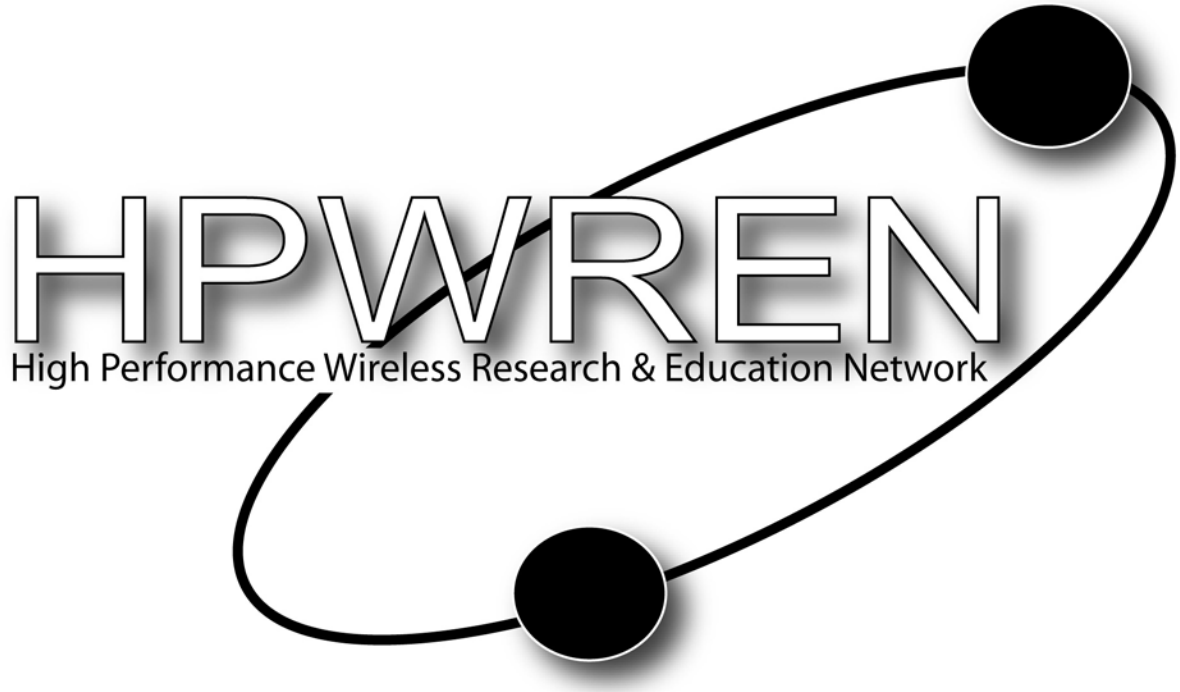


An interdisciplinary collaboration for research and infrastructure

University of California, San Diego:

San Diego Supercomputer Center
Scripps Institution of Oceanography

funded by the National Science Foundation

awards numbers 0087344 and 0426879

high performance wireless research and education network

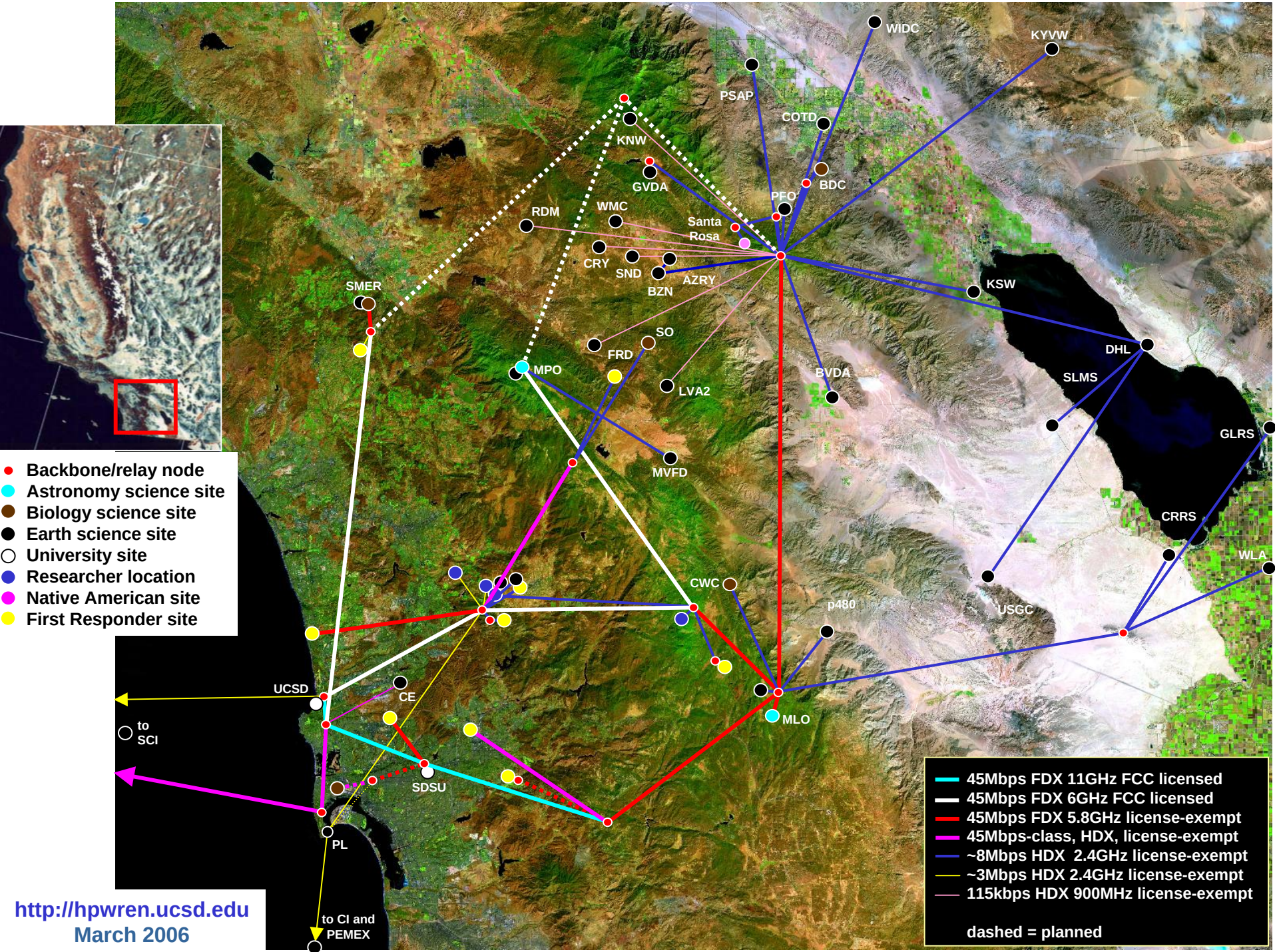
http://hpwren.ucsd.edu

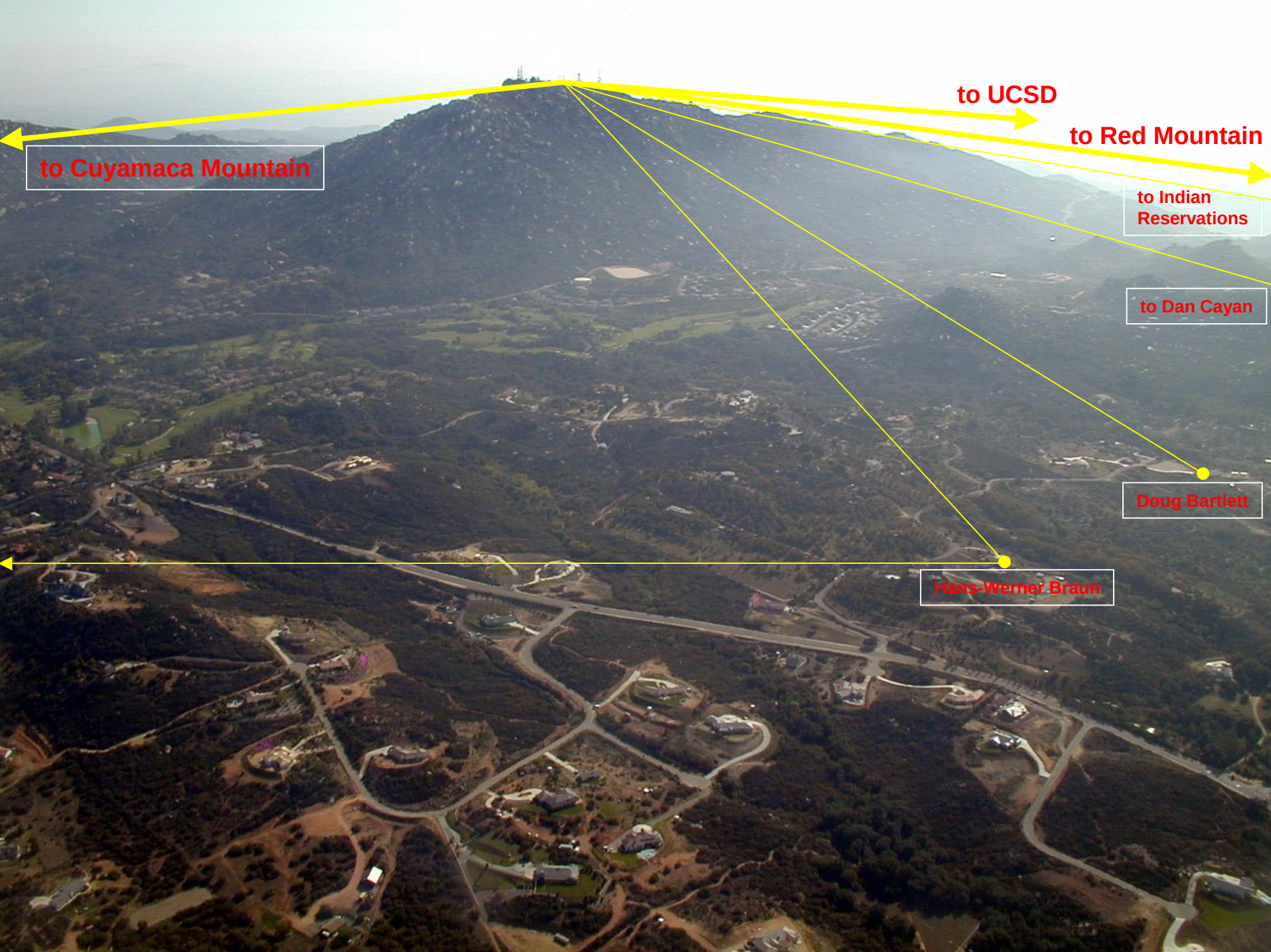
HPWREN project objectives

- wide area wireless high performance networking
- focus on access networks for research and education applications
- fixed or temporary/ad-hoc installations
- emphasis on interdisciplinary collaboration
- non-commercial prototype platform to demonstrate feasibility
- connection of sensor networks
- research to understand application performance requirements
- QoS and PBR research

Project participants and collaborator examples

- Led by UCSD's San Diego Supercomputer Center and Scripps Institution of Oceanography
- Science applications
    - Scripps Institution of Oceanography:
        - Geophysics -- earthquake sensors
    - San Diego State University, Astronomy department
        - Mt. Laguna Observatory
    - San Diego State University, Field Station Programs
        - Santa Margarita Ecological Reserve and Sky Oaks Field Station
    - Lawrence Berkeley National Laboratory and California Institute of Technology
        - Palomar Observatory
    - UC Natural Reserve System
        - Boyd Deep Canyon
    - UC San Diego
        - School of Engineering Bridge sensors (Coronado Bridge and desert highway bridge)
        - Laboratory for Atmospheric Acoustics
    - UC Santa Barbara – Institute for Crustal Studies
- Education applications
    - Originally: Pala, La Jolla, and Rincon Indian Reservations
    - Tribal Digital Village Network
    - California Wolf Center
- First responders and other agencies
    - San Diego Sheriff's department
    - California Department of Forestry and Fire Protection
    - SSC


WIDC
KYVW
PSAP
COTD
KNW
GVDA
BDC
PFO
RDM
WMC
Santa Rosa
CRY
SND
BZN
AZRY
SMER
KSW
SO
FRD
DHL
MPO
BVDA
SLMS
LVA2
GLRS
MVFD
CRRS
WLA
CWC
p480
USGC
UCSD
CE
to SCI
MLO
SDSU
PL
to CI and PEMEX
Backbone/relay node
Astronomy science site
Biology science site
Earth science site
University site
Researcher location
Native American site
First Responder site
45Mbps FDX 11GHz FCC licensed
45Mbps FDX 6GHz FCC licensed
45Mbps FDX 5.8GHz license-exempt
45Mbps-class, HDX, license-exempt
~8Mbps HDX 2.4GHz license-exempt
~3Mbps HDX 2.4GHz license-exempt
115kbps HDX 900MHz license-exempt
dashed = planned
http://hpwren.ucsd.edu
March 2006


to UCSD
to Red Mountain
to Cuyamaca Mountain
to Indian Reservations
to Dan Cayan
Doug Bartlett
Hans-Werner Braun

Technology
and
data collection

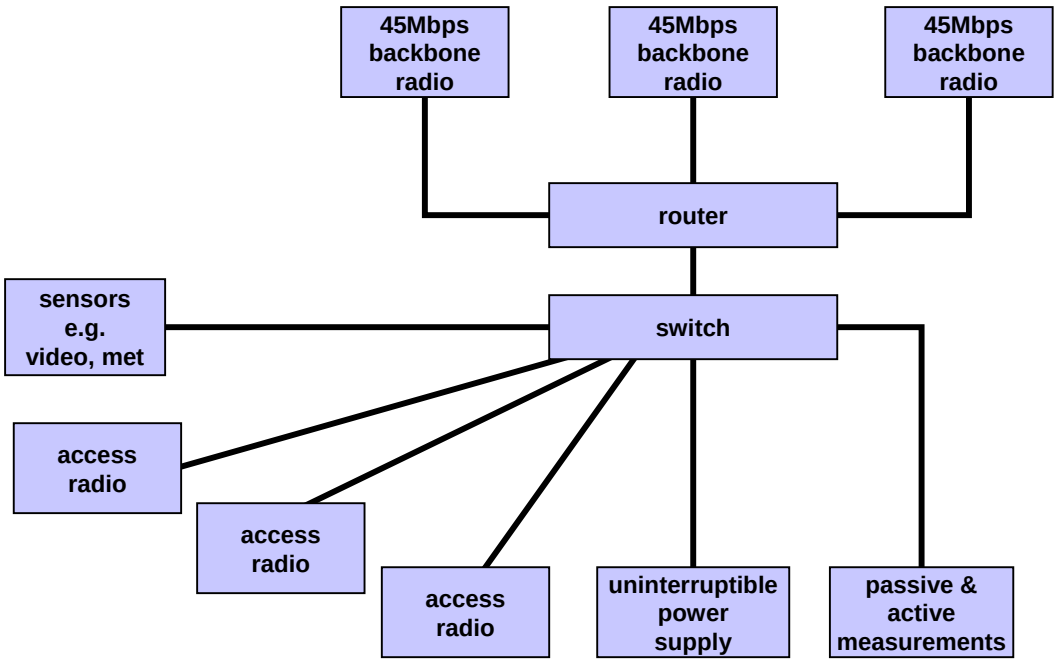
Network architecture

- high performance backbone network
  - commercially available 5.8GHz or 6GHz 45Mbps duplex point-to-point radios
    - WMux Tsunami, Interwave CX, Redline AN-50, or licensed Stratex DXR768
    - interconnected by IP routers
  - backbone nodes at “quality” locations, including UPS
  - fairly large antennas (10’, 8’, 6’, or 4’)
  - network performance monitors at backbone sites

- high speed access links
  - commercially available 2.4GHz spread spectrum radios
    - Lucent/etc. 802.11b and Wi-LAN VIP 110-24
  - some 5.8GHz 45Mbps access links
  - point-to-point or point-to-multipoint
  - commonly small (~2’ X ~3’) grid antennas for 2.4GHz
  - some sites include local performance monitors

- network statistics available at http://stat.hpwren.ucsd.edu/

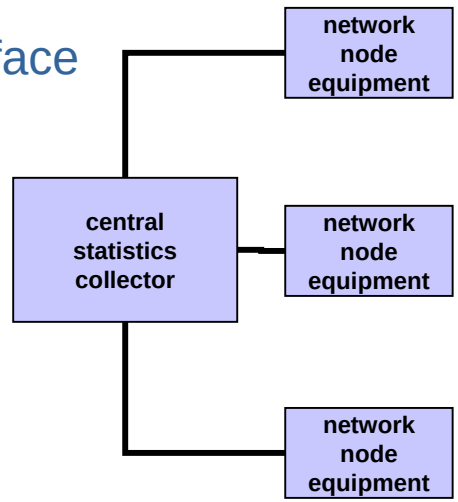
HPWREN backbone node architecture



HPWREN network measurements

Data sources for centralized server

- SNMP/MIB data (router, switch, radio, UPS, traps)
  - e.g., generates daily automated backbone performance data
- reachability tests
- regular inter-node matrix throughput tests
  - generates daily automated summary
- netflow data for HPWREN-external traffic
- DoS attack detection machine at HPWREN-external interface
- sensor data (e.g., weather, cameras)



NLANR PMA 24/7 traffic trace collection

Long-term HPSS
data server at the
San Diego Supercomputer Center

NLANR Passive Measurement and Analysis
traffic trace web server:
http://pma.nlanr.net/Special/hpwren.html

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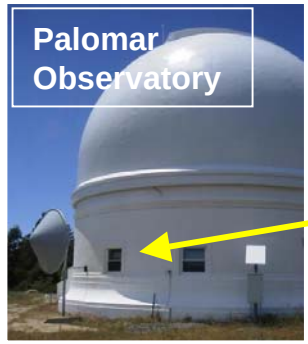
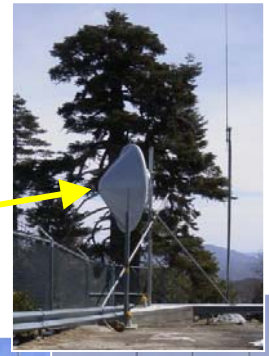
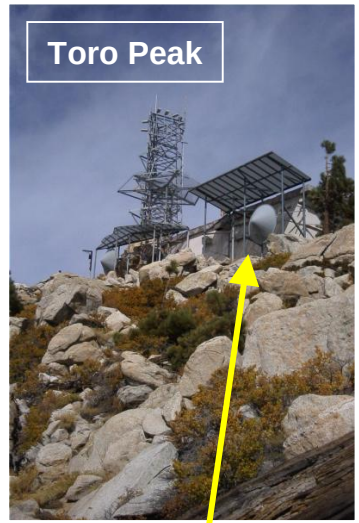
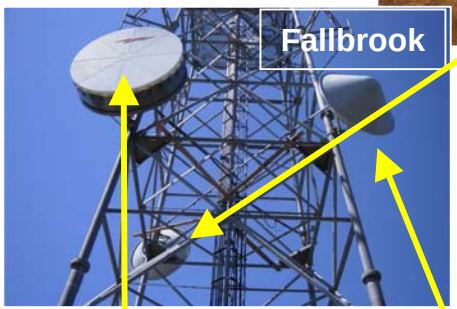
Persistent Connectivity for research, education, and first responders

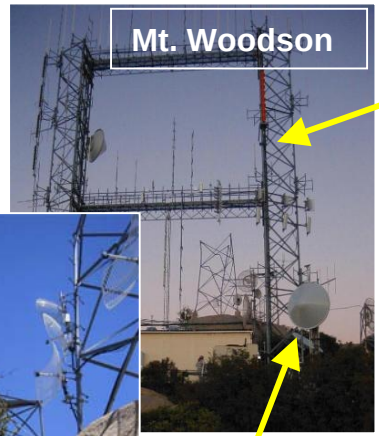
45Mbps HPWREN backbone

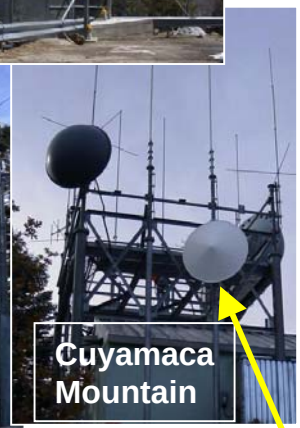










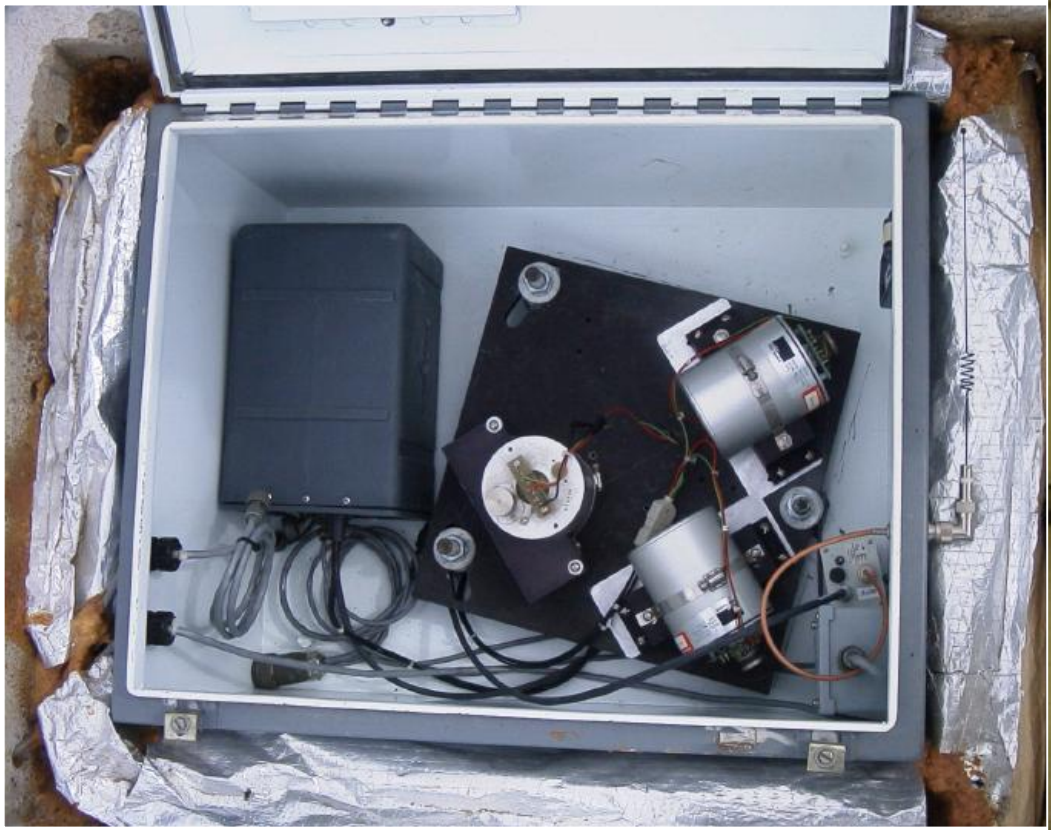


network

Example earthquake sensors in the desert

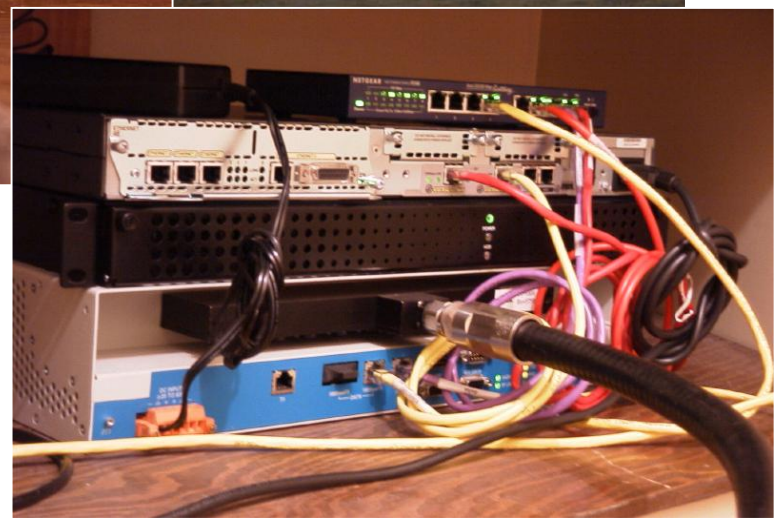
Earthquake sensor and data collector on Toro Peak

http://epicenter.ucsd.edu/ANZA/



SDSU's Mt. Laguna astronomy observatory
March 2001

Palomar Observatory, July 2001



http://www.astro.caltech.edu/palomarpublic/
http://snfactory.lbl.gov/
http://neat.jpl.nasa.gov/

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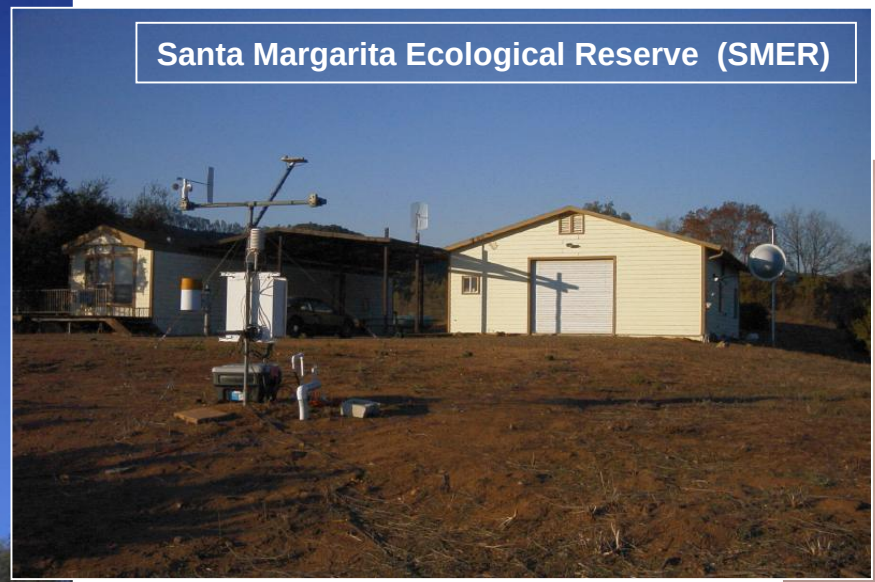
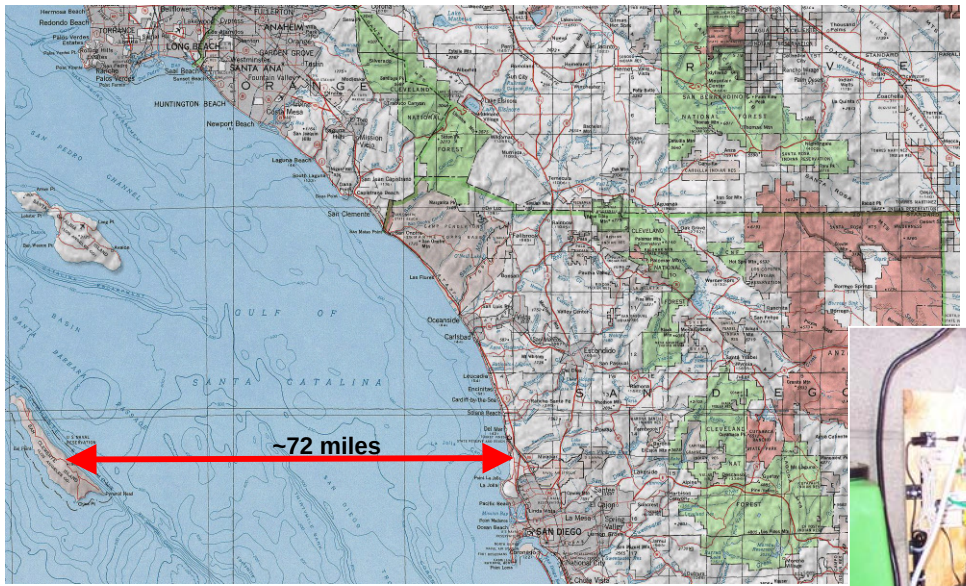
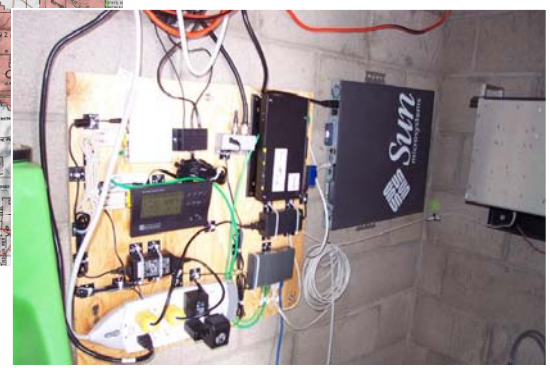
Link to the Santa Margarita Ecological Reserve, September 2001



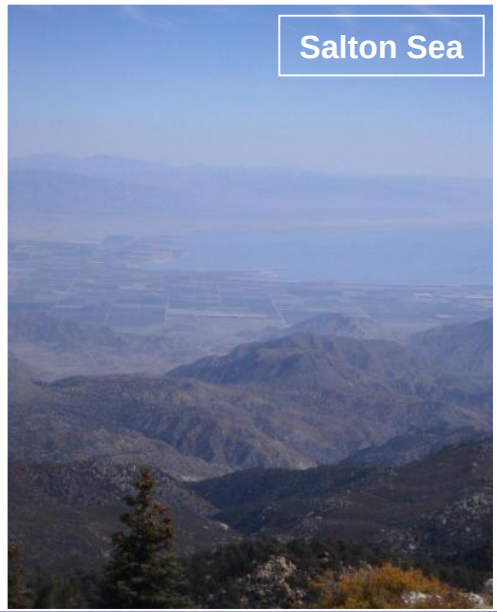
http://www.scec.sdsu.edu/SMER/SMER.html

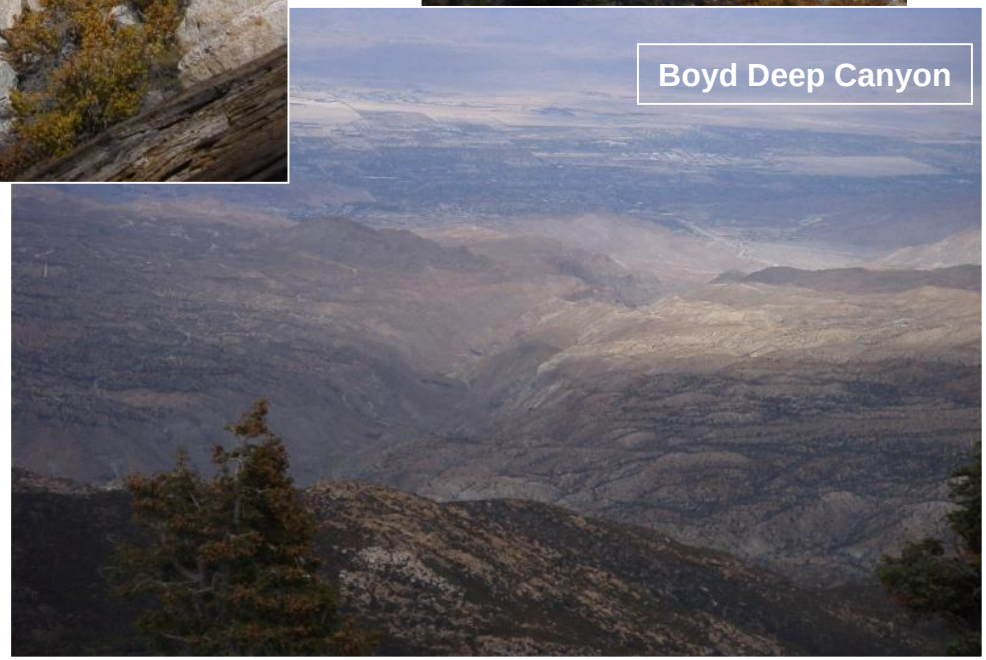
Link to San Clemente Island, October 2002





Toro Peak, 8700’
July 2002





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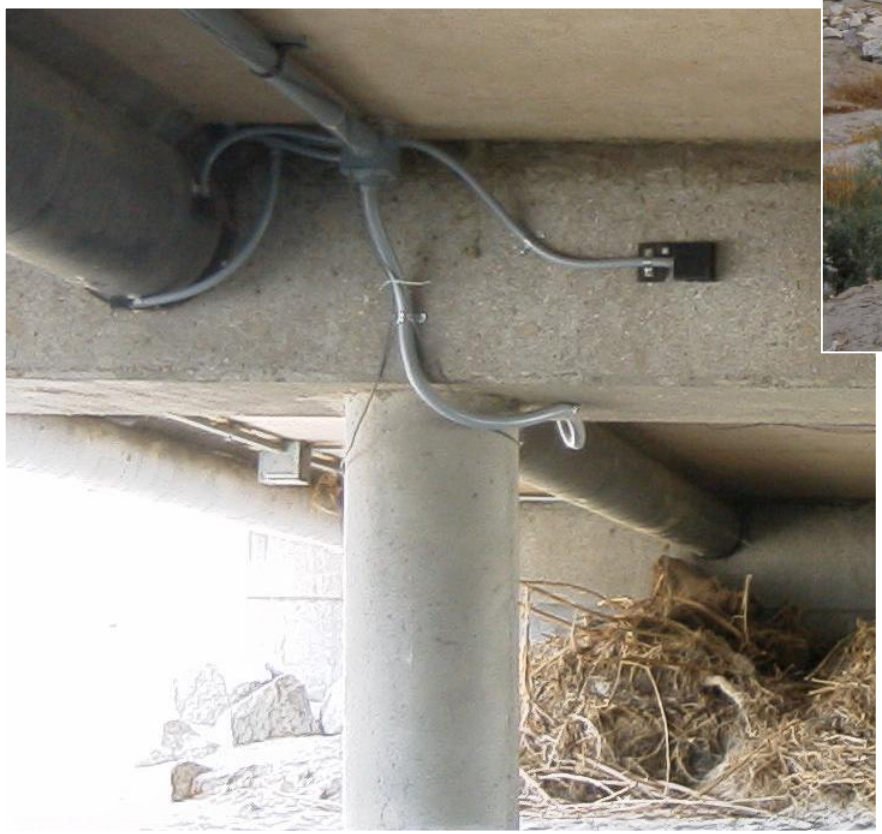
Boyd Deep Canyon, December 2002

CDF Fallbrook connection
August 2002

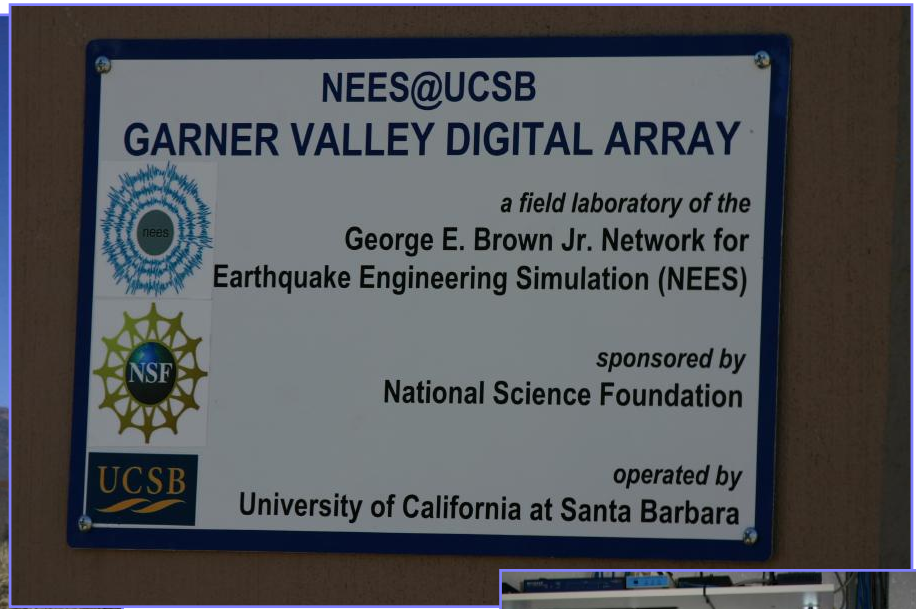
Collaborative agency connections

August 2005, Gillespie Helitack Base connection

Bridge connection near Salton Sea
Nov 2002



Garner Valley Downhole Array and NEES site



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CDF La Cima connection in the Cedar Fire post-burn area

June 2005, Native American collaboration at Mesa Grande

PLC

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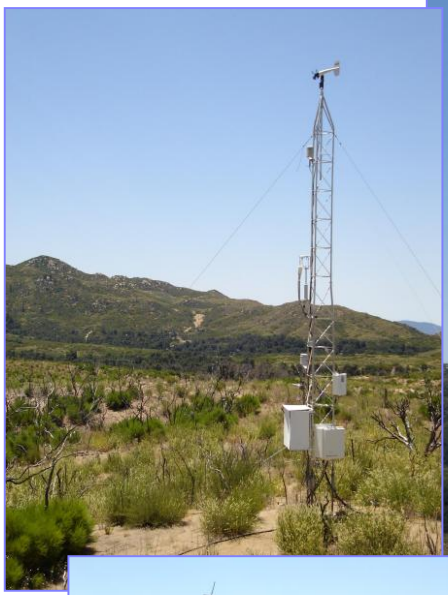
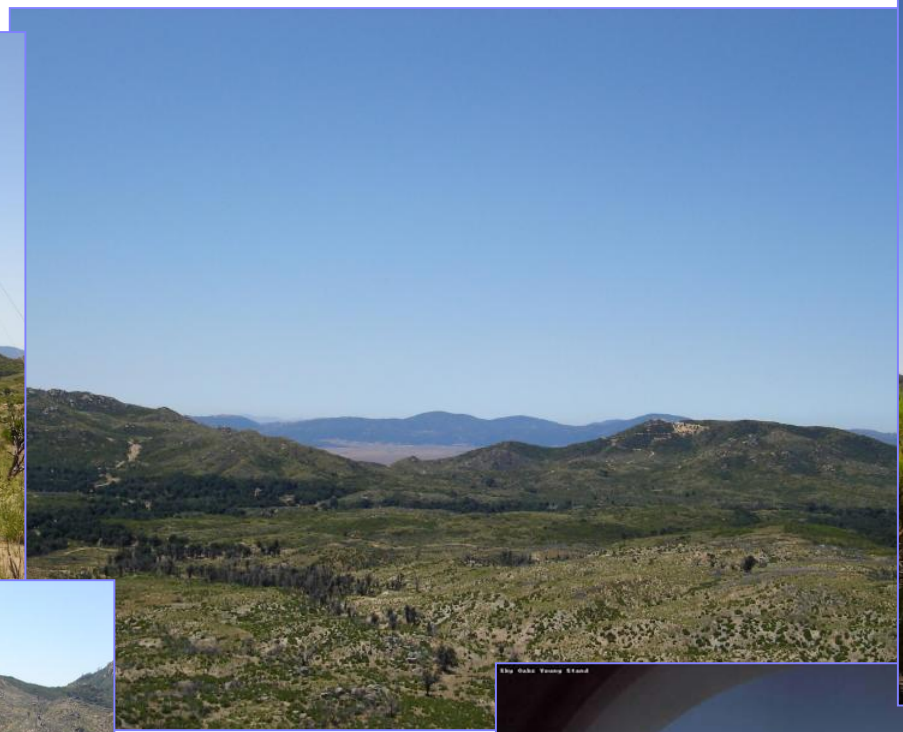
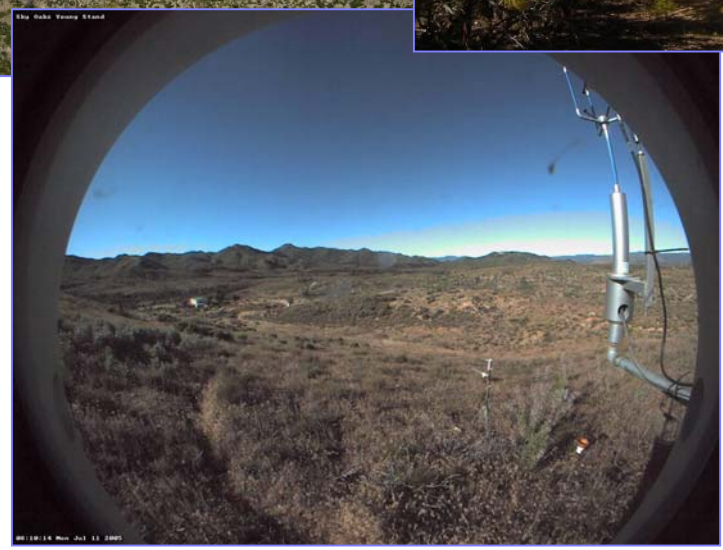
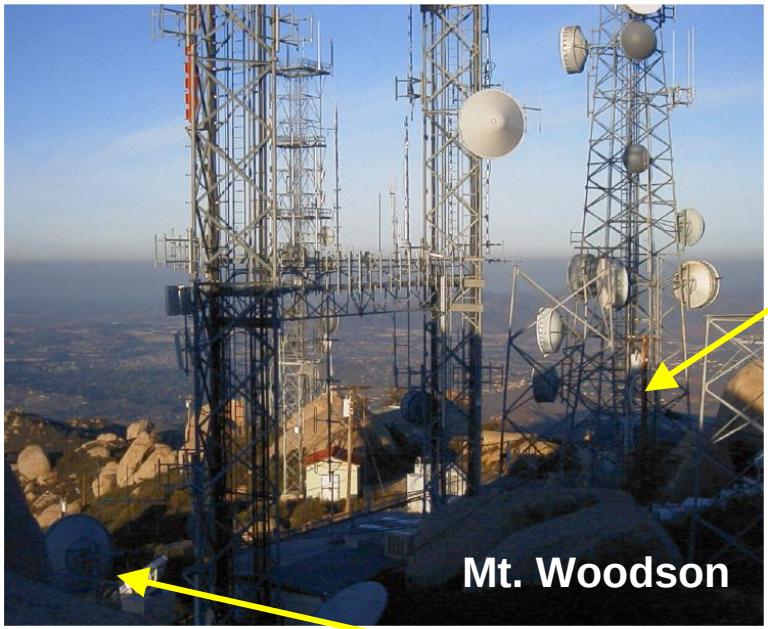
June 2005, SDSU Sky Oaks Field Station connection

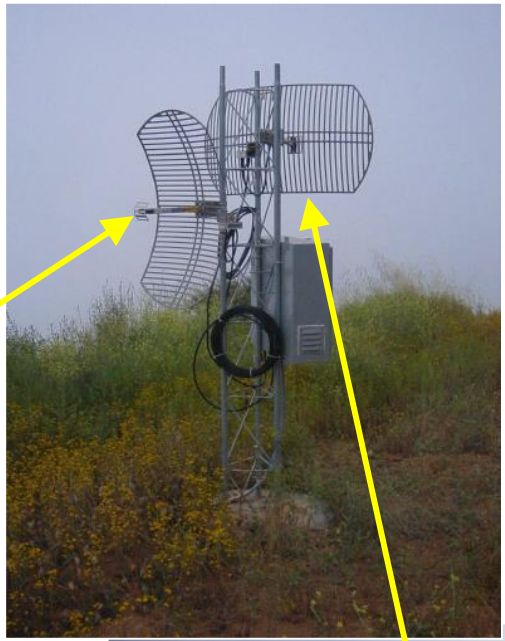


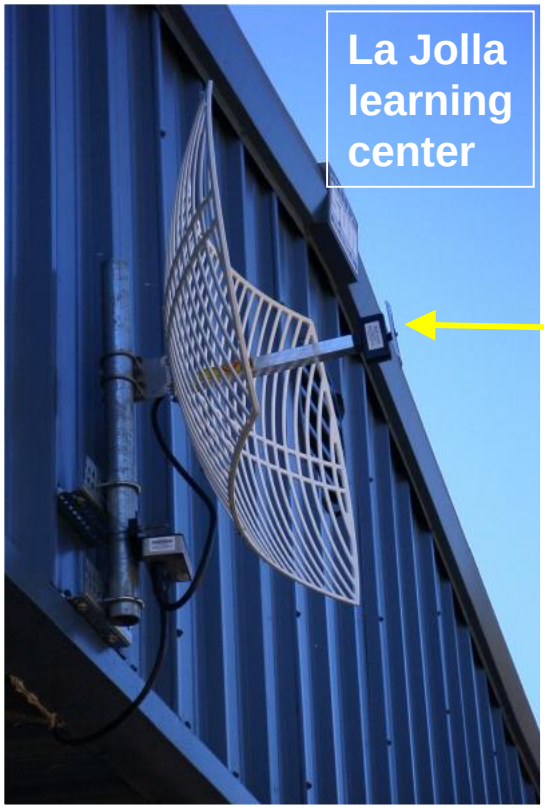


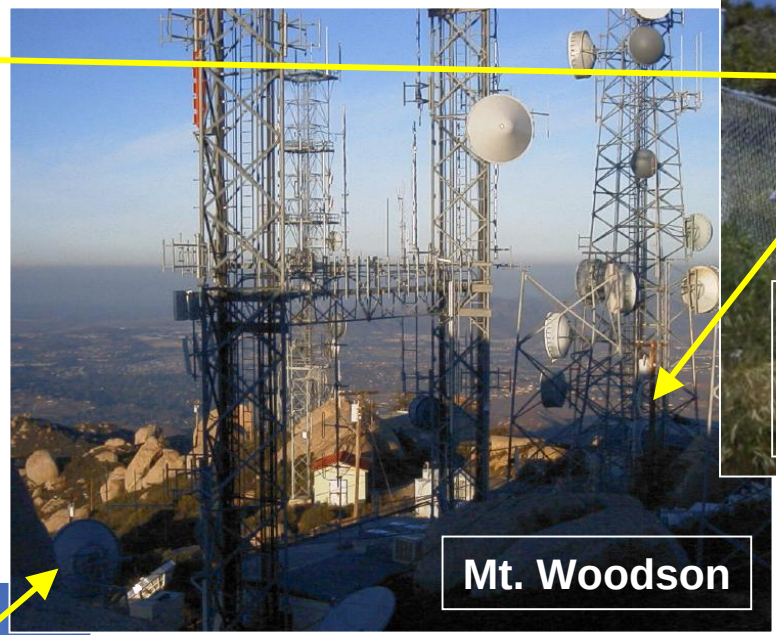


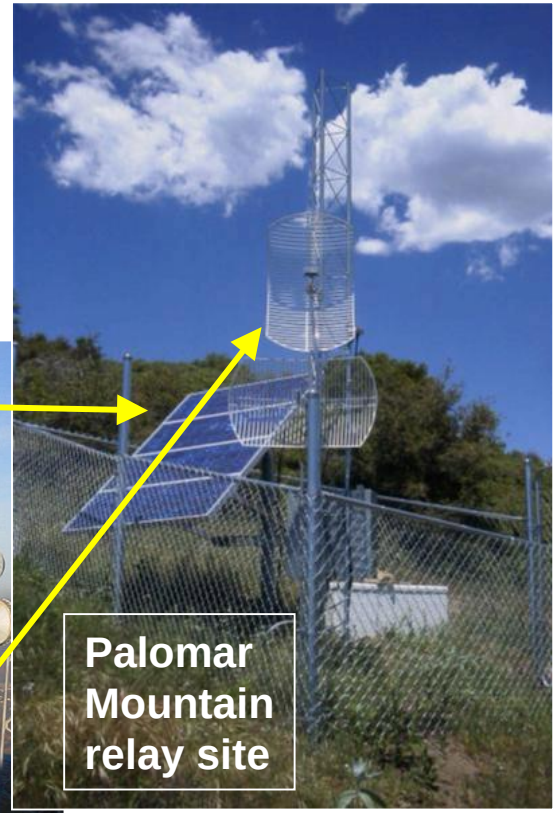
Initial Pala Indian Reservation connection
September 2000











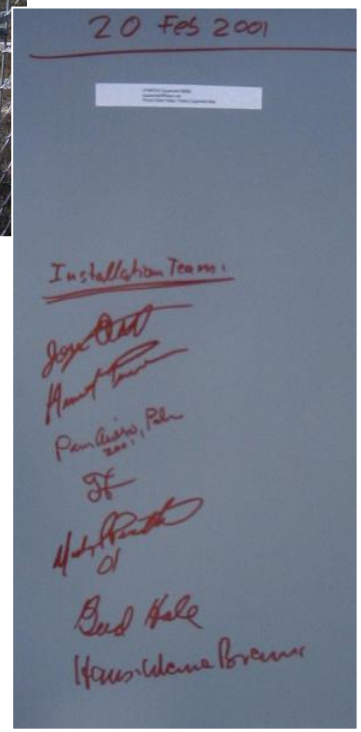
La Jolla Indian Reservation connection, January 2001

Native American connections


Pala, September 2000


Rincon, February 2001

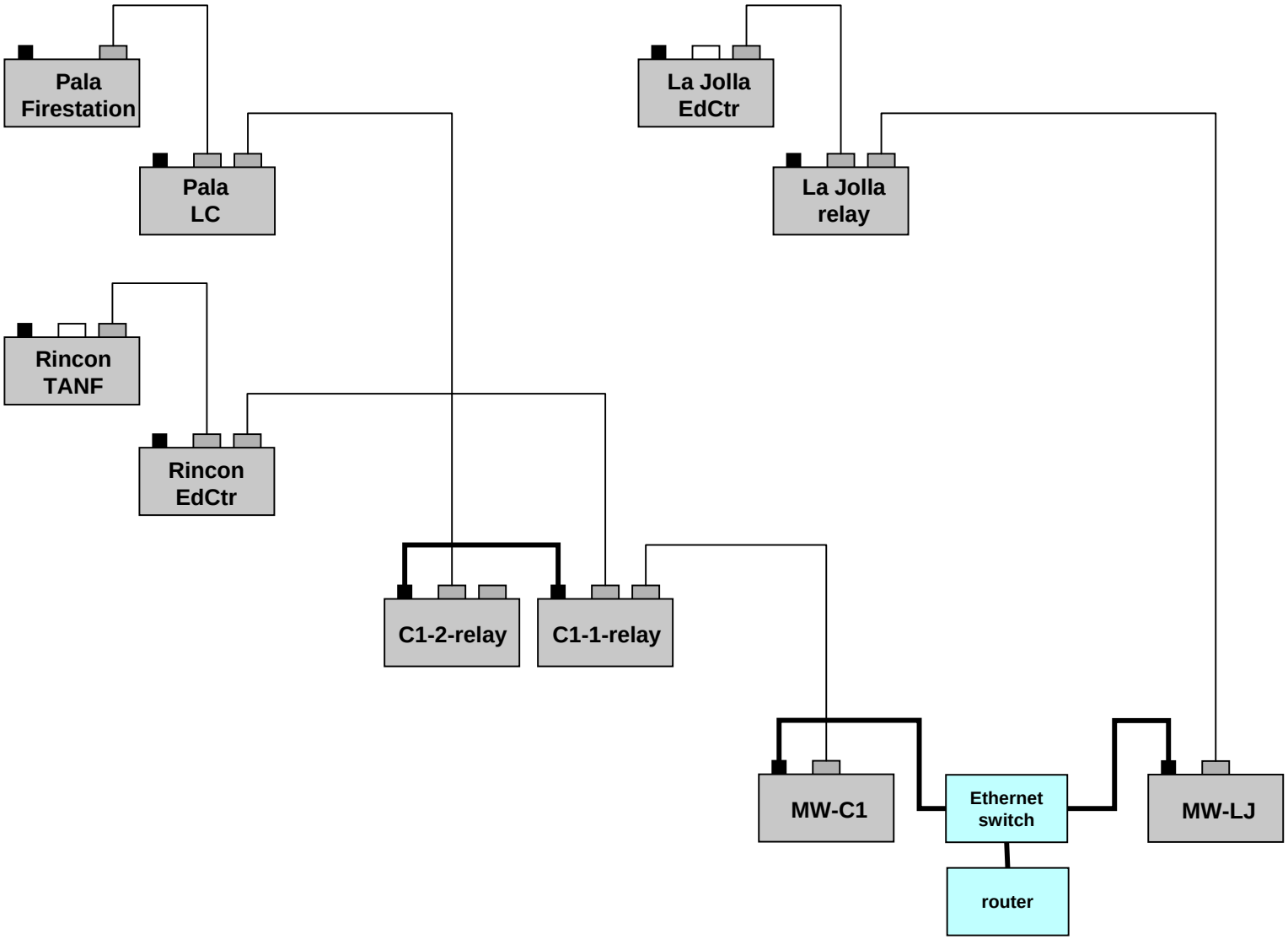

La Jolla, December 2000



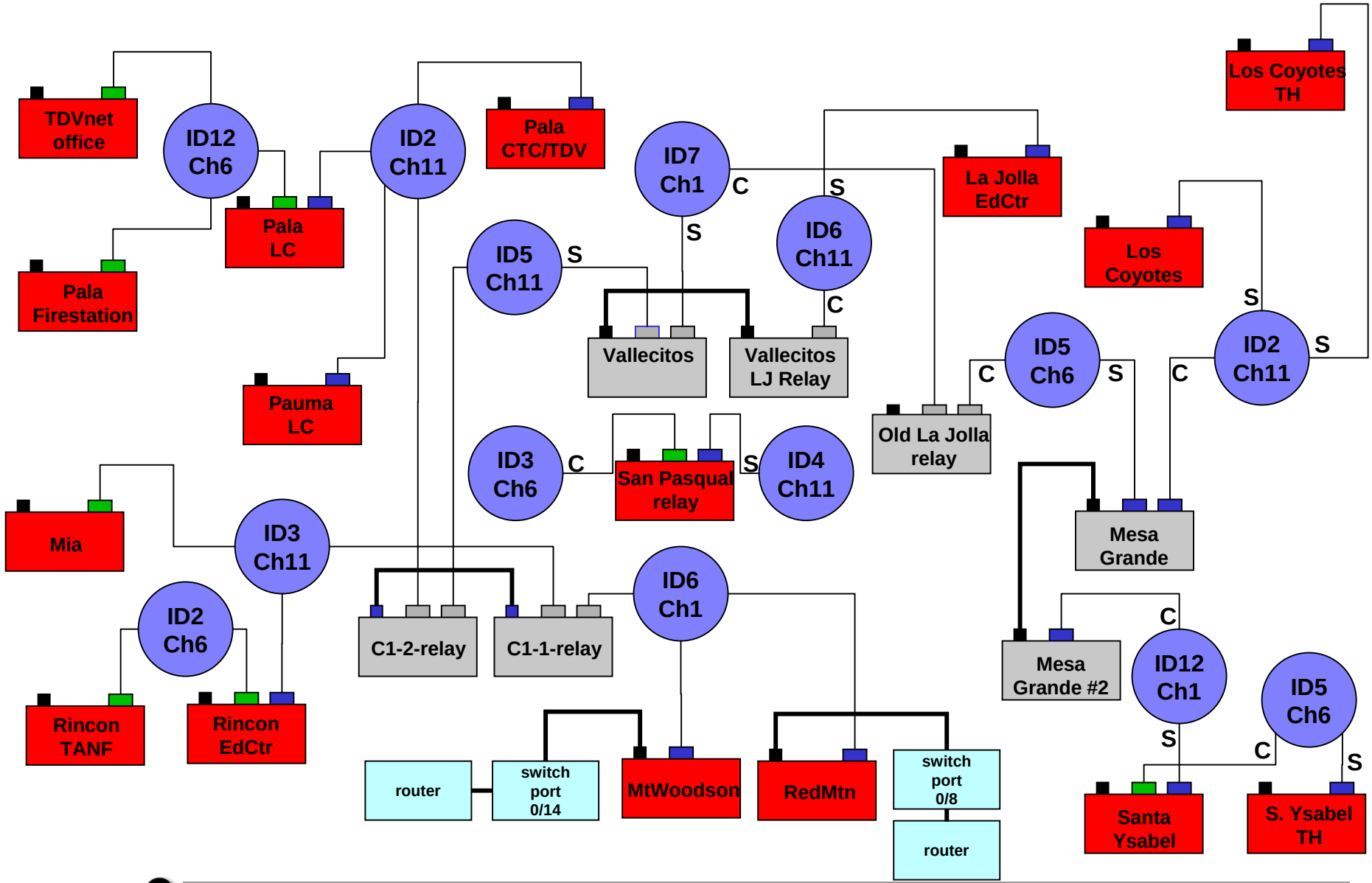
Tribal Digital Village network project

- Native American activity building up on HPWREN
- Funded by Hewlett Packard
- Awarded to the Southern California Tribal Chairmen's Association
- HPWREN is collaborator, and not the service provider
- Objective of a utility architected and operated by Native Americans

Mt Woodson to Pala, Rincon and La Jolla Indian Reservations



TDVnet Cluster1/Cluster2 – eight reservations



July 2005, post-fire at Adams Road, Pala Indian Reservation

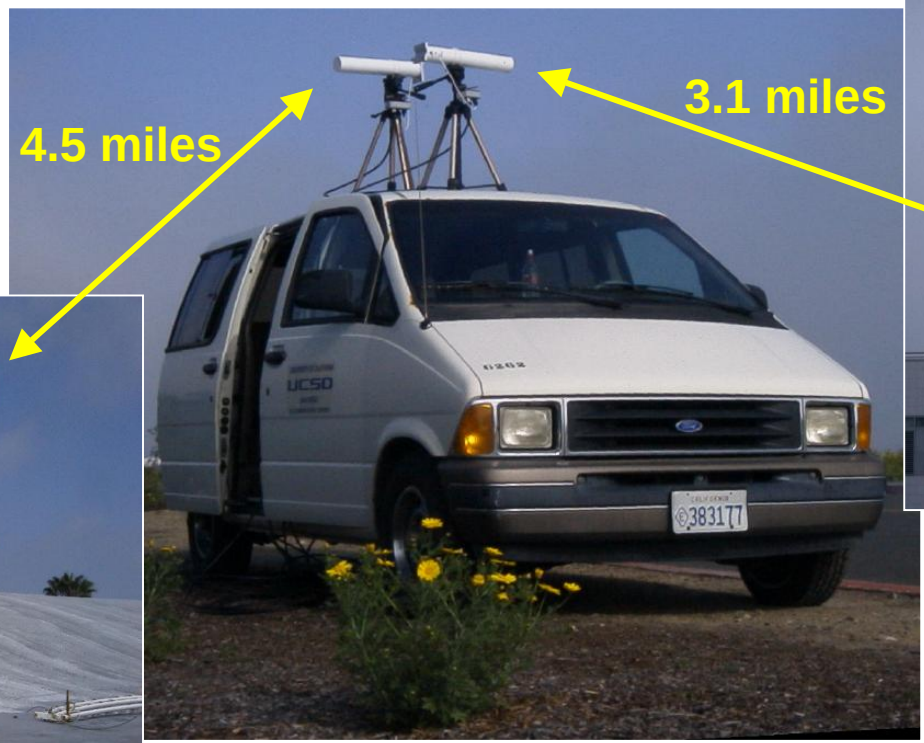
La Jolla relay site on Palomar Mountain January 2001

Cuyamaca Mountain 2.4GHz antenna

Ad-hoc Connectivity

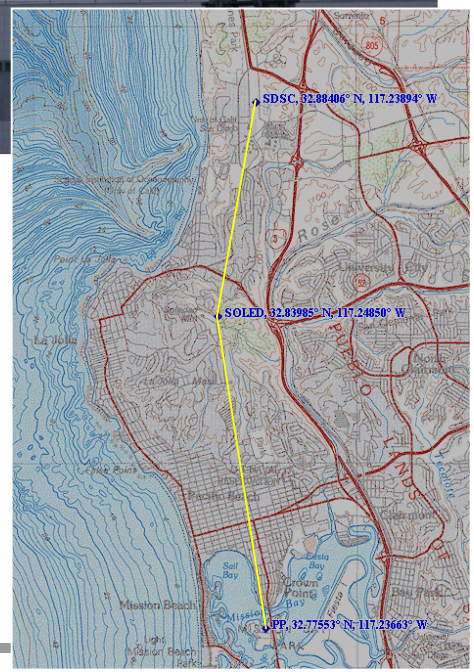
CENIC networking conference
May 2001

SDSC at UCSD



Mt. Soledad relay site

Paradise Point conference site



http://www.cenic.org/

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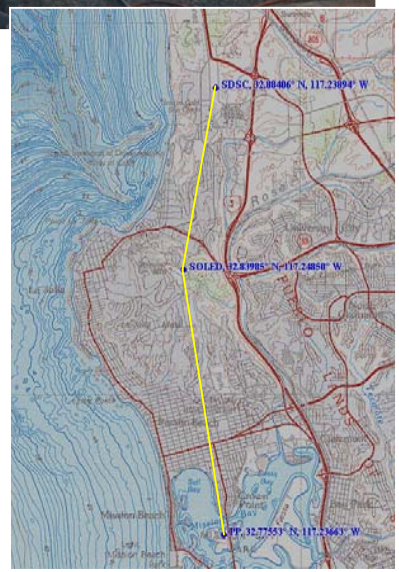
CENIC networking conference
May 2002

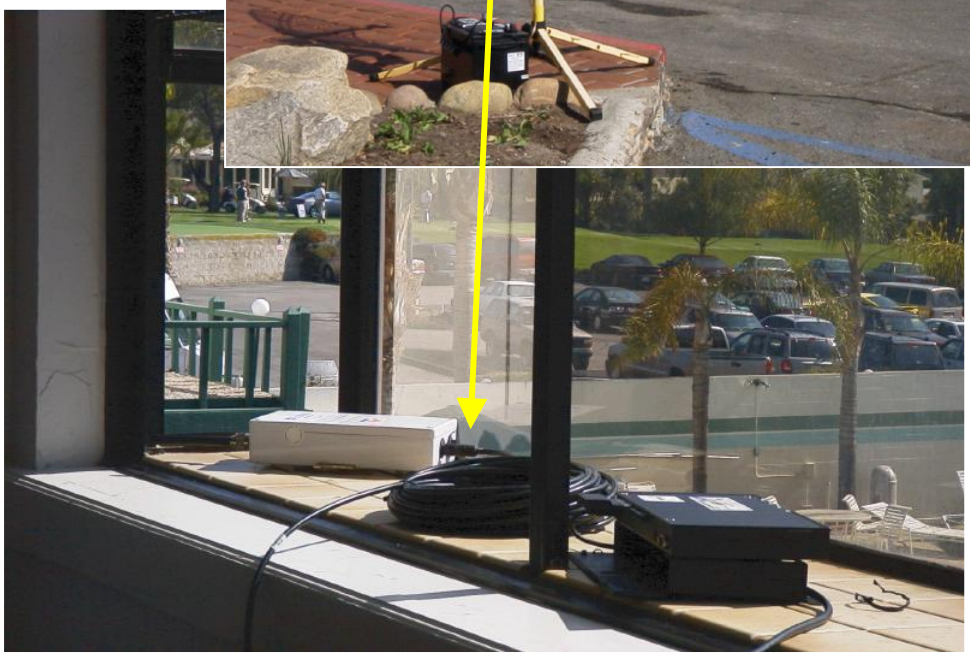
Mt. Soledad relay site

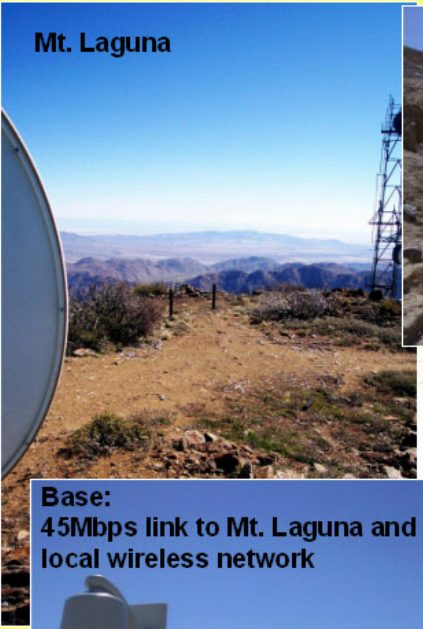
Paradise Point conference site
temporary 45Mbps connection

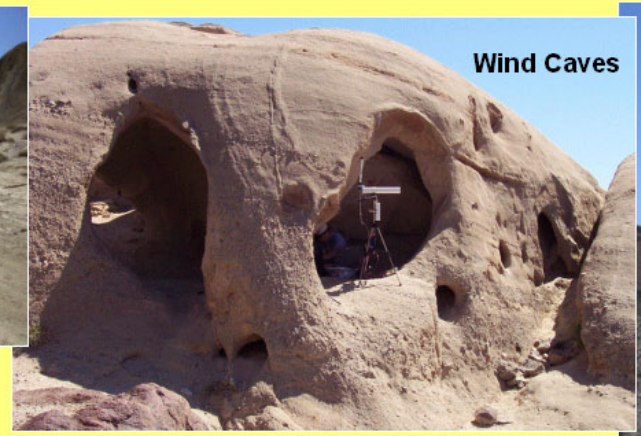


http://www.cenic.org/

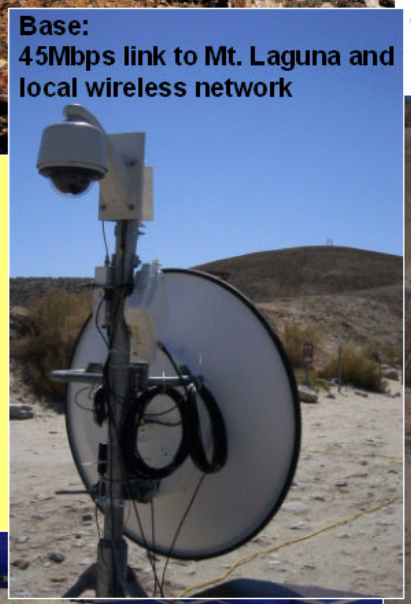
HPWREN - Fire Chiefs Association meeting Nov 2002

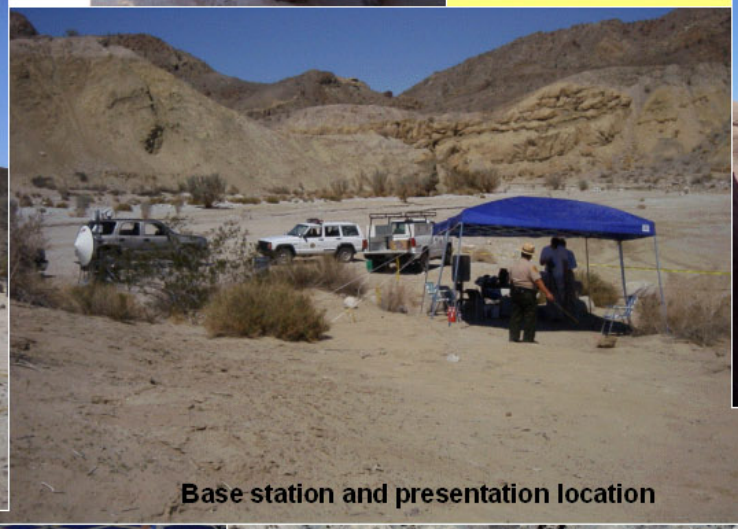


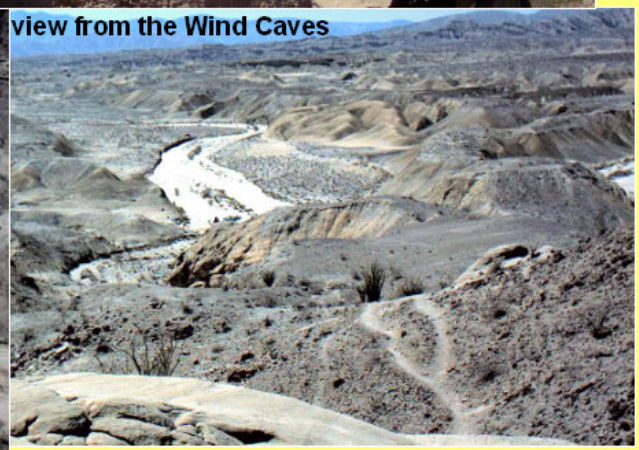




Anza Borrego Desert State Park connection
March/April 2003







HPWREN ICP connections concept, using one or more radio relays

Mountain-top HPWREN Backbone site

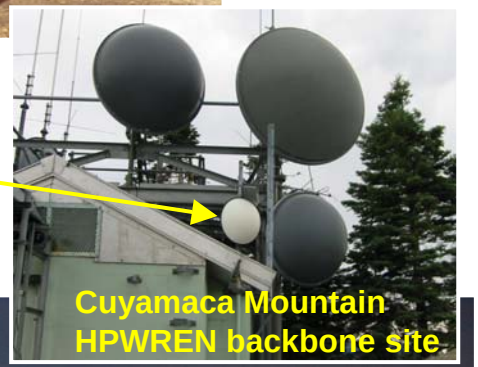
Line-of-sight radio relay site

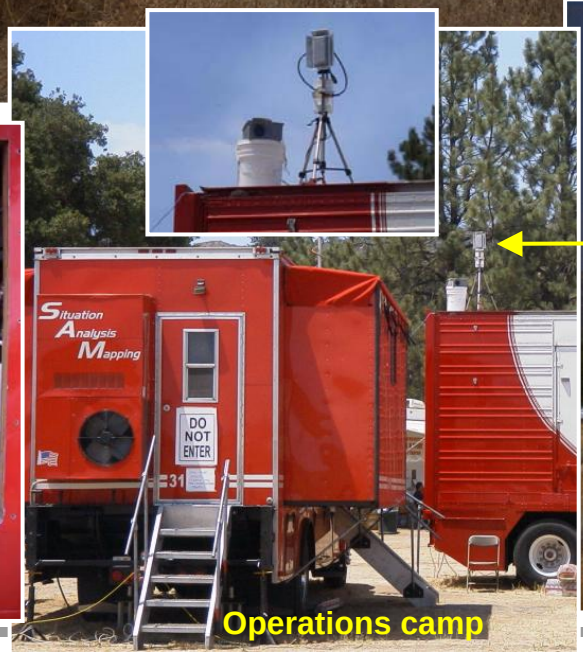
Incident Command Post site

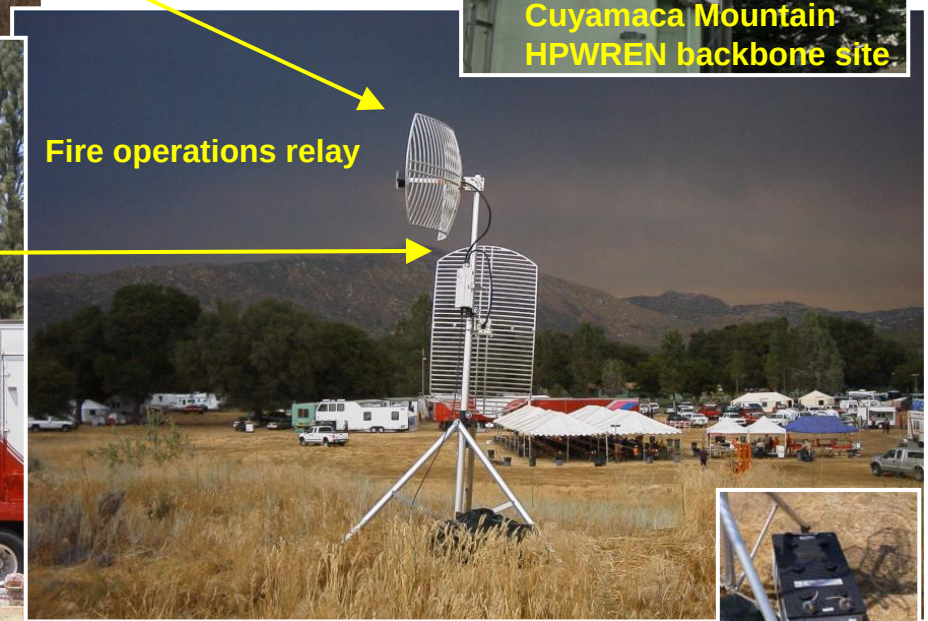
Line-of-sight radio relay site

Coyote Fire HPWREN connection

July 2003







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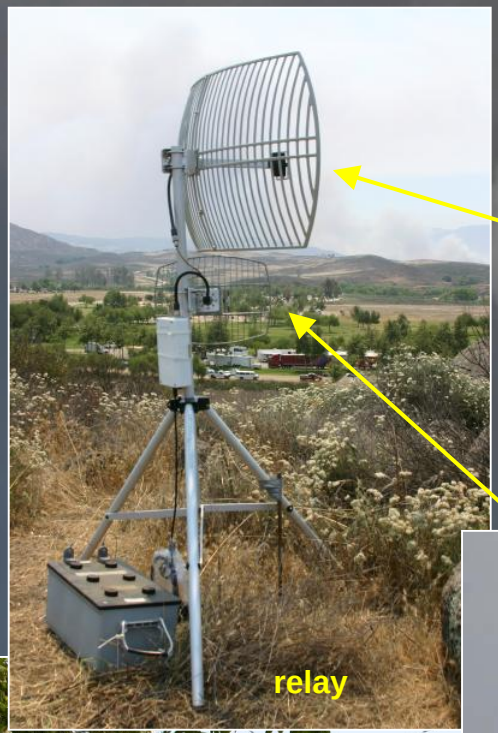
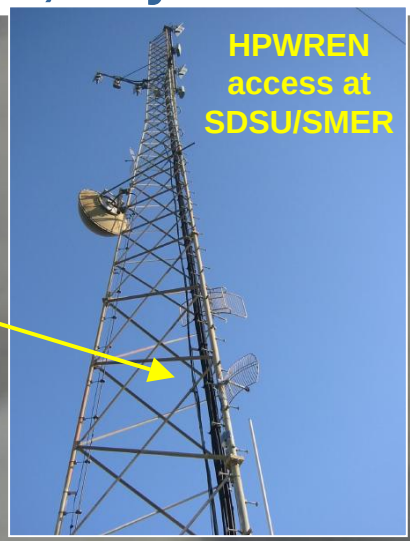
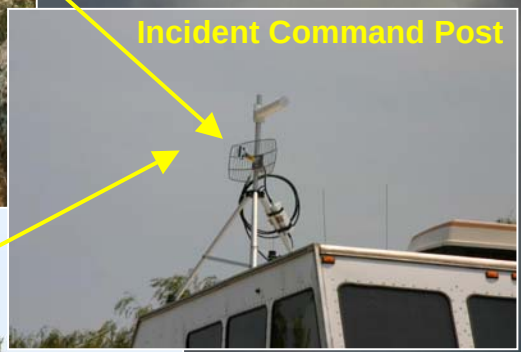
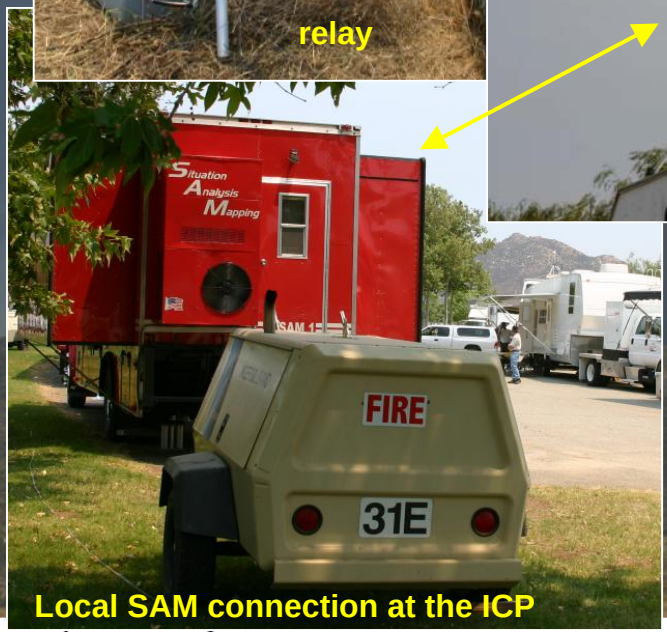
Eagle Fire HPWREN connection, May 2004



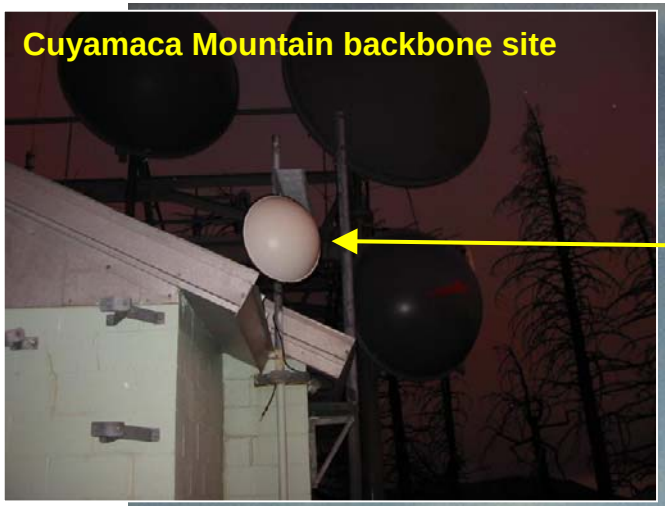


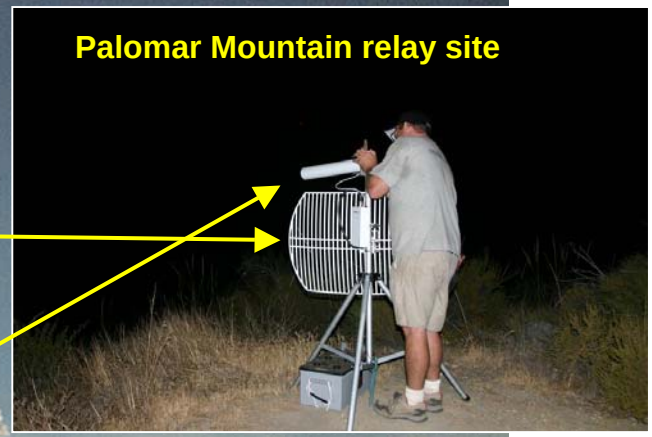




http://hpwren.ucsd.edu

Mataguay Fire HPWREN connection, July 2004





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Volcan Fire HPWREN connection, September 2005

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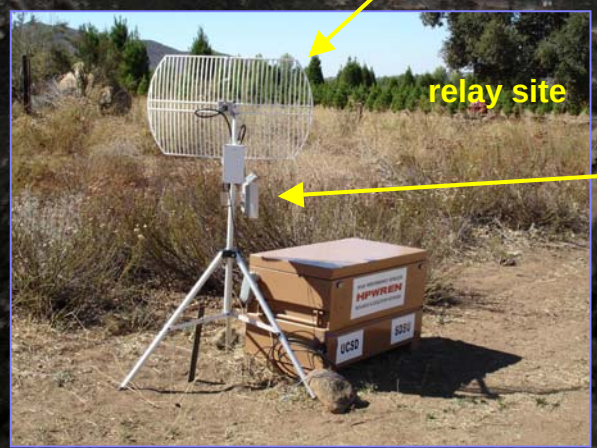
Border 50 Fire HPWREN connection, October 2005



May 2005 joint exercise with CDF and San Diego Sheriff's Department


Equipment preparation


CDF staff guiding the slingshot load of the Sheriff's helicopter

Deployed wireless relay and sensors

Equipment return

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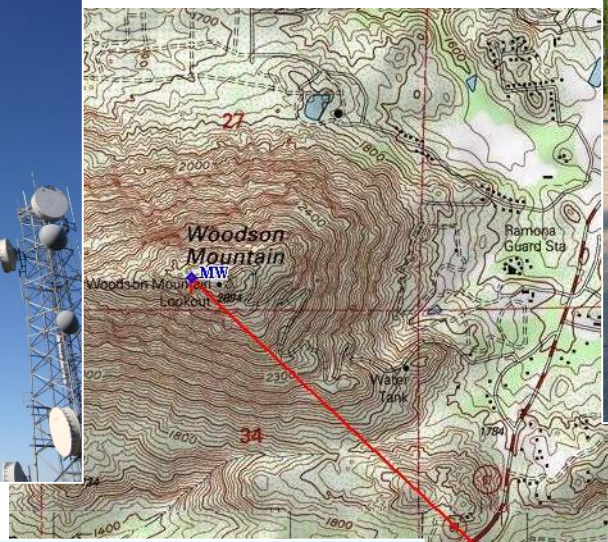
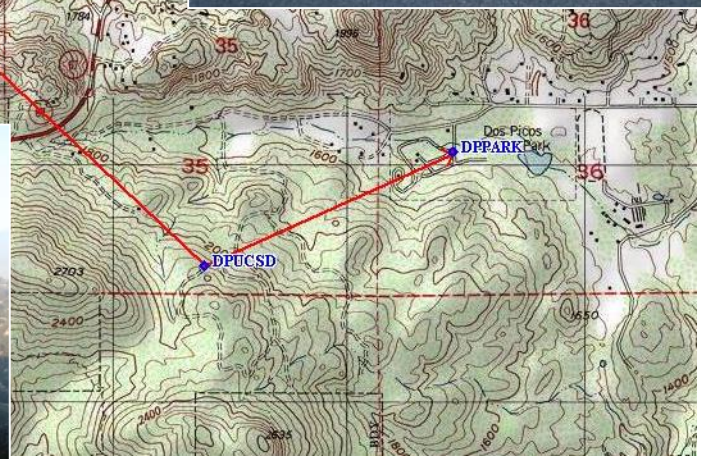
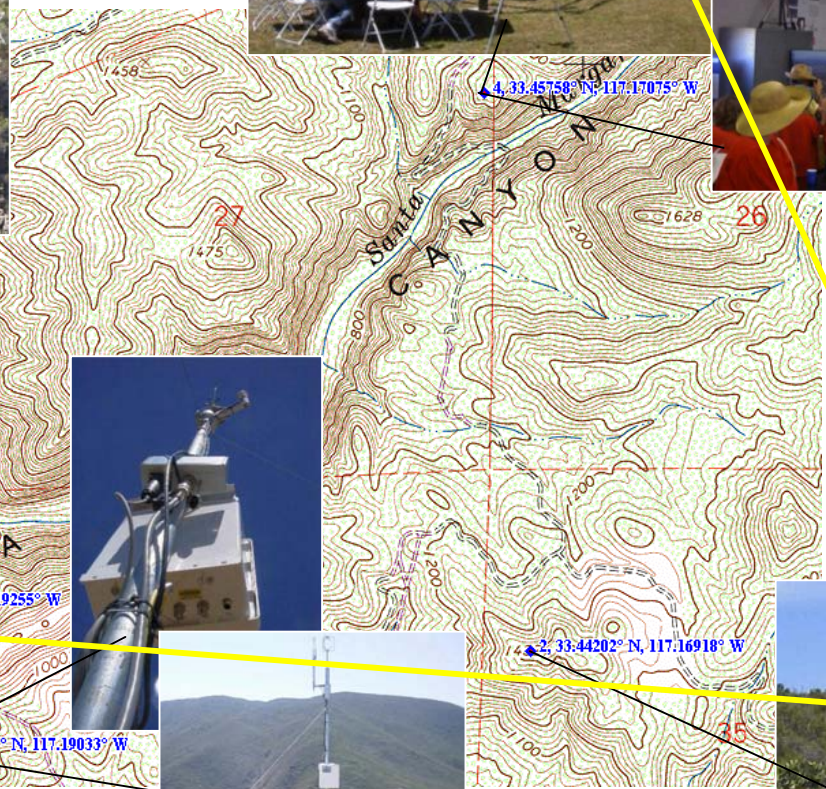
Ad-hoc firefighter Incident Command Post capability at Dos Picos





Demonstrations and Exercises

Santa Margarita Ecological Reserve May 2001



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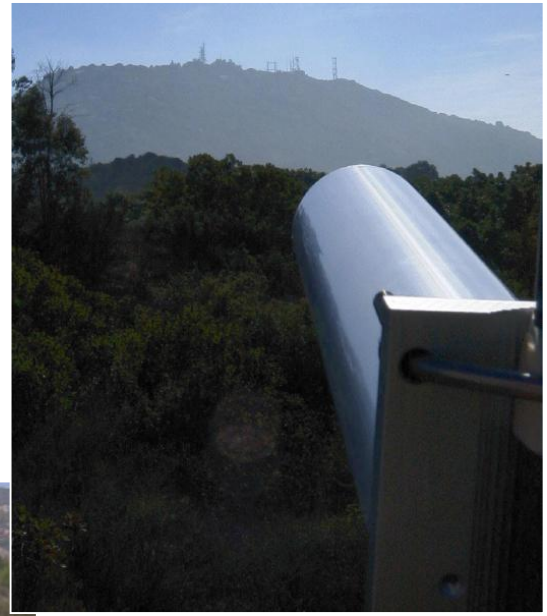
Researchers in the field



- antenna mounted on tripod
- connected to laptop PCMCIA card
- no external power or equipment

Yagi antenna on tripod

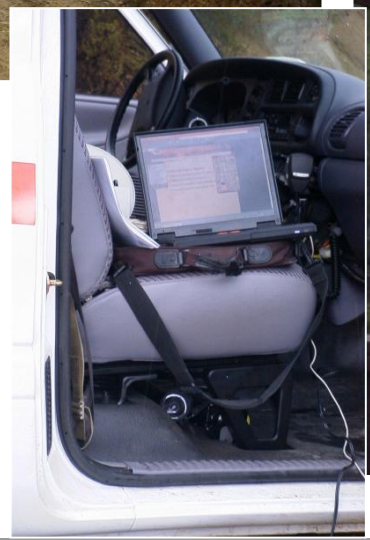
yagi antenna

amplifier

tripod

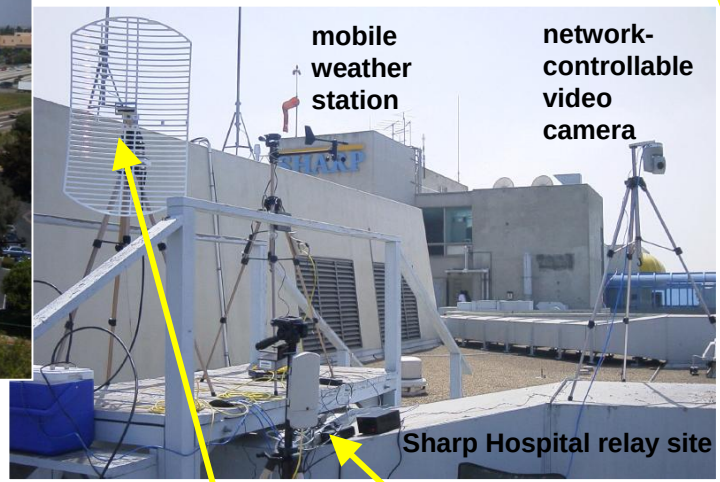
antenna cable to power injector

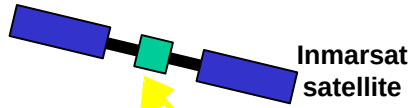
CDF demonstration
February 2001

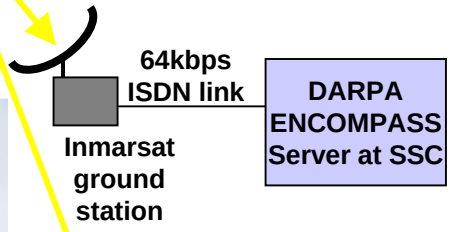


http://www.fire.ca.gov/

Multi-agency crisis management demo
28 August 2001

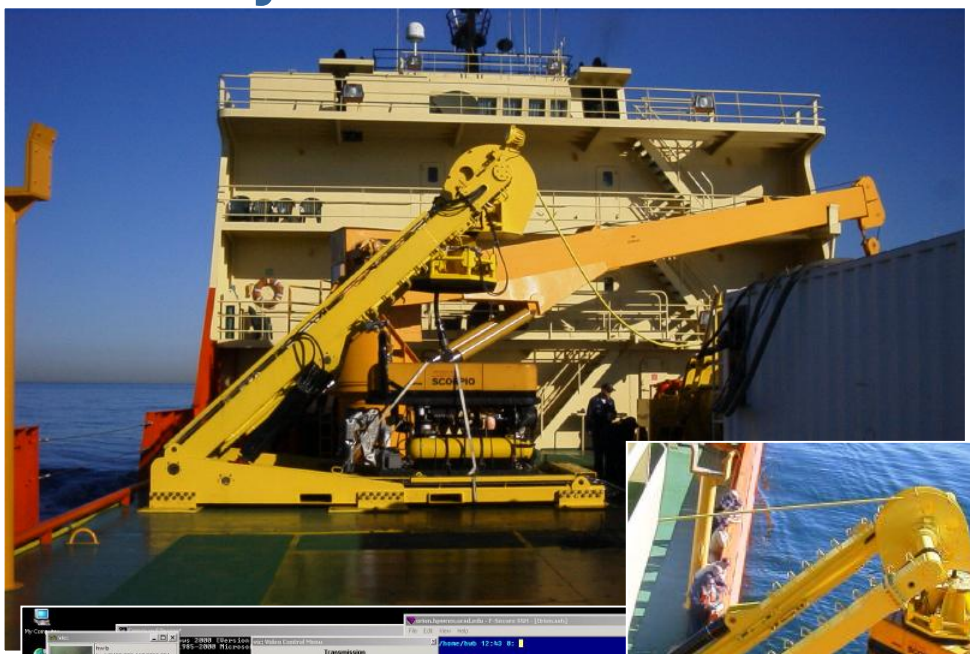


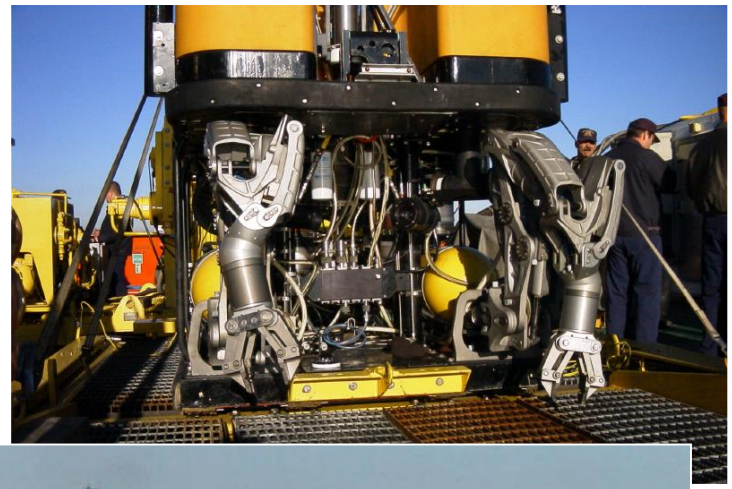


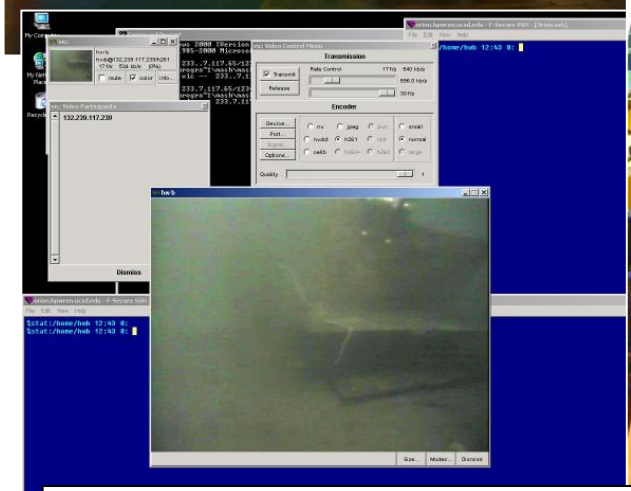


k

U.S. Navy Deep Submergence Unit – SIO SeaLab II site February 2002







http://www.csp.navy.mil/csda5/dsu/dsu.htm

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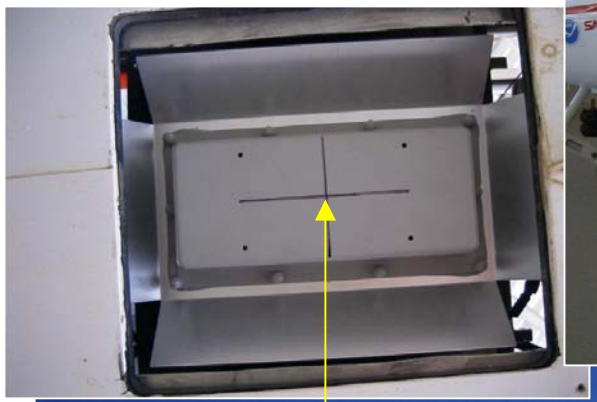
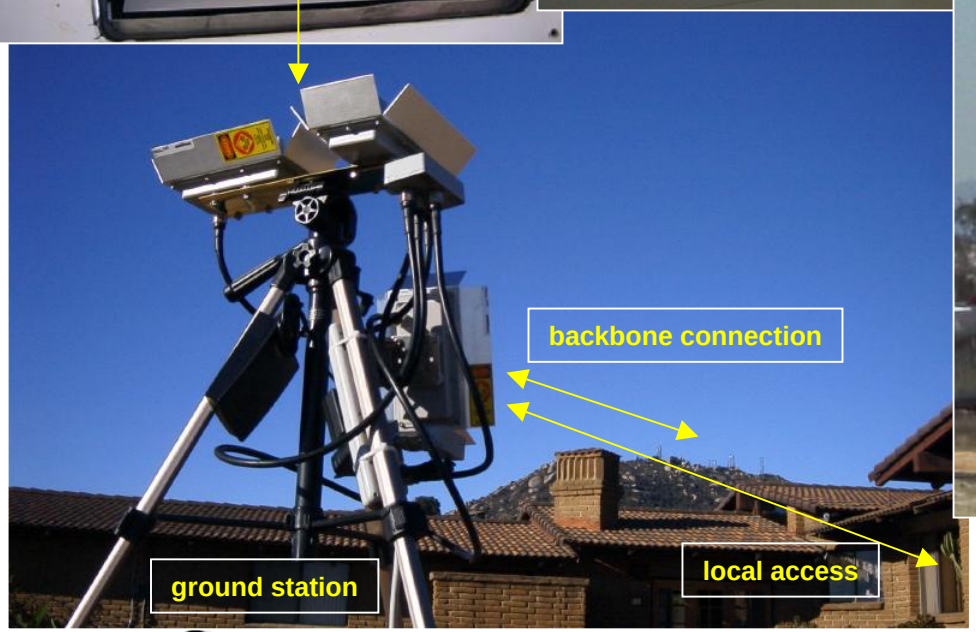
Flight communications test, ground tracked April 2002

Flight communications test, fixed antenna
August 2002






2048 X 1536 sized image taken from the ground
via a network-accessible camera in the airplane

Coronado bridge demonstration topology

UCSD

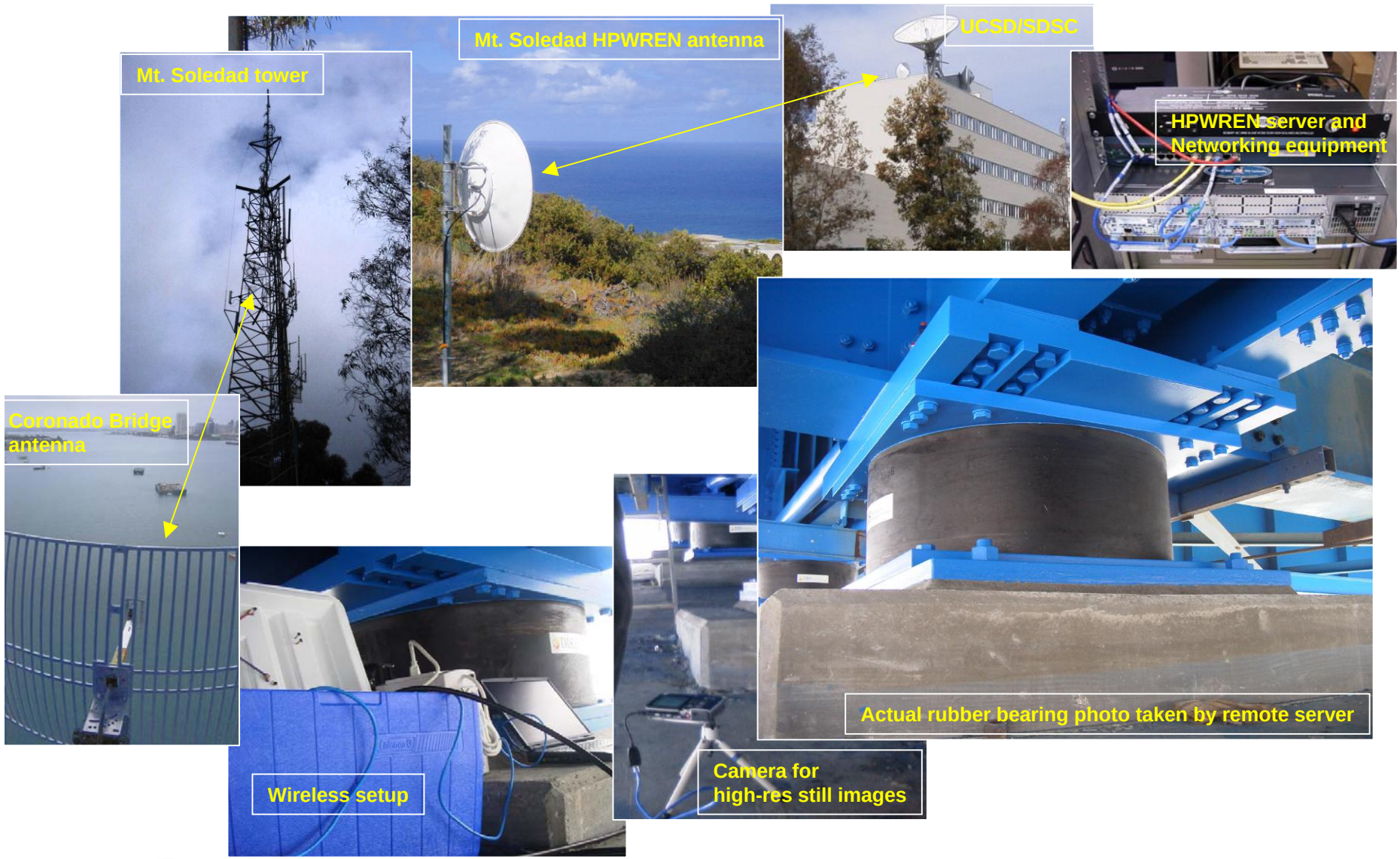
↕ ~3 miles

Mt. Soledad

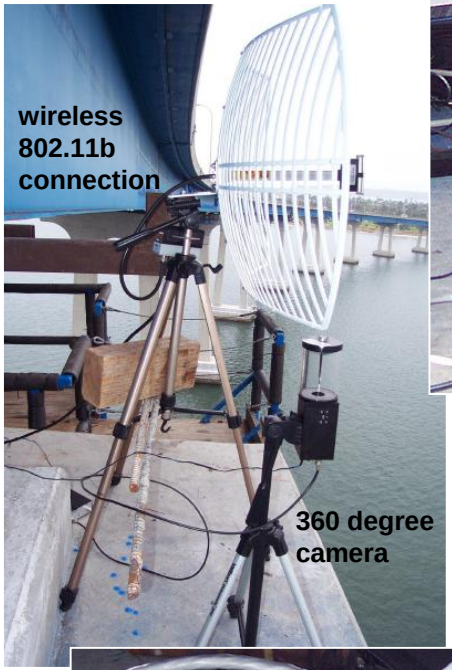
↕ ~12 miles

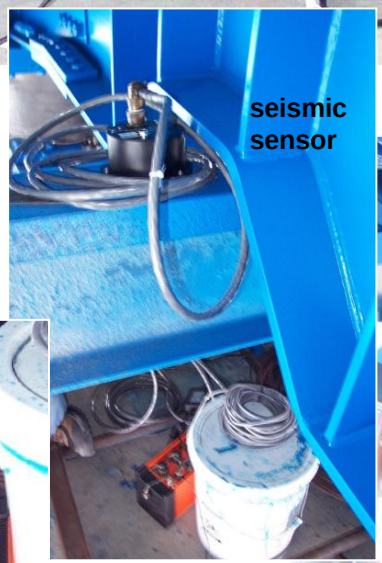
Coronado Bridge

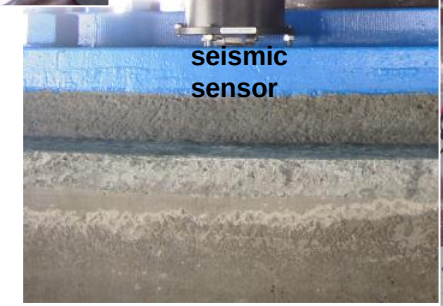
Coronado bridge communications test, April 2002

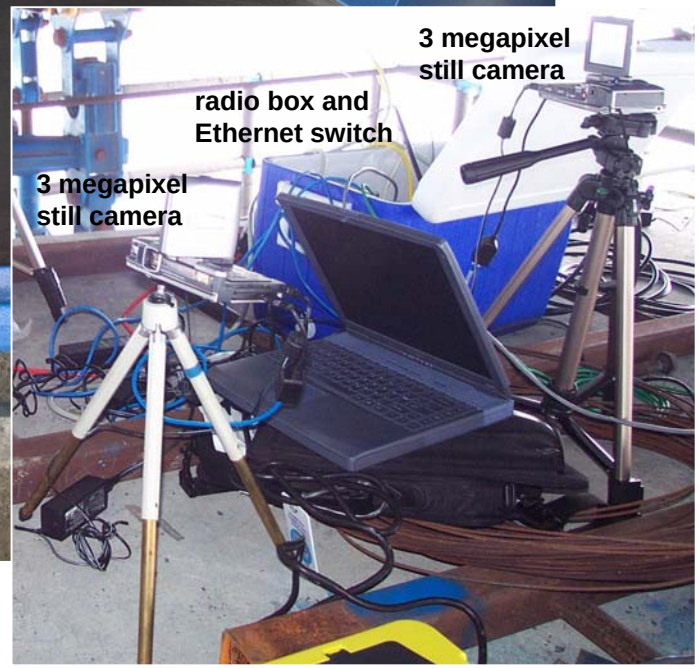


15 May 2002 Coronado bridge telemetry demonstration

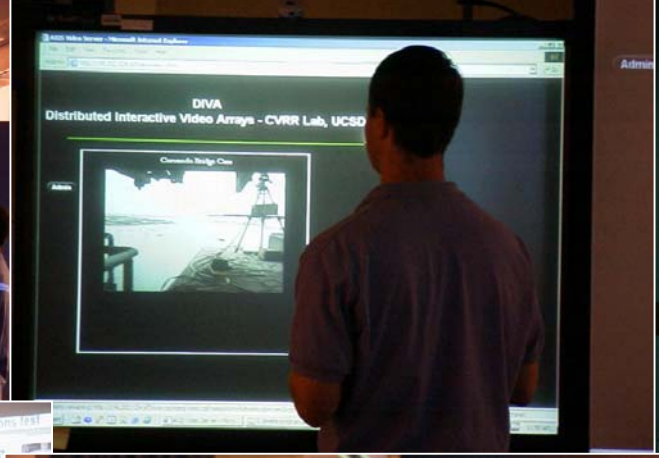


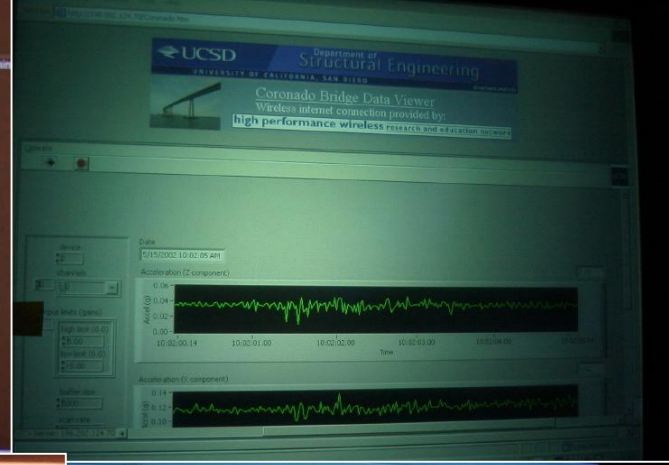


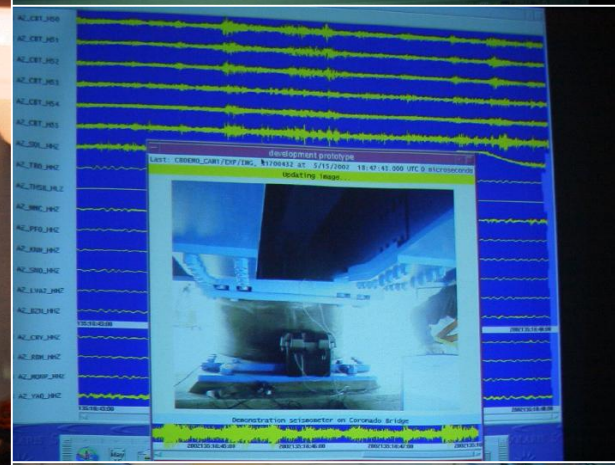





DIVA
Distributed Interactive Video Arrays - CVRR Lab, UCSD


DIVA
Distributed Interactive Video Arrays - CVRR Lab, UCSD


UCSD
Department of Structural Engineering
Coronado Bridge Data Viewer
Wireless internet connection provided by:
high performance wireless

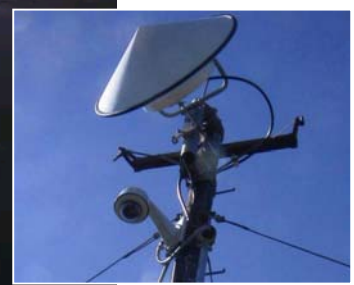

development prototype
Updating image...
Demonstration seismometer on Coronado Bridge


Coronado bridge communications test


Coronado bridge communications test

Cameras

Video cameras



Mountain fire stills, observed by stationary p/t/z video camera

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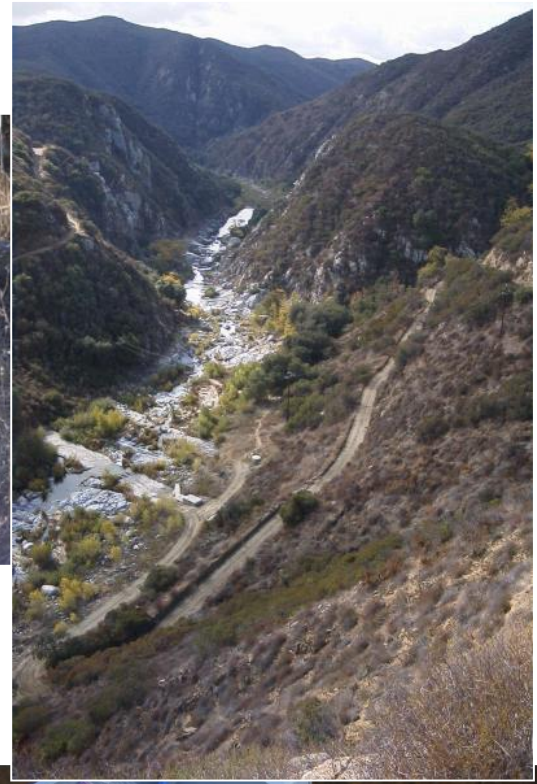
Mountain fires video clips, observed from Mt. Laguna

Mountain fire video clip, Pines Fire from Mt. Laguna

High resolution still camera at SMER

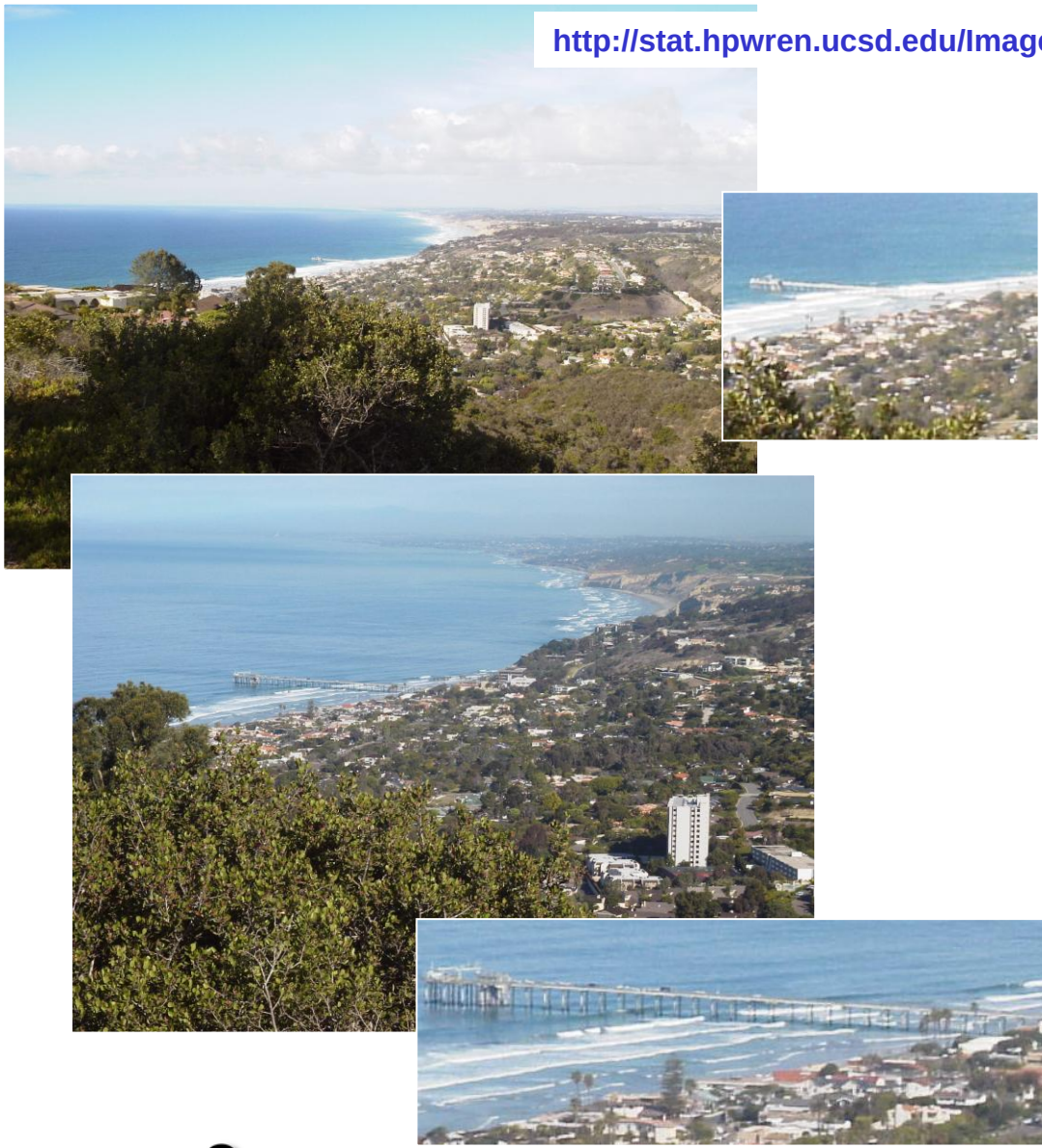


High resolution still camera at SMER, animations


Mimulus
Flower Imaging Project
2002
2002/ 5/18 6:06

High resolution still camera at La Jolla, February 2002

http://stat.hpwren.ucsd.edu/Imagery/LaJollaCoast/Data/TODAY/CURRENT-large.html



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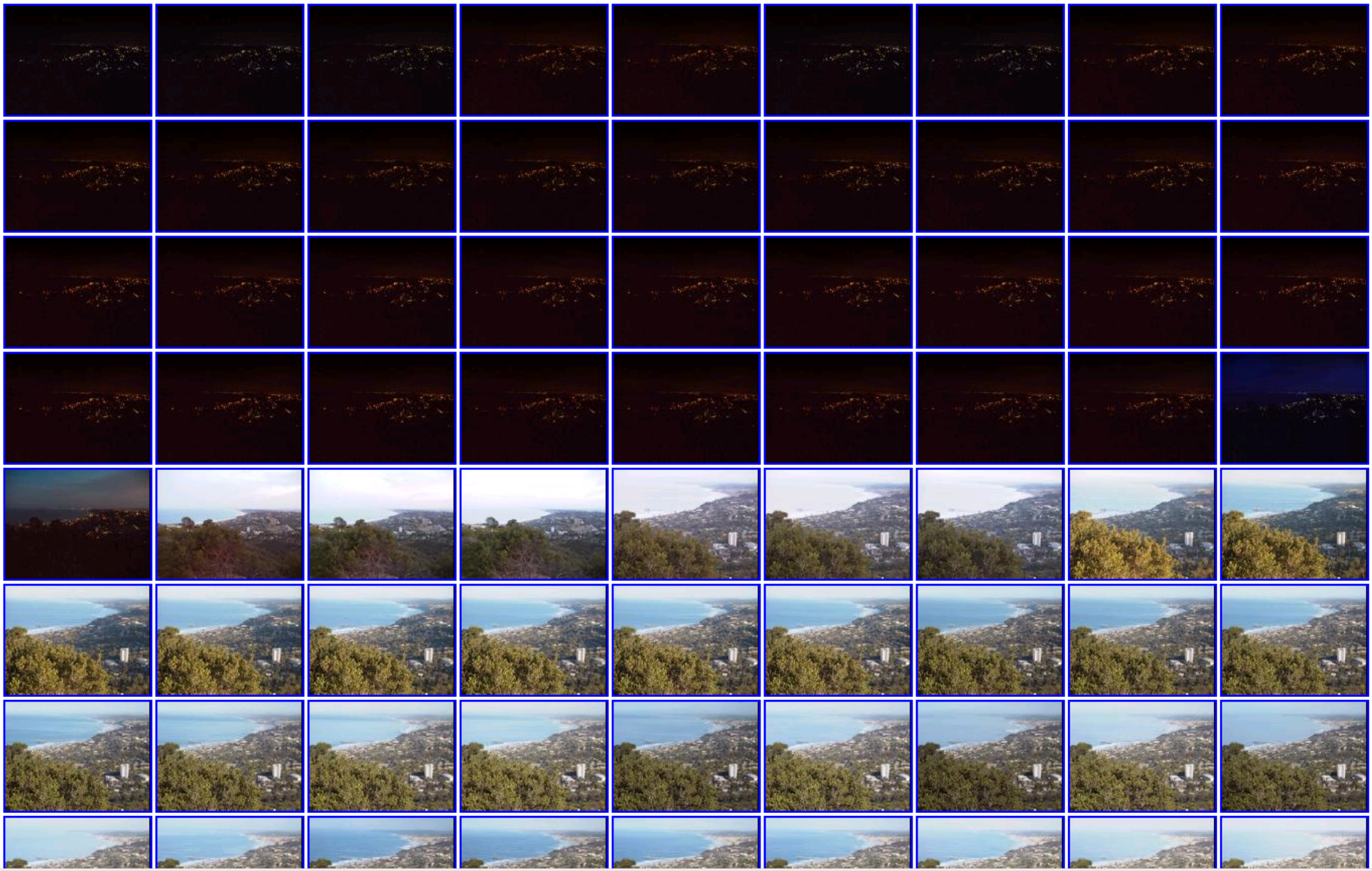
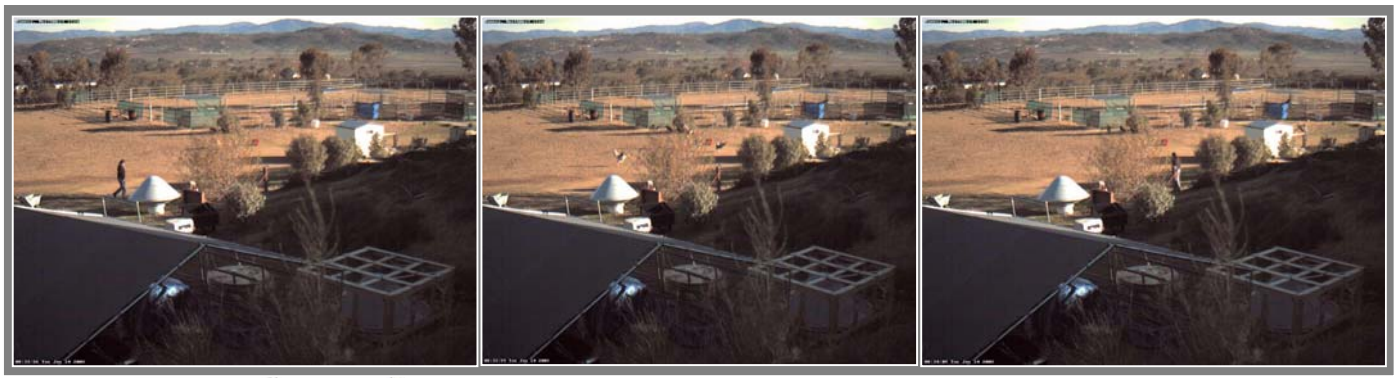
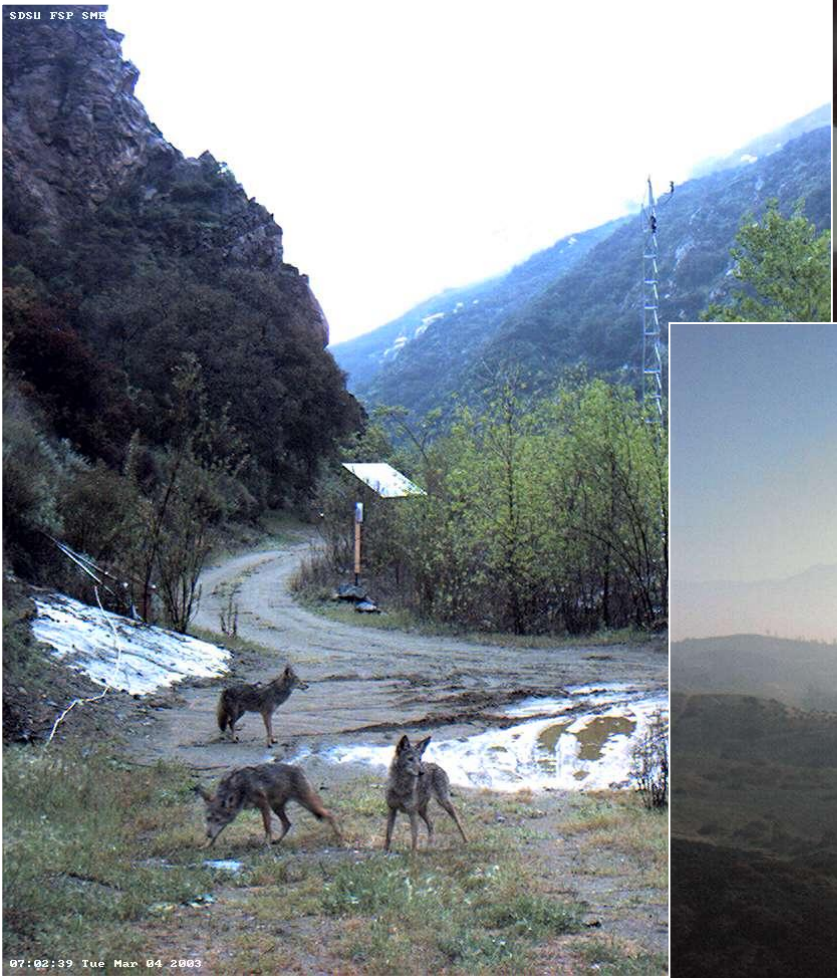


Motion detect camera, Ramona, January 2003



Various images



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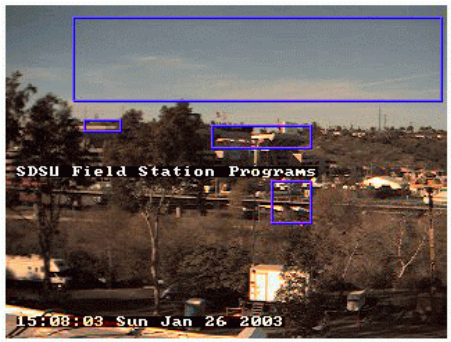
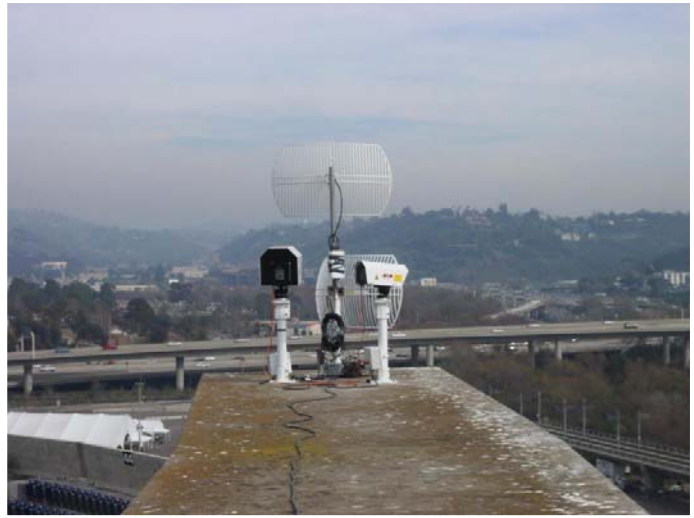
Superbowl, January 2003





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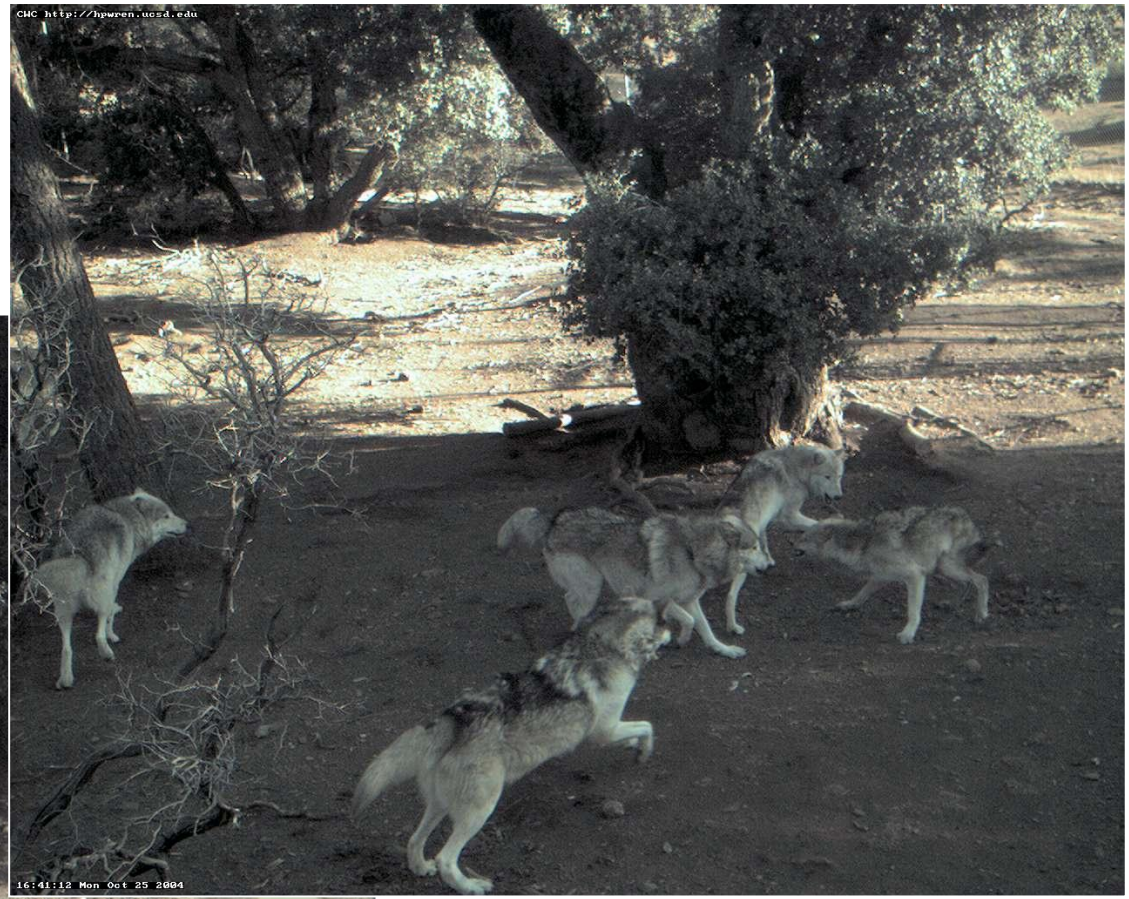
Superbowl, January 2003

Camera at the California Wolf Center



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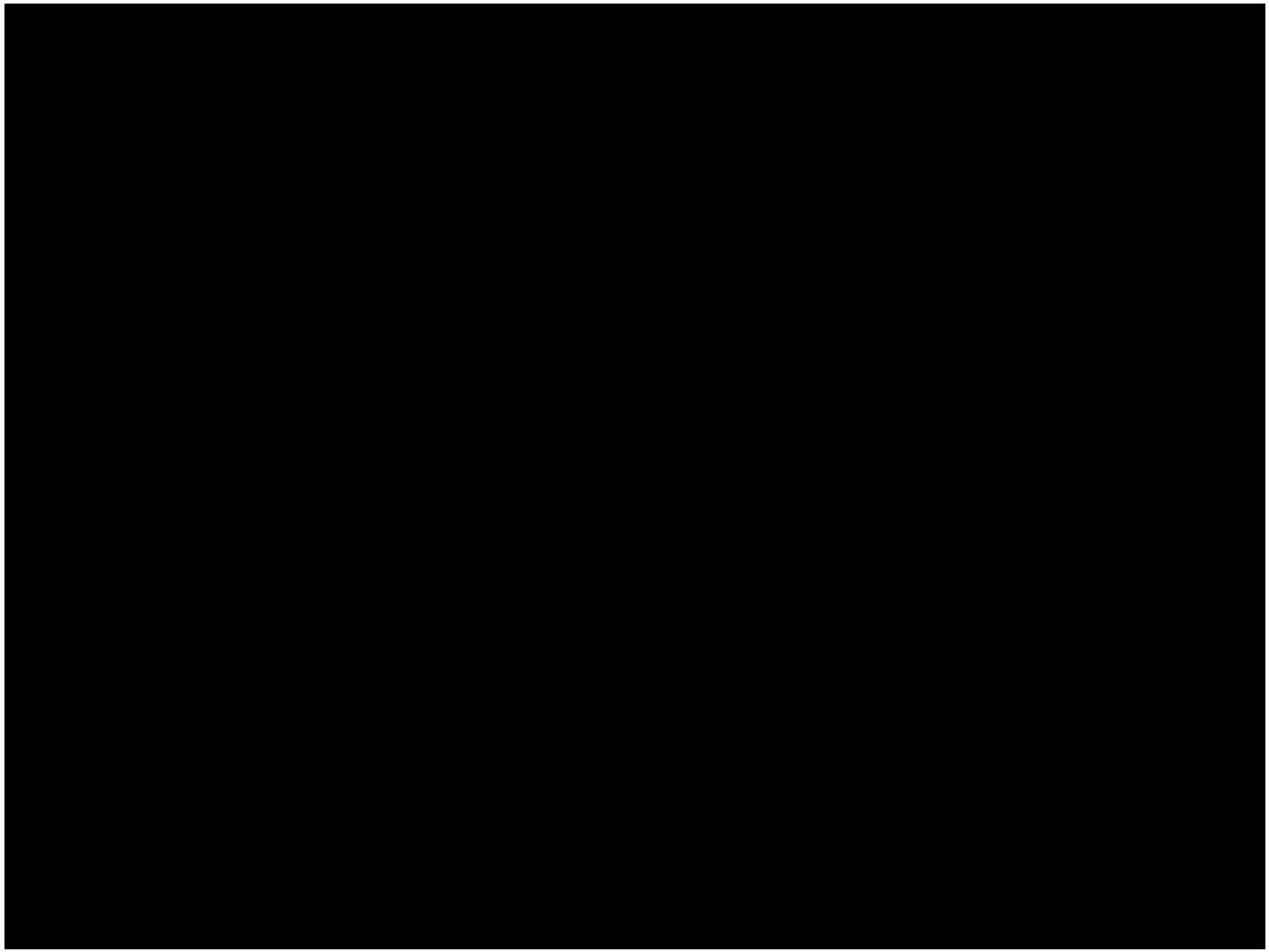
Cedar Fire, 28 October 2003, Mt. Laguna looking towards Cuyamaca



Mt. Laguna 360 degree four cameras, July 2003

Mt. Laguna 360 degree view cameras

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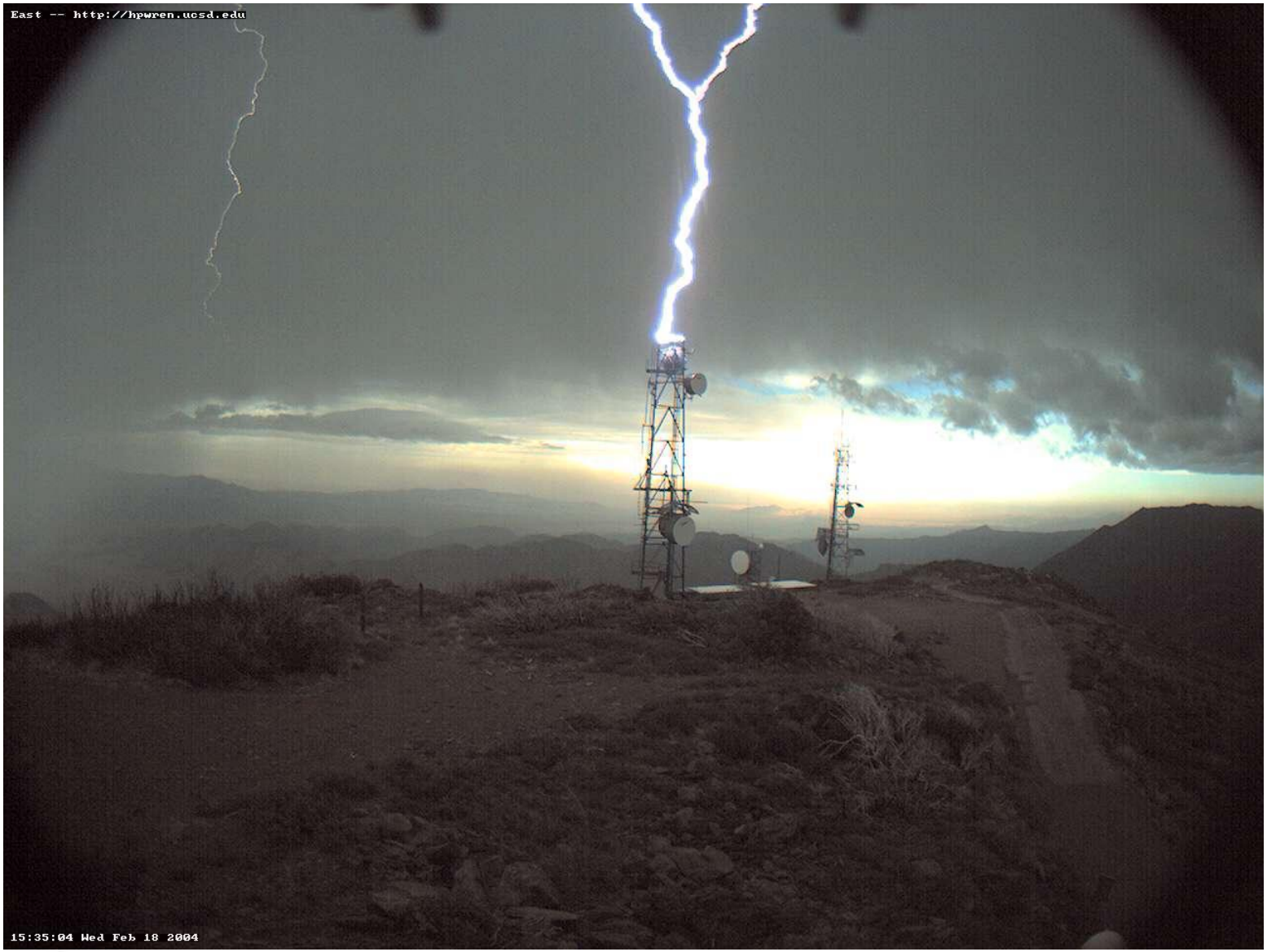
Mt. Laguna automatic motion detect capture



Ramona CDF Air Attack Base

Ramona CDF Air Attack Base

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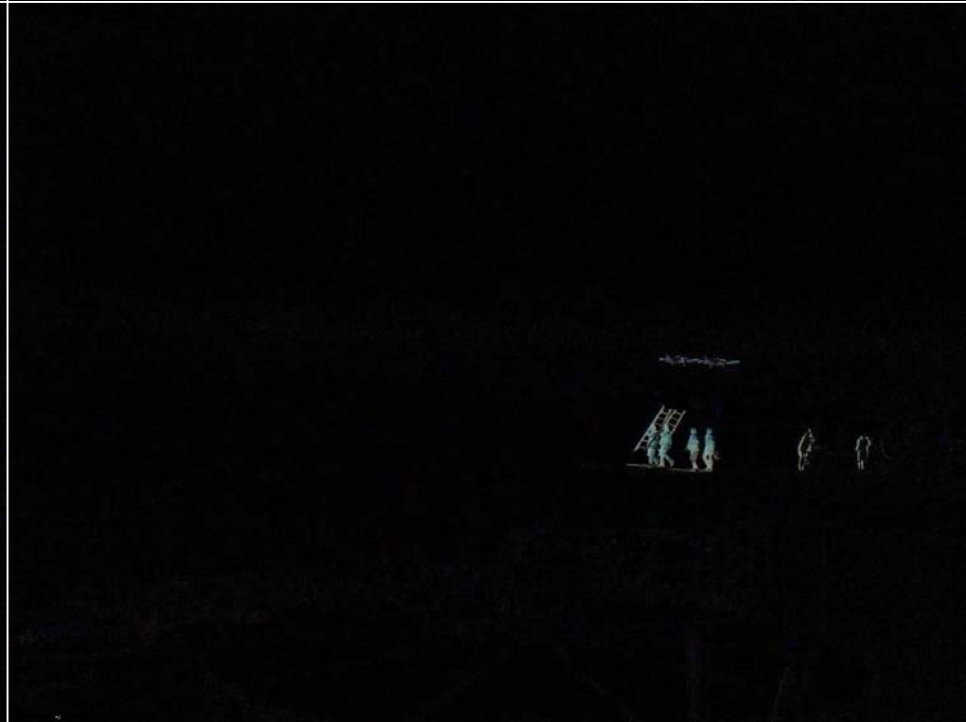
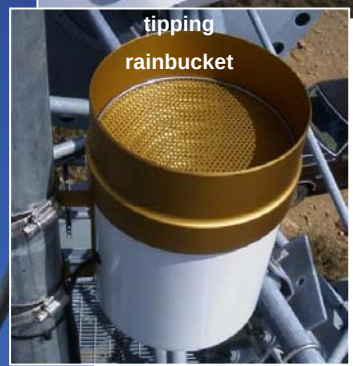
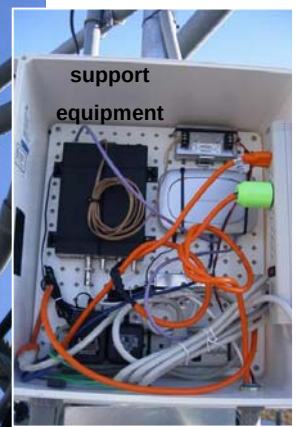
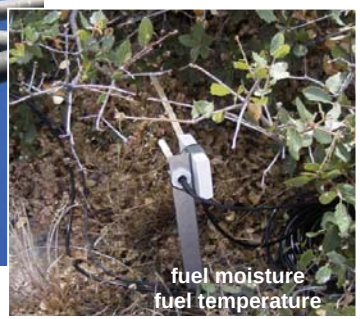


Meteorological sensors

Mount Laguna sensor instrumentation







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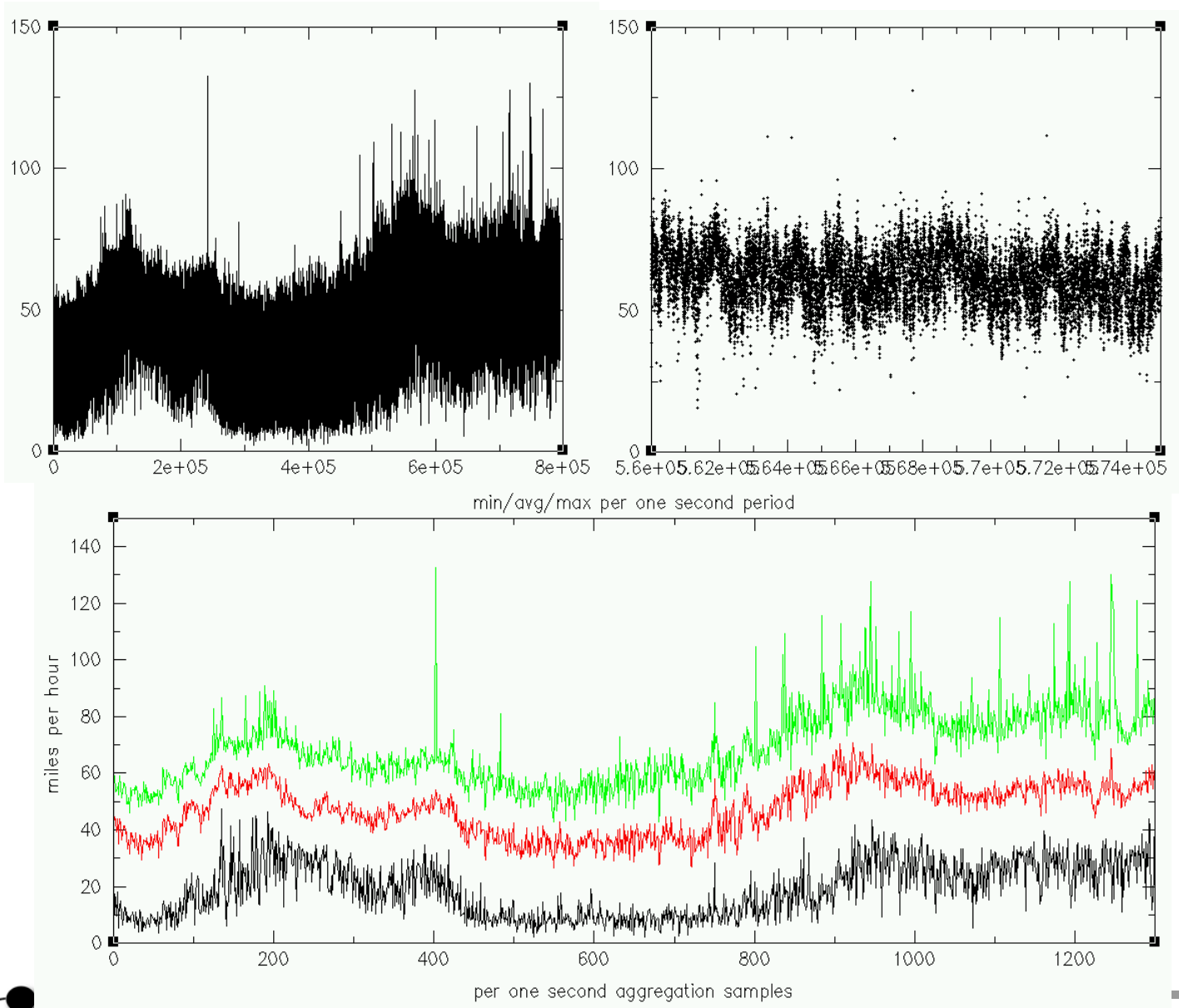
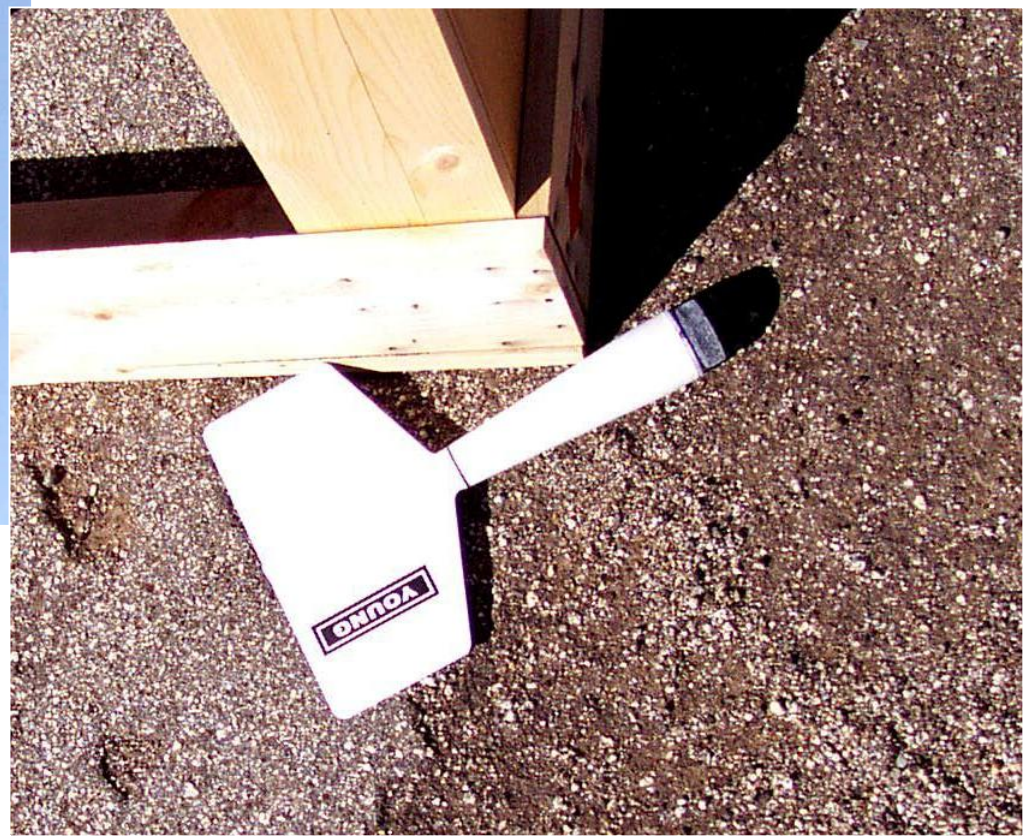
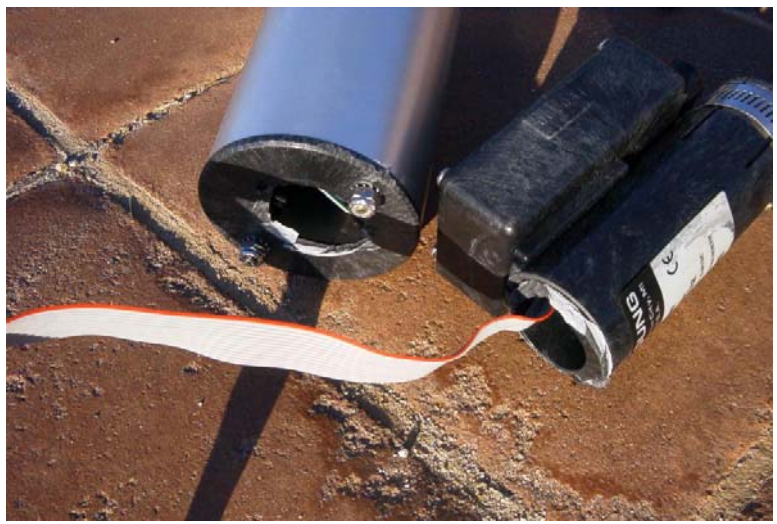
Wind gusts on Mt. Laguna



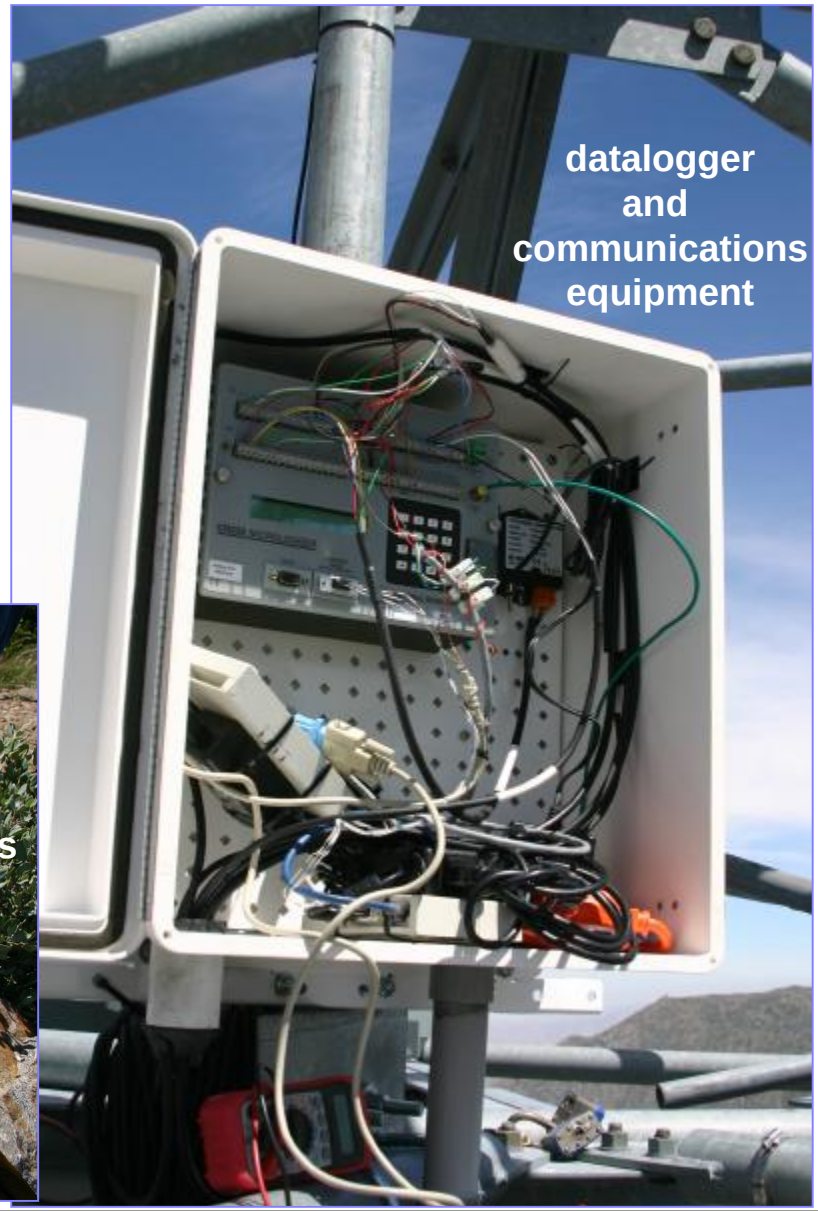
Mount Laguna sensor instrumentation



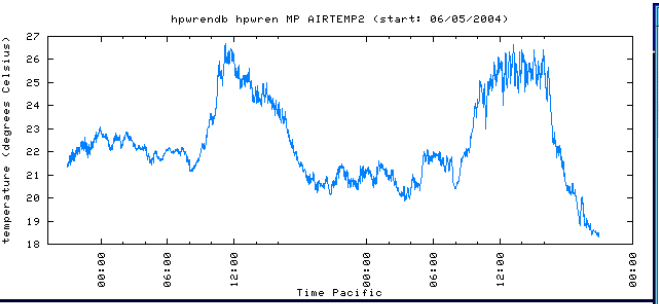
Mount Laguna sensor instrumentation

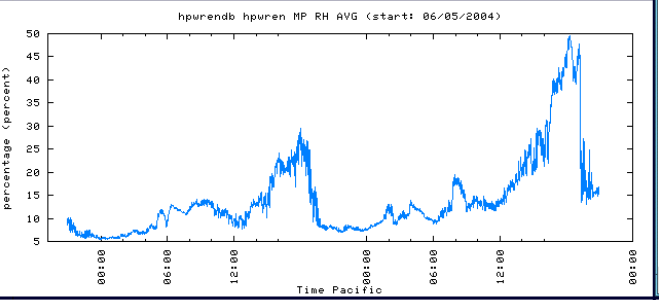


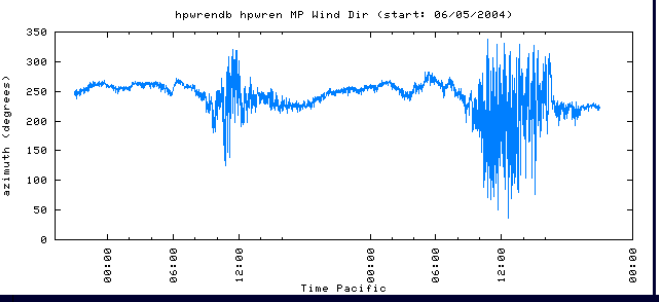
Real-time sensor implementation at an HPWREN backbone site

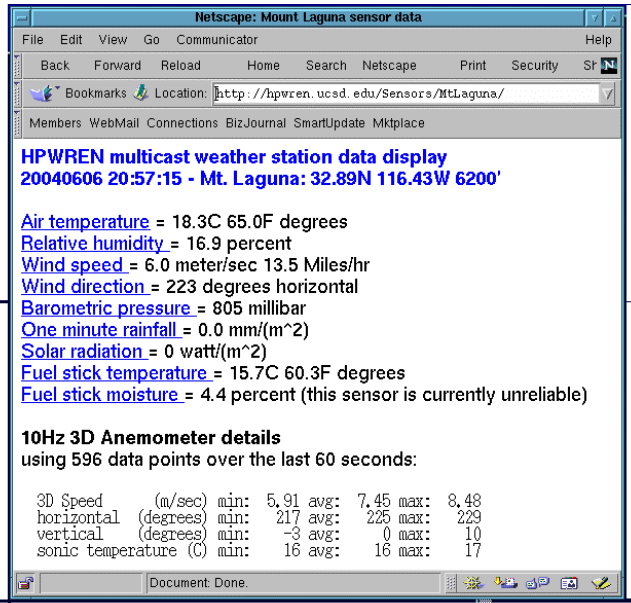


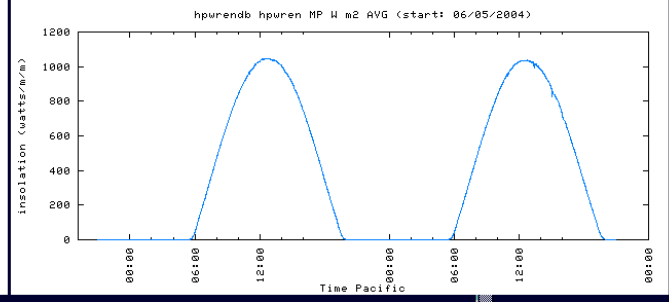
Real-time text display with history graphing support

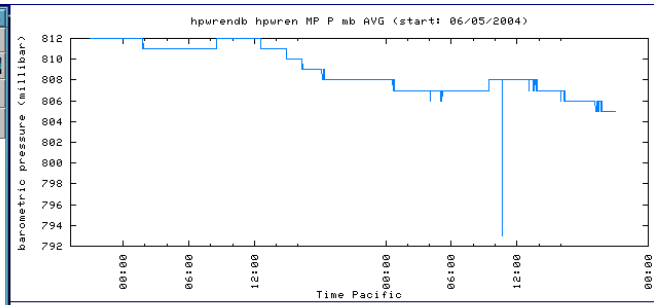


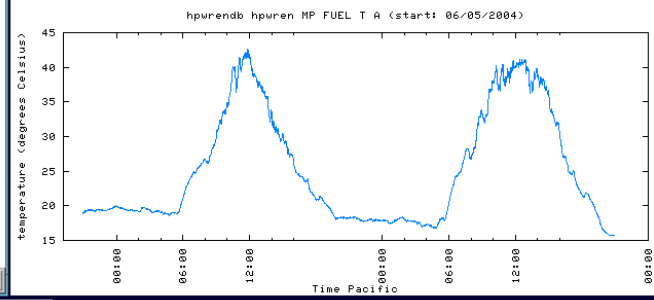




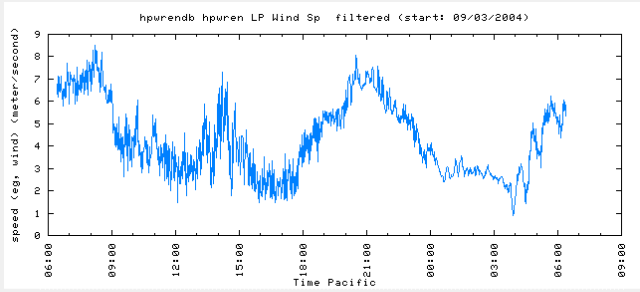


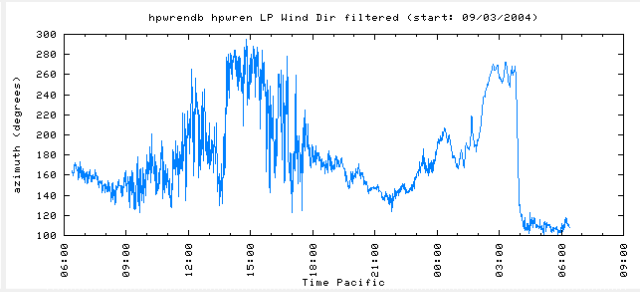


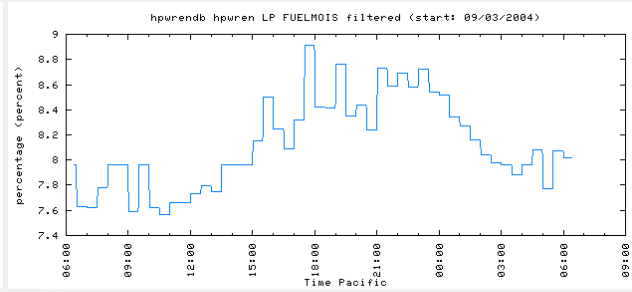


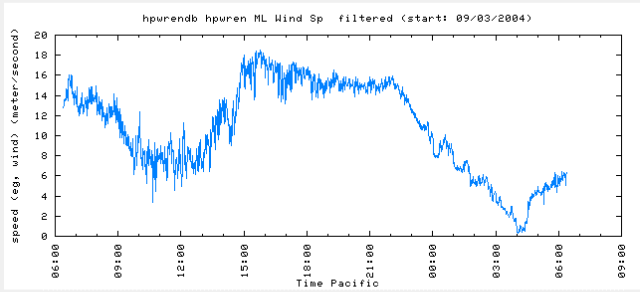


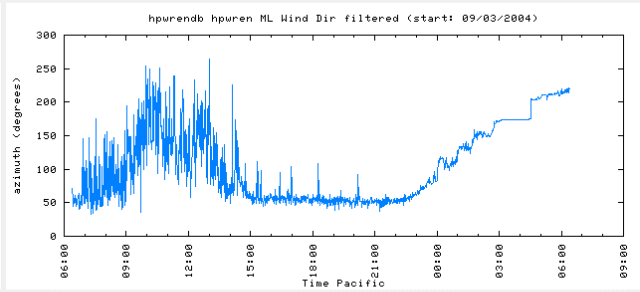
Real-time graphics display

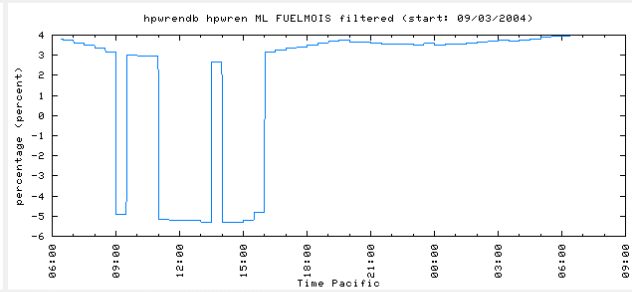


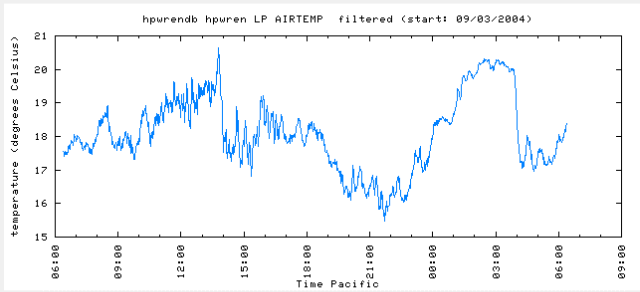


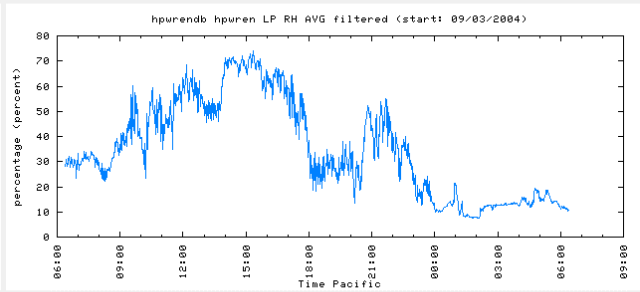


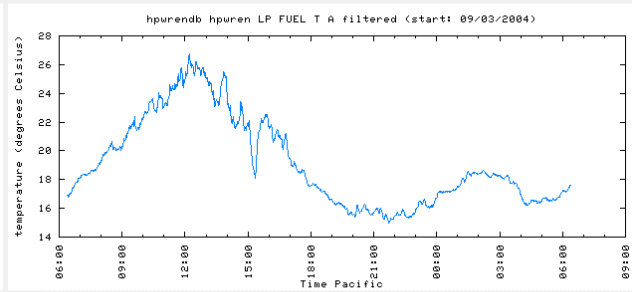


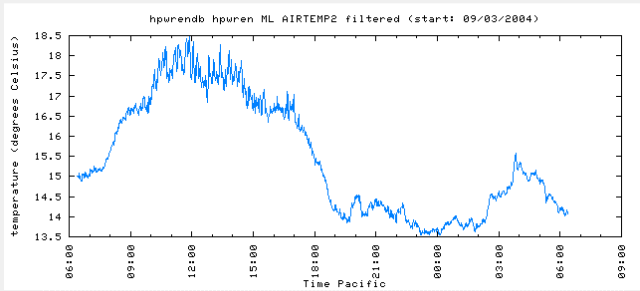


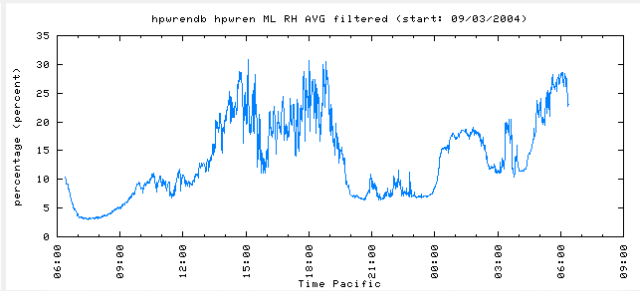


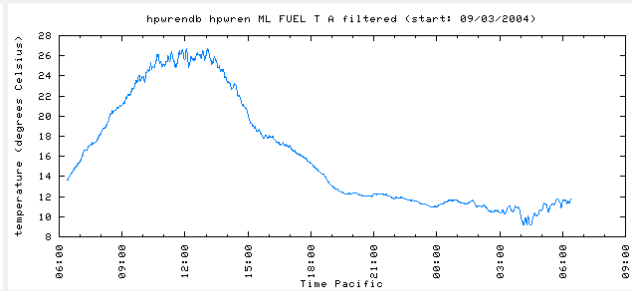










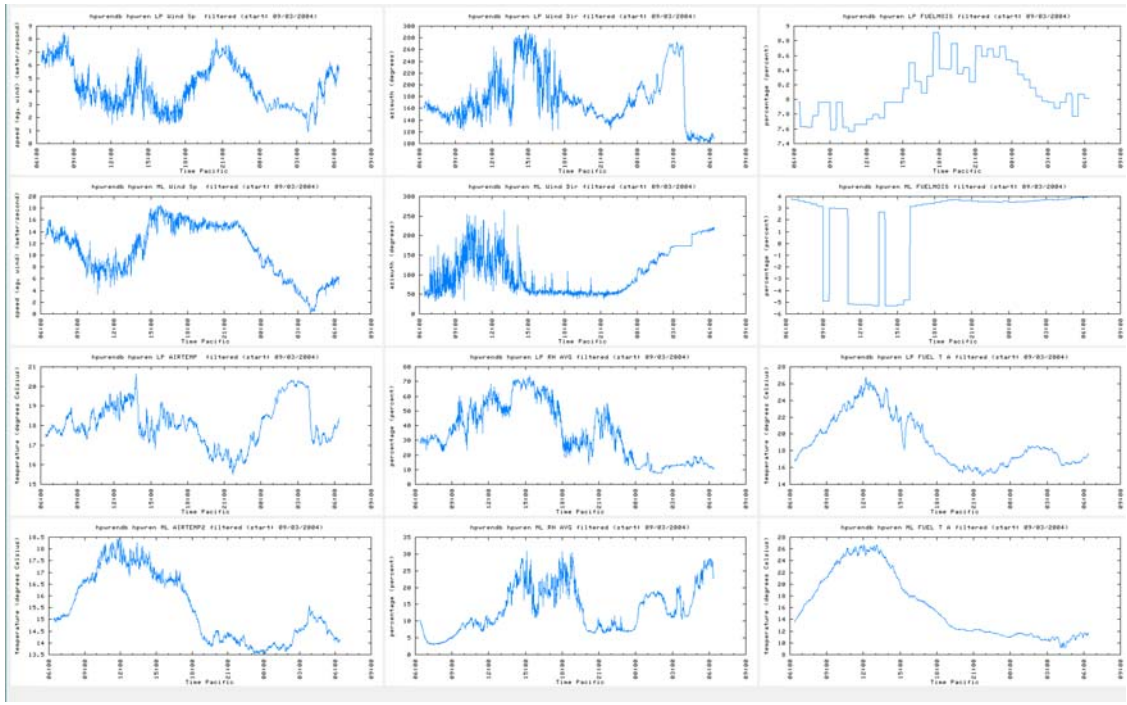


Real-time data based alerts

Trigger email/pager/….
if:

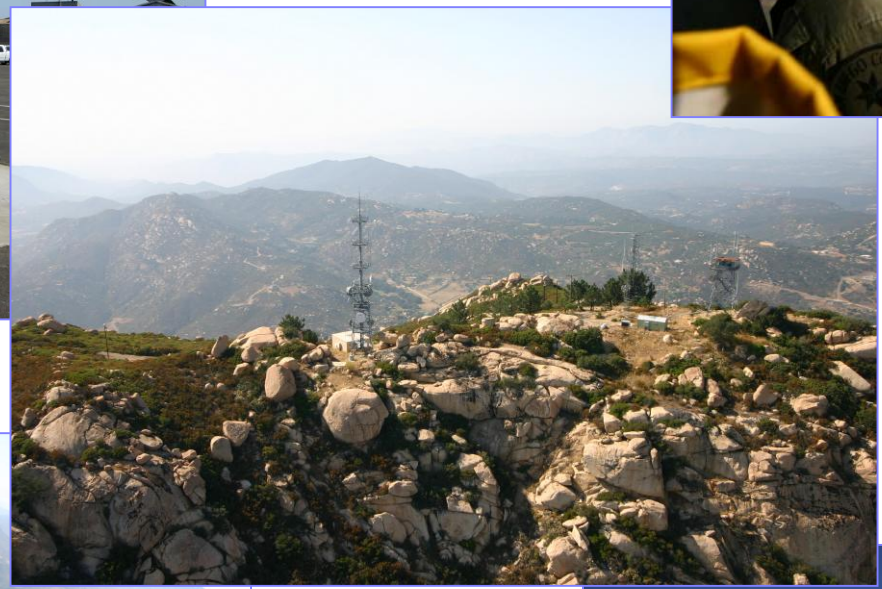
condition A +
condition B +
condition C

happens



several San Diego fire officers are currently being paged during alarm conditions, based on HPWREN data parameterization by a CDF Division Chief

July 2005, Fuel stick replacement on Lyons Peak



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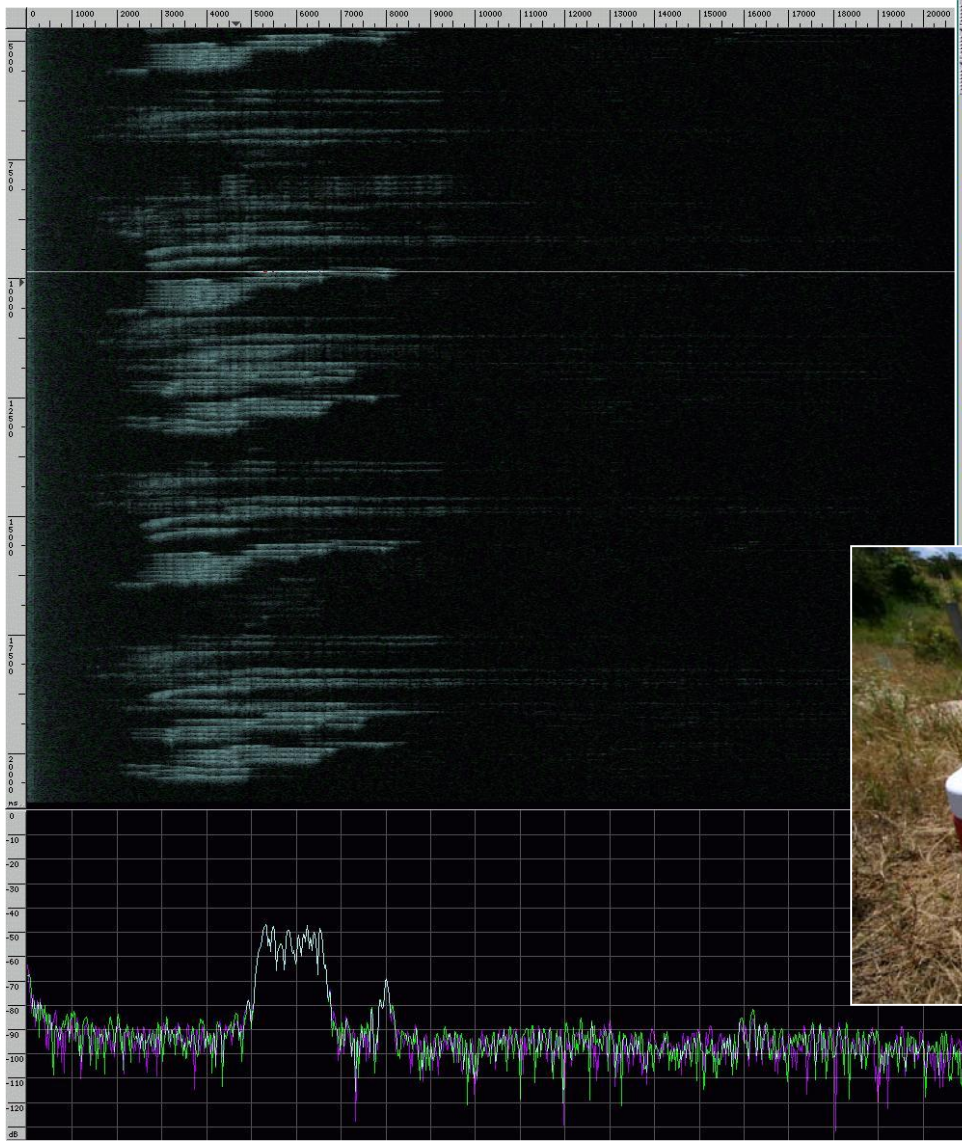
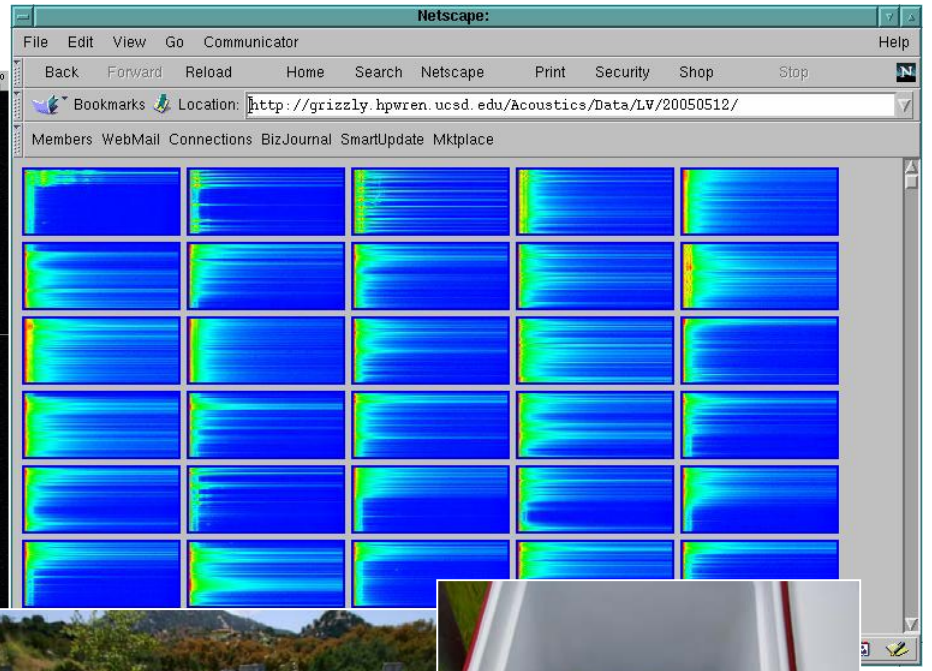
Acoustics sensors

Acoustics research with automated data collection





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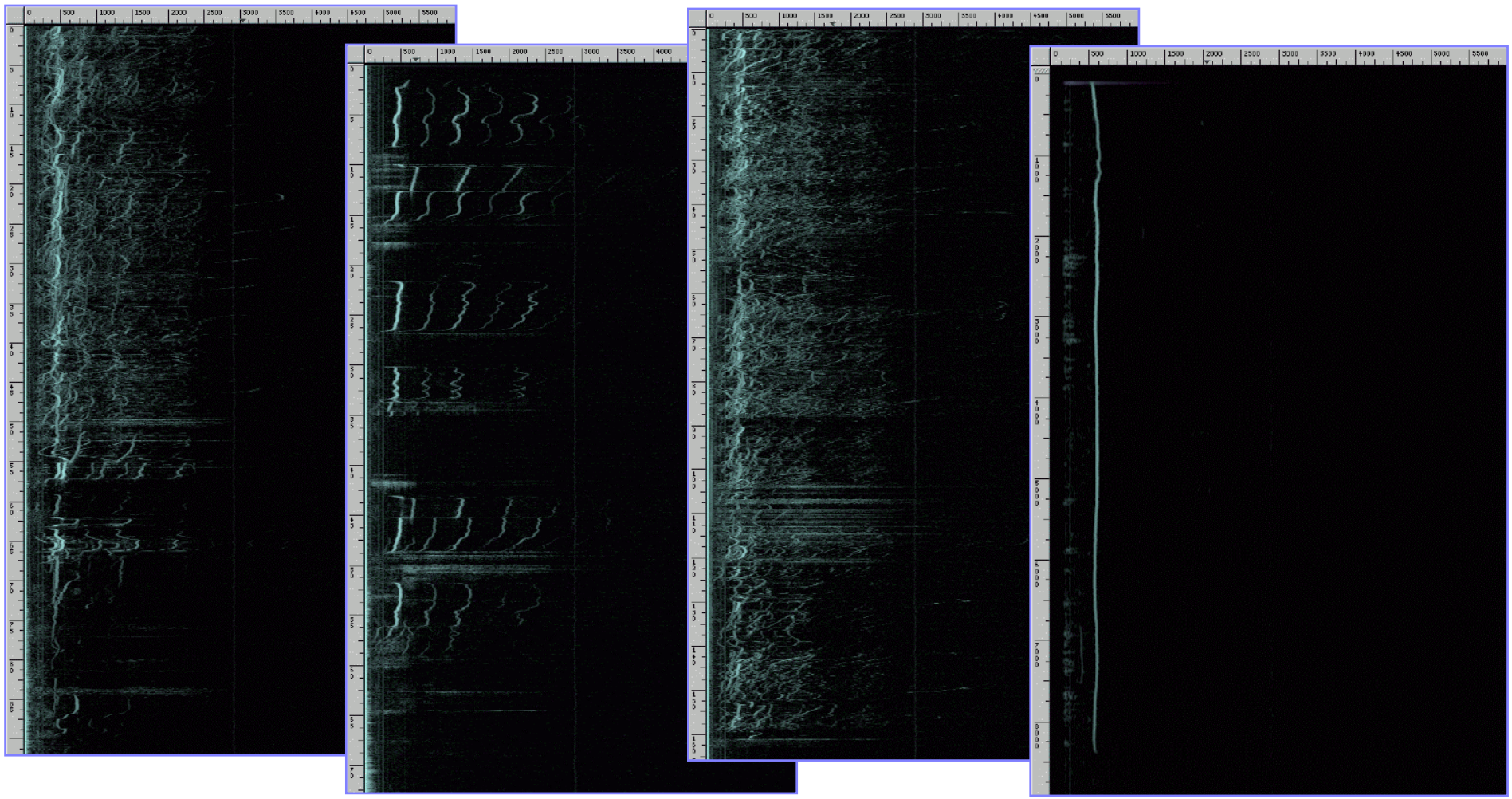
Wolf howls at the California Wolf Center



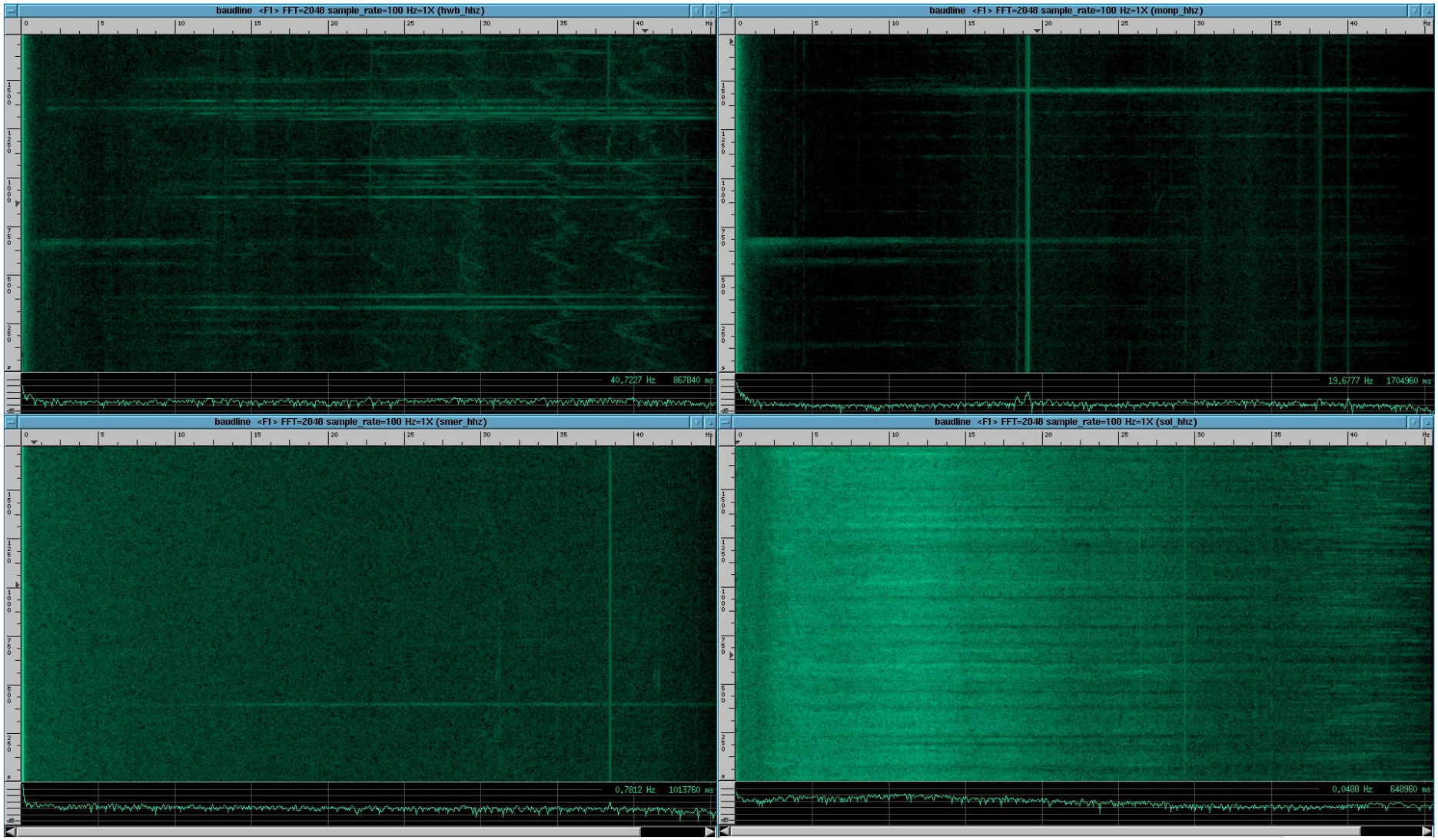
Seismic sensors

Interactive spectrum analysis of real-time seismic sensor data

(magnitude 1.6, near Banning, Riverside County, CA)

~59 miles

~73 miles



~34 miles

~75 miles

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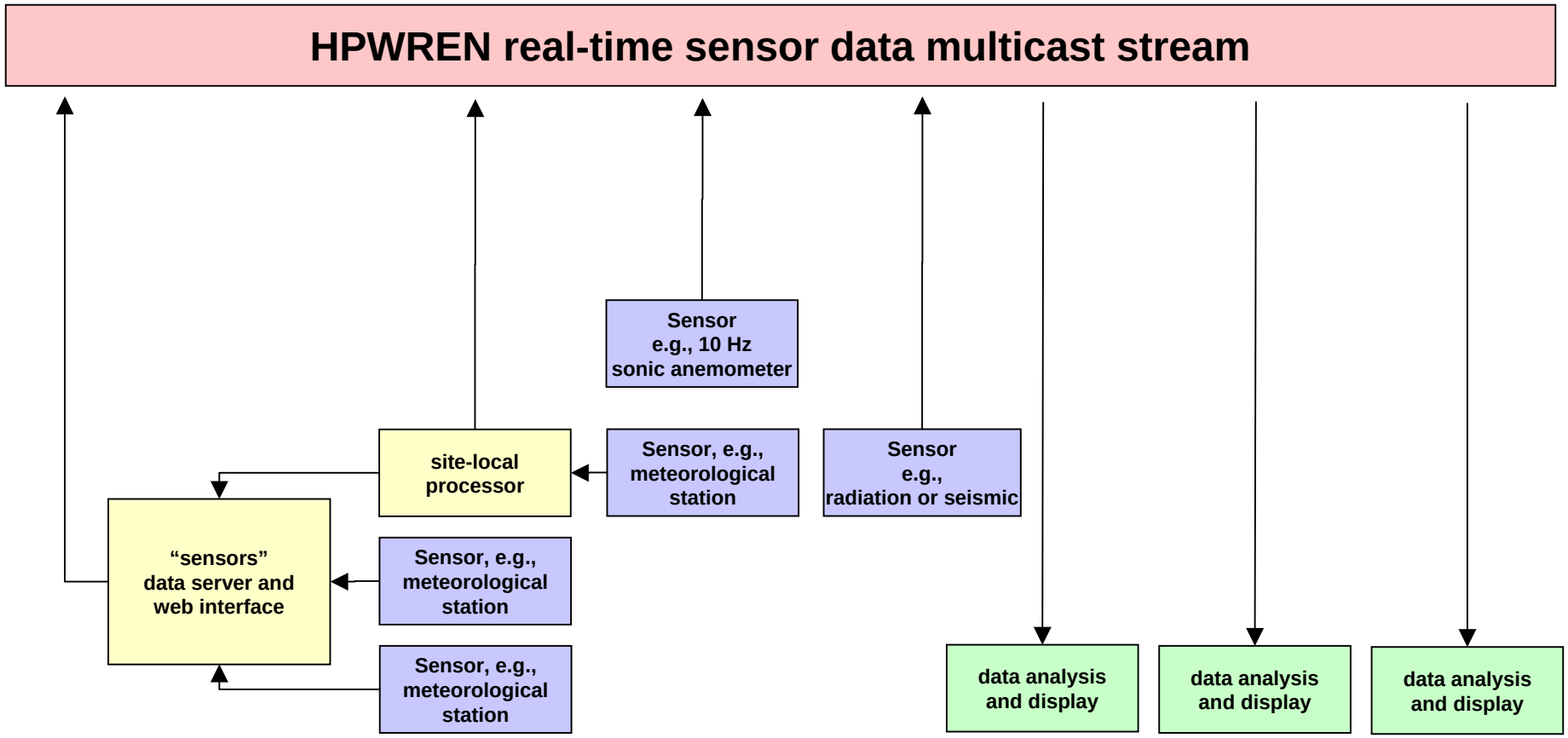
Concepts

Multicast real-time sensor data distribution



Ramona CDF camera collaborations

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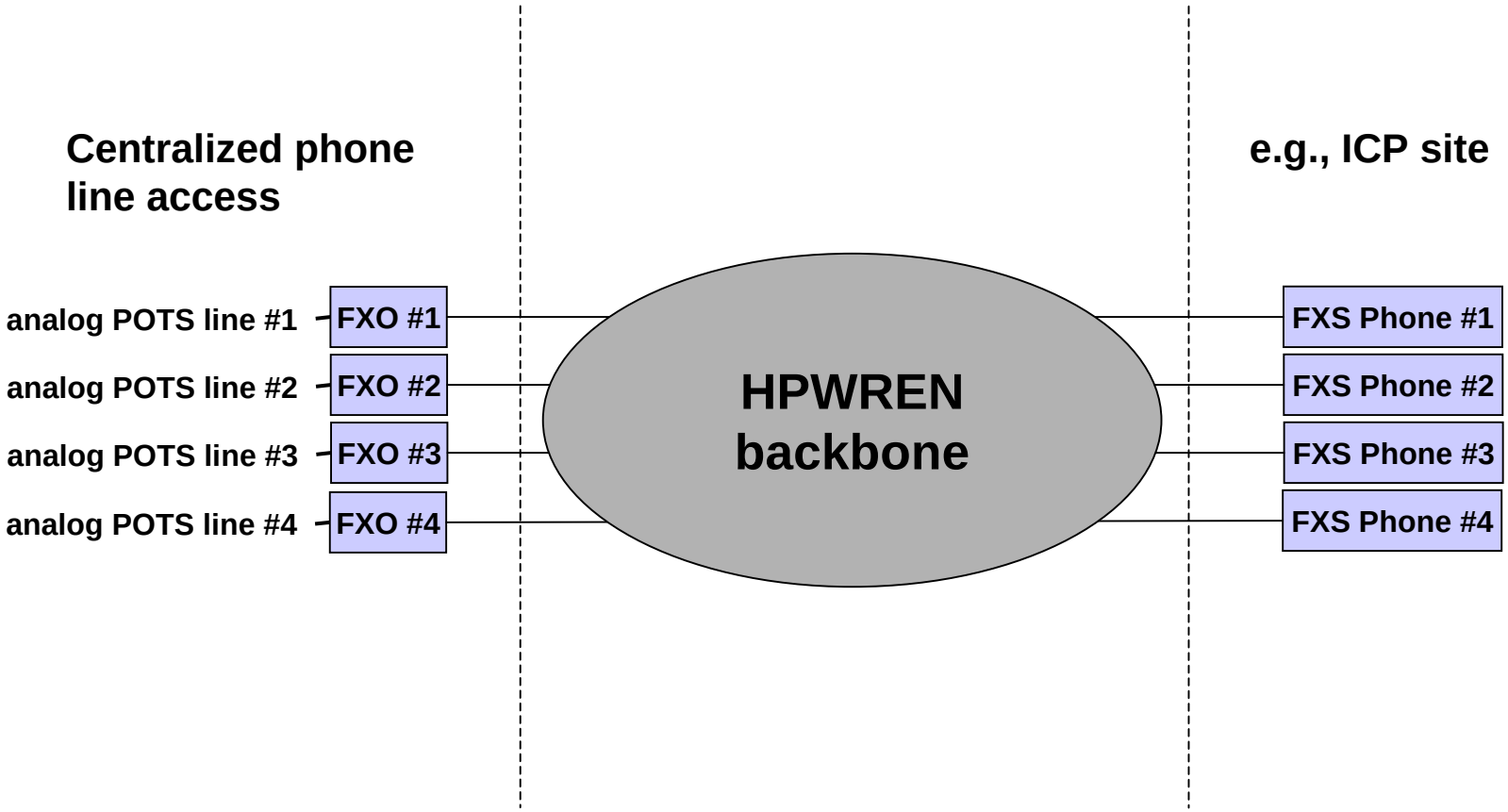
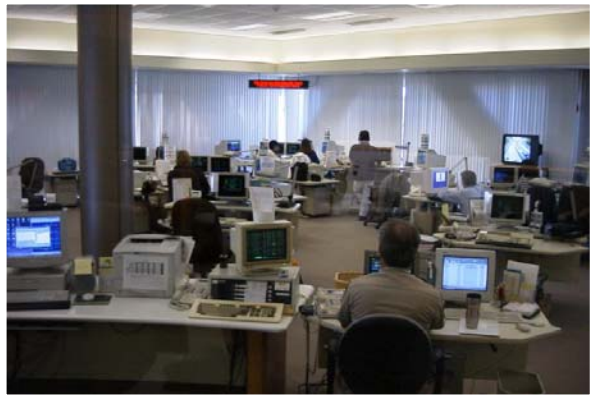
Planned VoIP prototype (e.g., for ICPs)



Post-incident research concept

Potential incident management scenario concept



operations center

Real-time sensor telemetry (video, high resolution stills, …)

Perimeter weather station

Perimeter weather station

Perimeter weather station

Incident area

command post

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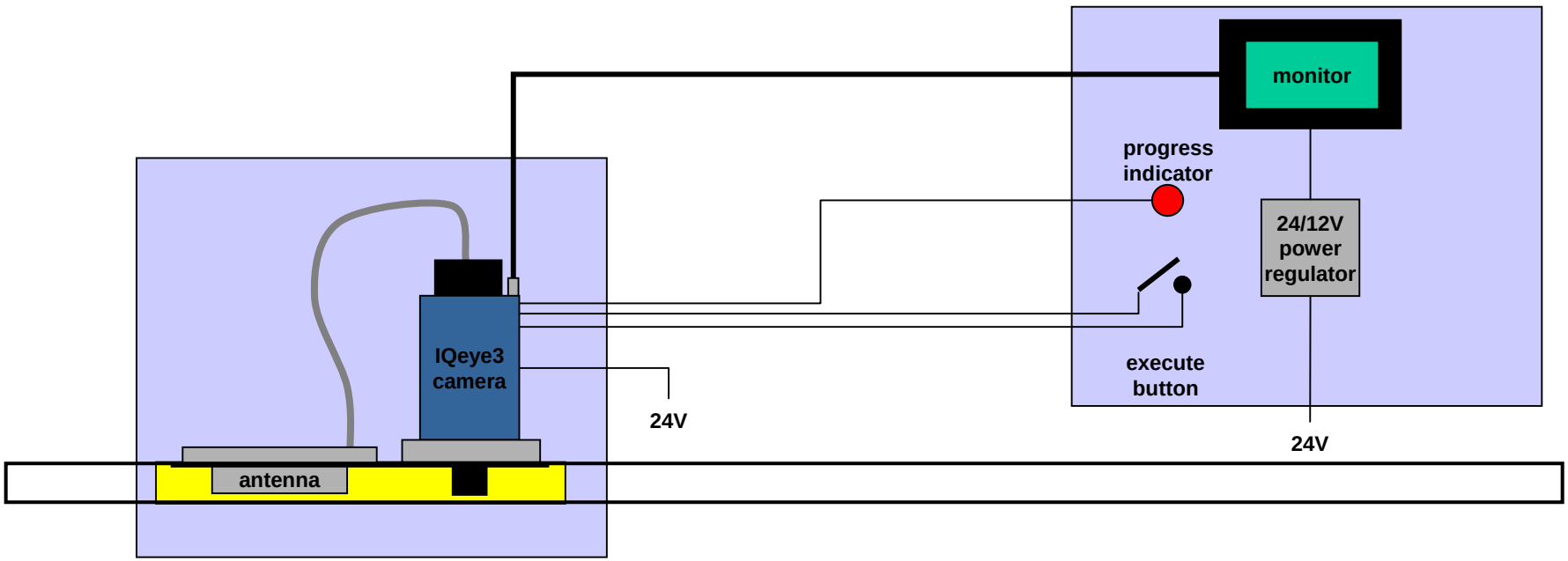
OV-10 camera concept



Annual HPWREN Users Workshop

2004 HPWREN Annual Users Meeting

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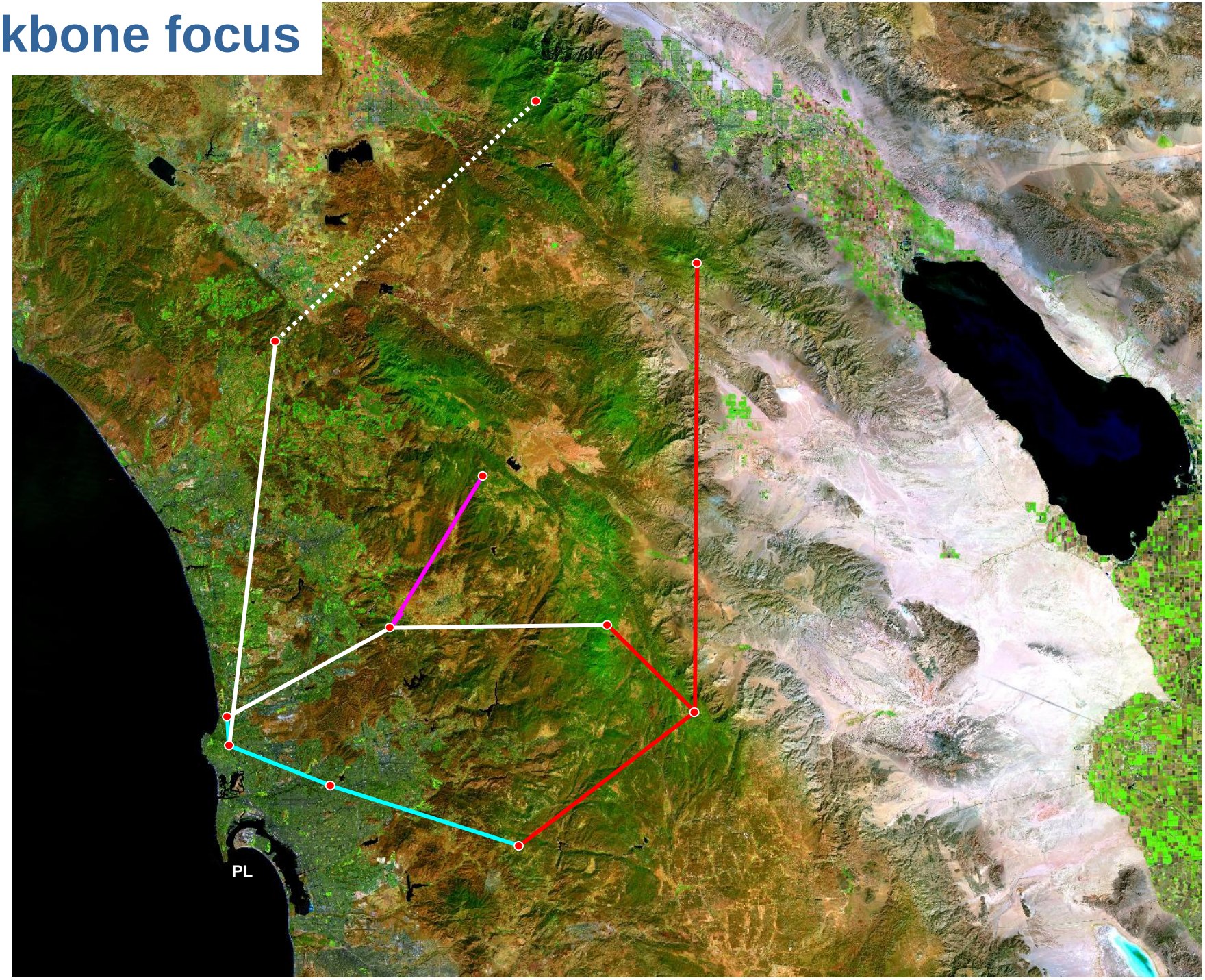
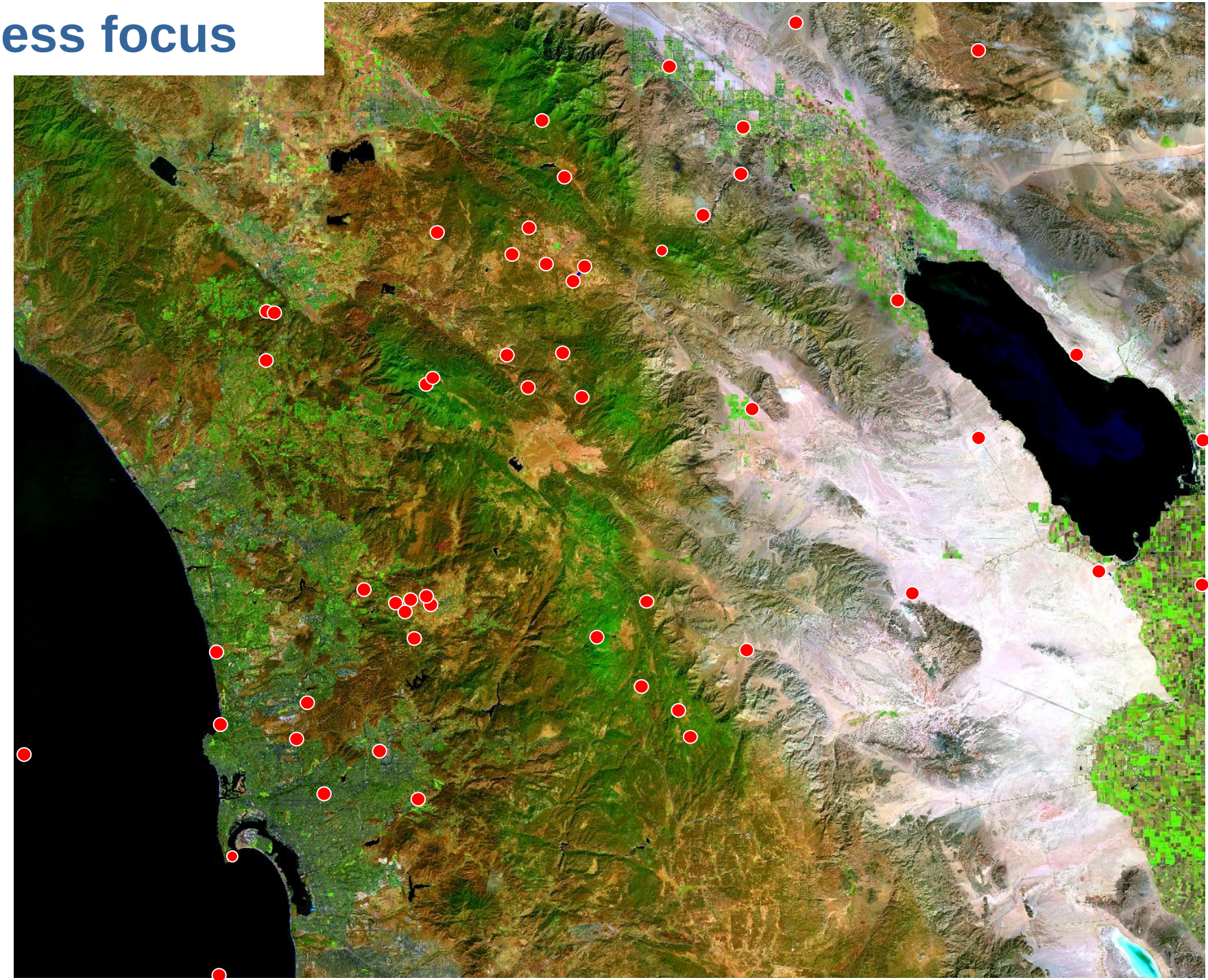
Strategies

Backbone focus



Access focus



Web pages

- **main site:** http://hpwren.ucsd.edu/
- **cameras:** http://hpwren.ucsd.edu/cameras
- **sensors:** http://hpwren.ucsd.edu/Sensors
- **statistics:** http://stat.hpwren.ucsd.edu/
- **various photos:** http://hpwren.ucsd.edu/Photos