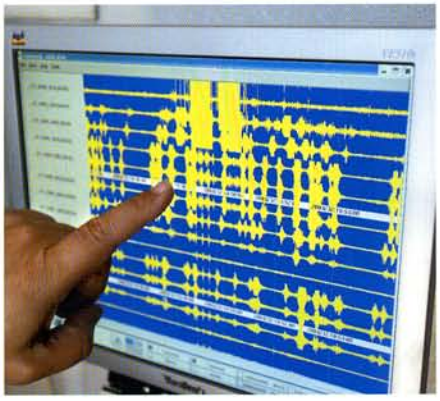
Scientists with the California Spatial Reference Center at Scripps use ROADNet for streamlining data from GPS sensors that monitor precise ground movements for land surveying and other uses. ROADNet technology also aids the Network for Earthquake Engineering Simulation project, which uses giant earth-shaking machines to study the response of buildings to ground motion.

Climate researchers are using ROADNet with devices that measure snowpack levels and provide resource planners with information for vital water-supply management.



A new ROADNet proposal would allow ecologists studying lakes in Wisconsin to cross-reference data with their colleagues studying lakes in Taiwan.

ROADNet is even coming into play on sunny southern California beaches, where Los Angeles County lifeguards are using the system to monitor meteorological conditions and make them available to the public.



"That's just one part of the project, but it's the kind of thing that makes life a lot easier," Orcutt said. "When people need to make decisions about what the beach is going to be like—the water and the weather—they can have this information before they spend their time going over there."

ROADNet's developers plan to keep expanding the program, adapting it across an ever-increasing swath of sensors, settings, and scientific disciplines. According to Vernon and ROADNet systems coordinator and Scripps graduate student Todd Hansen, this will become the project's legacy of success.

Left, *Frank Vernon shows a group of Los Angeles-area high school students the seismic recordings of T-Rex ground shakings at Garner Valley.* **Above,** *One of the students examines an earthquake instrument.*

Even if you looked closely, you'd scarcely see any visible sign of the project. But it is there, an important component of research programs far away and close to home. ROADNet is helping drive new scientific discoveries and build new ways of understanding our planet.

ROADNet's sponsors include the National Science Foundation, the Office of Naval Research, the California Institute for Telecommunications and Information Technology (Cal-[IT]^2), Scripps Institution of Oceanography, San Diego State University, the G. Unger Vetlesen Foundation, and the Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics.