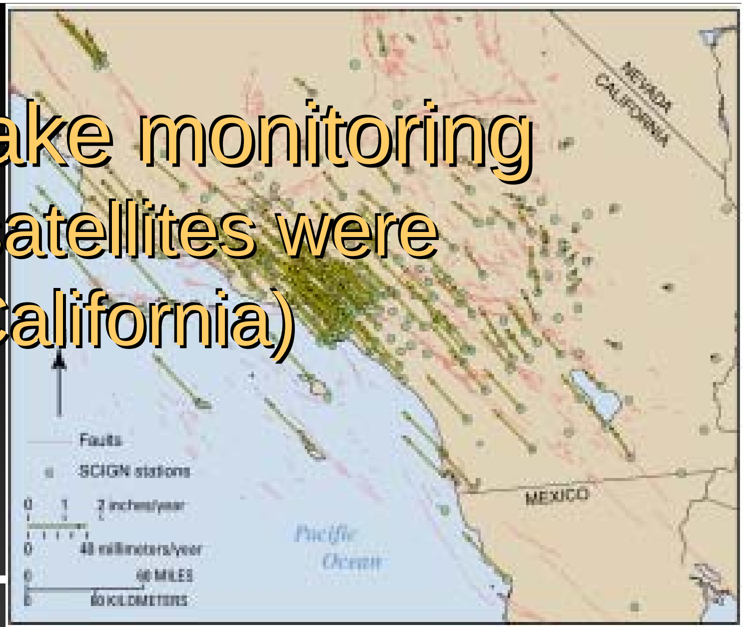
SCIGN science report
& GPS fault slip sensors

Kenneth W. Hudnut *USGS, Pasadena, CA*

UJNR Earthquake Research
Panel Meeting
Morioka, Japan
Nov. 6-7, 2002

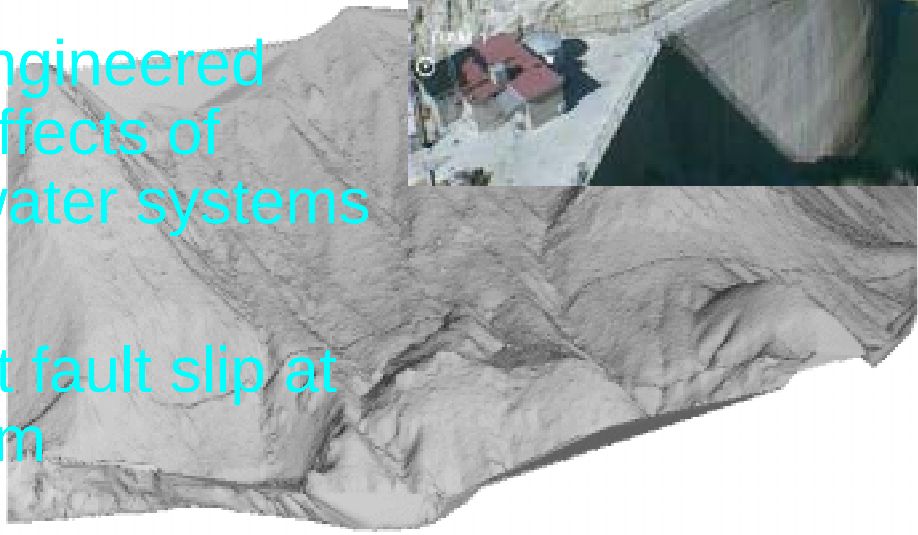
GPS is now vital to earthquake monitoring
(array technology and GPS satellites were developed in Southern California)



Measures buildup of strain on faults due to accumulating tectonic motion

Used to detect damage to large engineered structures such as dams, and effects of ground tilt and subsidence on water systems

Can be used in real-time to detect fault slip at surface, for early warning system



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- Damage estimation
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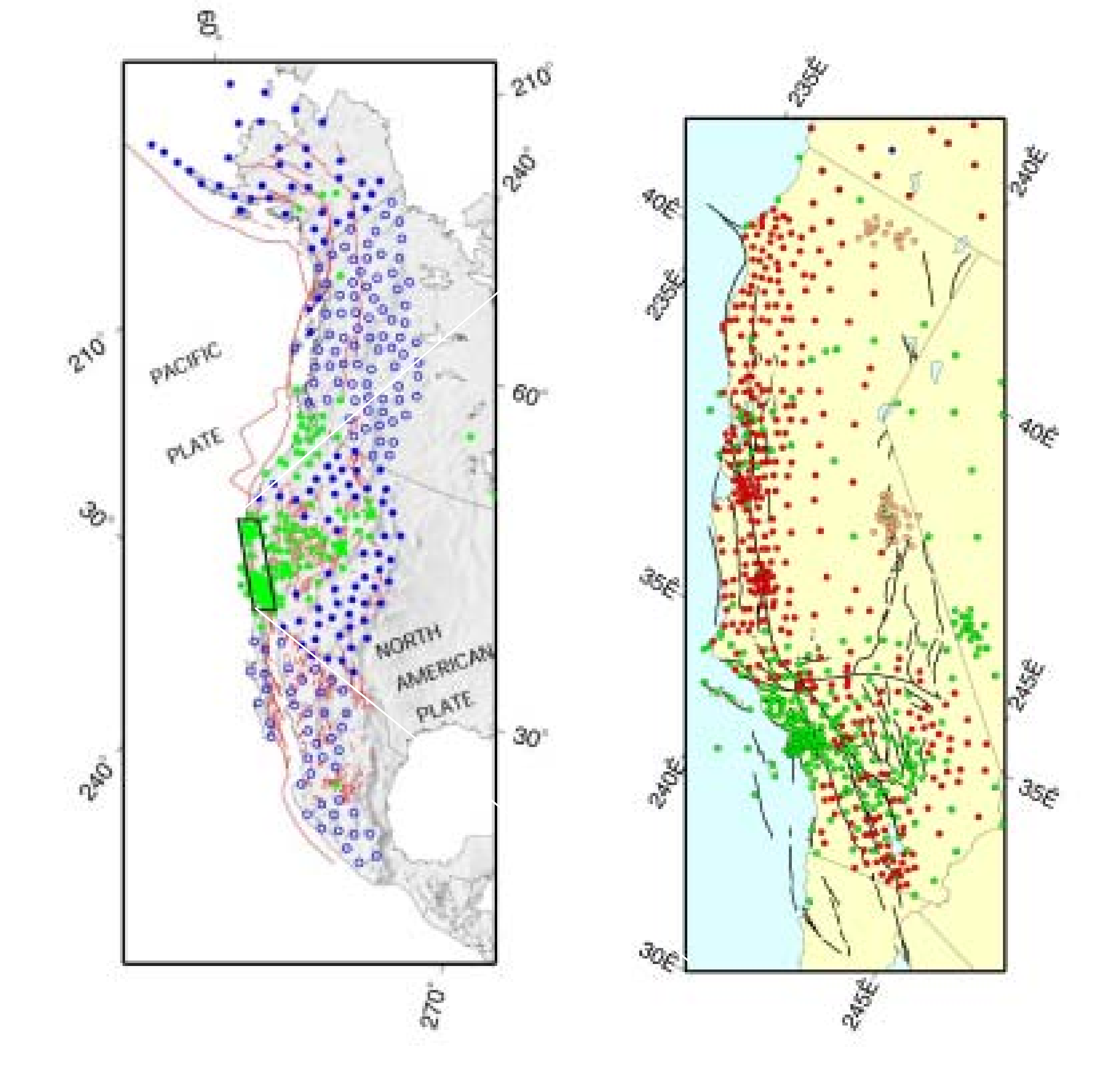
- Infrastructure for positioning
  - to support spatial and temporal aspects of *fundamental data collection and mapping* (e.g., surface rupture mapping - ALSM)



The Plate Boundary Observatory

- GeoNet & SCIGN are prototype deployments for PBO
- PBO will extend the GPS & strain arrays throughout the Western U. S. A. and Alaska
- With Canada and Mexico, we hope to cover the North American – Pacific plate boundary

SCIGN

SOUTHERN CALIFORNIA INTEGRATED GPS NETWORK

The SCIGN array uses GPS to measure the buildup and release of strain on the fault system in southern California

Operational Groups:

USGS science for a changing world

SOPAC

JPL

Major Funding (total of $18 M)

W. M. Keck Foundation

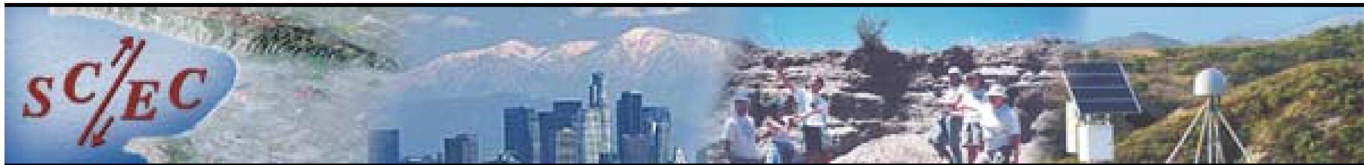
NASA

NSF

USGS science for a changing world

SCEC

SCIGN is an integral part of SCEC



SCIGN
SOUTHERN CALIFORNIA INTEGRATED GPS NETWORK

Status and Plans

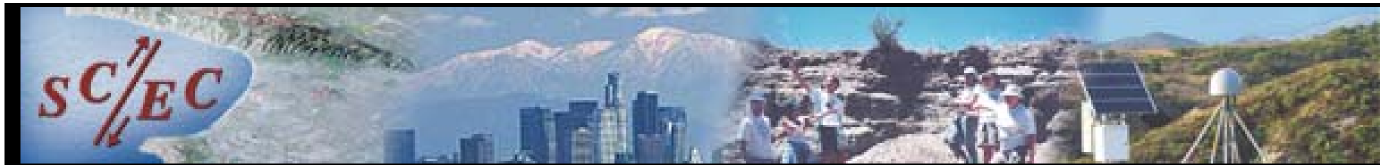
- SCIGN is now almost entirely built (a few remaining things to finish). There's always room for improvement, but we're just about out of W. M. Keck Foundation money (we are under-funded through our current sources of support to continue basic operations in future years).

- Impressive list of accomplishments as of April 2002 is on the SCIGN web site. Analysis Committee has re-run '96-'02 series - they agree very well (<1 ppb). Velocities estimated robustly to within 0.5 mm/yr for many stations already (after ~3 yrs.), but groundwater effects confirmed to be a major effect on some stations. Reports due to W. M. Keck Foundation and SCEC BoD. Operations plan update is needed - the EC has agreed to request approx. $1.5M/yr. The SCIGN CB has approved, but we need to raise that money.

- We are working with UNAVCO, Inc. and the PBO community on a major, collective proposal to the NSF. The proposal is due in early December - Will Prescott is PI and has asked for input from SCIGN - we are providing this. We also will submit a major cooperative proposal to NASA with Fra nk Webb as PI (due at JPL on Nov. 19).

- Many who had major roles in SCIGN are now very active in the UNAVCO, Inc. and PBO groups that are carrying forward the PBO initiative. Through this input, lessons learned in creating SCIGN ought to be taken into account during construction of the PBO.

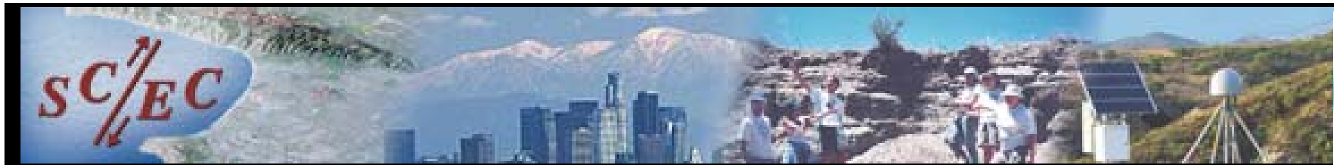
SCIGN
Southern California Integrated GPS Network
Pacific Ocean
UNITED STATES
MEXICO
NEVADA
ARIZONA
SONORA
BAJA CALIFORNIA
Gulf of California
Los Angeles
San Diego
Phoenix
Long Beach
Santa Catalina Island
Oceanside
Escondido
El Cajon
Tijuana
Tecate
Mexicali
Ensenada
Santo Tomás
Lázaro Cárdenas
San Vicente
Colnett
Colonia Vicente Guerrero
San Quintín
El Rosario de Arriba
Misión San Fernando
Santa Inés
Laguna Chapala
Punta Prieta
El Toro
Bahía de los Ángeles
Ángel de la Guarda
Agua de las Flores
La Rumorosa
La Puerta
San Luis Río Colorado
Colonia Benito Juárez
Riito
La Ventana
Sonoyta
Puerto Peñasco
Heroica Caborca
Yuma
Dateland
Gila Bend
Ajo
Tohono O'odham I.R.
San Luis
Blythe
Kofa N.W.R.
Parker
Aguila
Wickenburg
Congress
Peoria
Prescott
Prescott Valley
Chino Valley
Seligman
Williams
West Sedona
Kingman
Hualapai I.R.
Lake Havasu City
Bullhead City
Needles
Henderson
Death Valley N.P.
Baker
Barstow
Ridgecrest
Lake Isabella
Porterville
Delano
Wasco
Bakersfield
Paso Robles
San Luis Obispo
Santa Maria
Lompoc
Santa Barbara
Oxnard
Lancaster
Victorville
Apple Valley
Hesperia
Riverside
Hemet
Indio



SCIGN
SOUTHERN CALIFORNIA INTEGRATED GPS NETWORK

Science Review

- List of publications - updates on the main project web page at http://www.scign.org/
- 45 papers from 1996 through April 2002 (includes several on Hector Mine co-seismic) - many important contributions that would have been impossible without SCIGN.
- BSSA Hector Mine special issue (May, 2002) contains ***16 papers*** (out of a total of 36) that made direct or indirect use of SCIGN data. Nearly all 36 then also cited these 16.
- Fall AGU 2002 abstracts contain reports on several new projects using SCIGN data in innovative ways, as well as reports of the new results from the ongoing and coordinated SCIGN Analysis Committee effort, chaired by Nancy King. The use of continuous GPS data for various geophysical and other uses is increasing worldwide, and SCIGN has provided data used in a far wider range of studies than was ever imagined (e.g., *Varner and Cannon*, 2002). The open data policy has been a key to success.
- SCIGN has become an integral part of what the broader SCEC community does in southern California. These results influence peoples' thinking well outside of our regional scope, just as we all learn greatly from studies of other regions. Others see the value inherent in having a state-of-the-art array like SCIGN available (hence the PBO part of the EarthScope initiative). New data products are making SCIGN data more easily accessible to a larger and broader base of earthquake and other earth scientists.



SCIGN Data Products

1st Year

- Combined time series (1996-2002)

3rd Year

- Real-time earth-quake response

5th Year

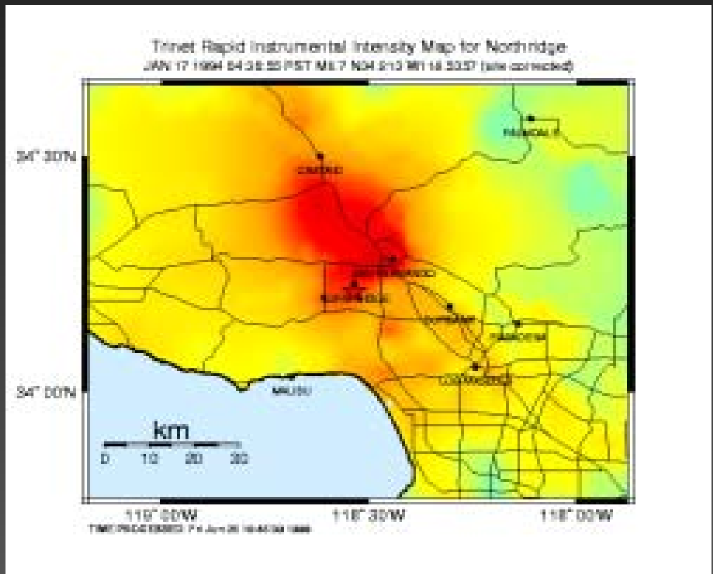
- Resolve rates on primary LA basin faults (and others)

- **Earthquake response**
  - *rapidly assess the earthquake source*

Hector Mine (M_w7.1)

● Damage estimation

➢ *rapidly assess damage, casualties, and losses*



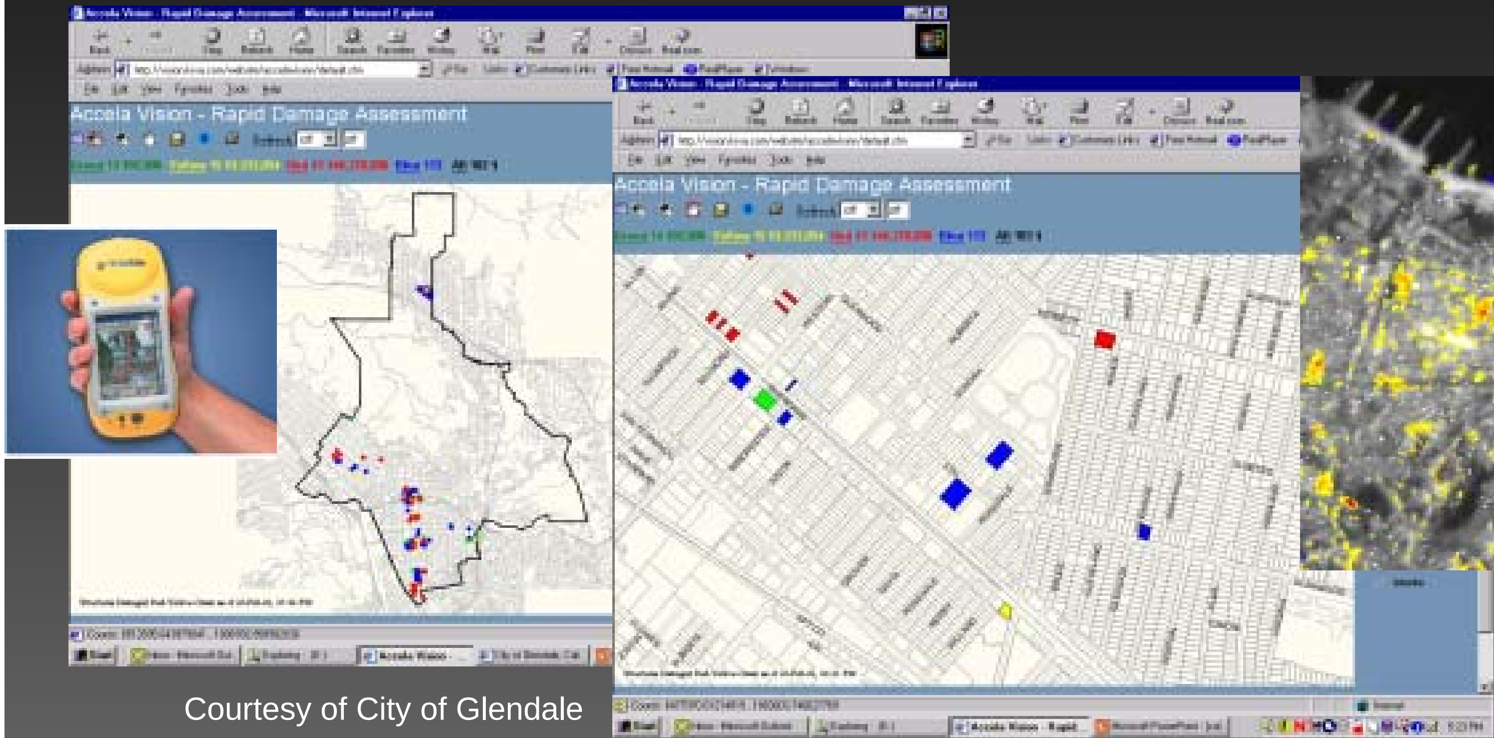
ShakeMap/HAZUS

Pacoima Dam GPS structural health monitoring system

(with LA County since Sept. 1995)

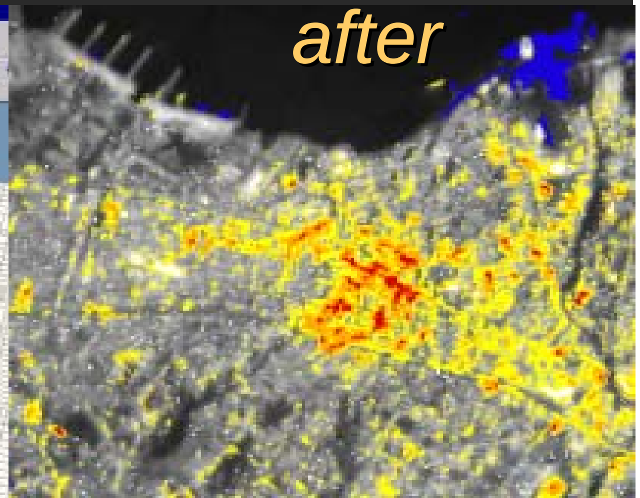
Infrastructure for positioning

- *supports data collection and mapping during disaster recovery efforts*



Courtesy of City of Glendale

imagery before & after



Courtesy of Ron Eguchi

ATC-20 building safety inspections (red, yellow and green tagging)

GPS can help with…

- Earthquake response information
  - Identify fault source, extent and amount of slip
  - Model finite fault source
  - Measure and model deformation field
  - Provide all of the above to the public, to emergency responders, and to other scientists
- Damage estimation
  - Provide data for use in HAZUS, etc.
  - Support of remote sensing and positioning for accurate and timely collection, reporting and control of other data that require accurate position and/or timing
- Basic positioning infrastructure

GPS Fault Slip Sensor is proposed to augment *Earthquake Early Warning Systems*

what we cannot do…

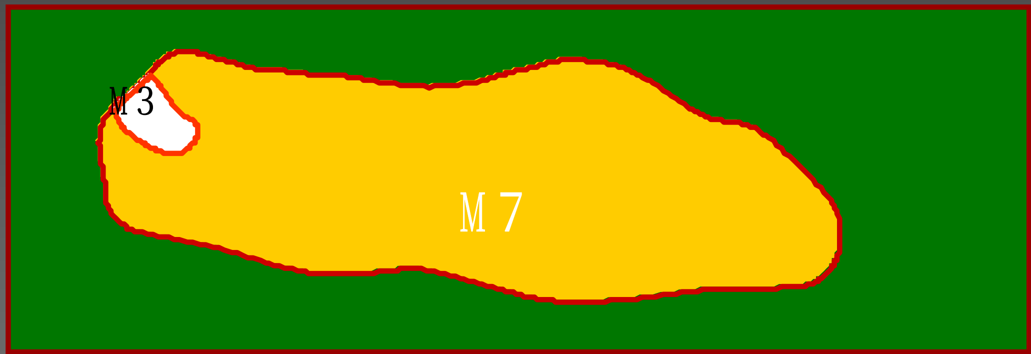
because the physical process is too chaotic

weather – *turbulence*

earthquakes - *friction*

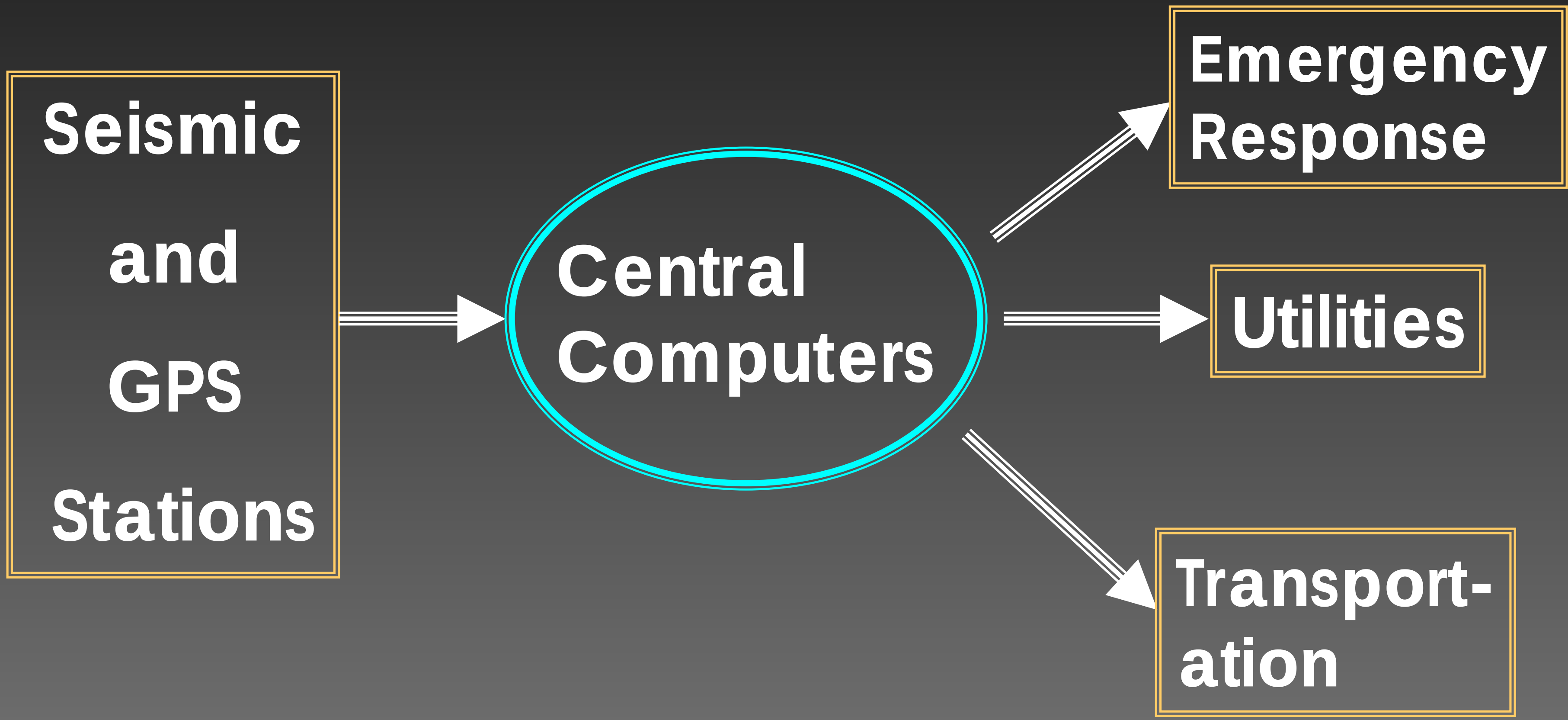
- Recognize a precursor for a particular event
- Differentiate between the beginning of a M3 and a M7

GPS 'slip sensor' can help with this!



Early Warning

The speed of light >> the speed of sound



Mitigative Actions

Is 30 seconds of warning enough?

- Stop trains
- Stop nuclear reactions
- Stop computers
- Secure hazardous materials
- Stop elevators

GPS fault slip sensor

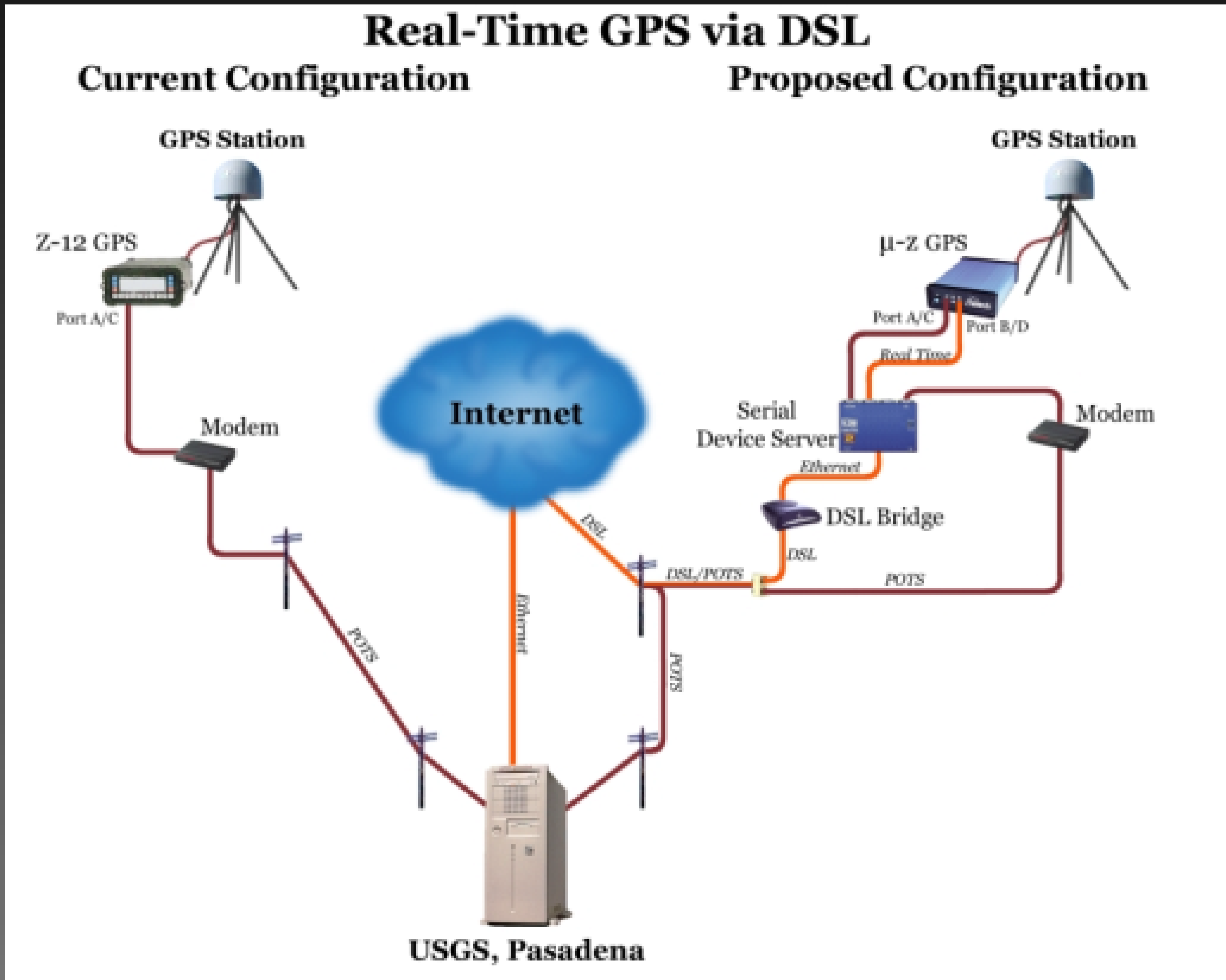
Real-Time GPS Network - enhancing SCIGN

- This week, first-ever GPS fault slip sensor deployed across San Andreas fault at Gorman, Calif.

- Upgrade SCIGN telemetry
  - DSL, frame relay
  - Radio repeaters, WiGate and dedicated links
  - Data buffering

- Augment SCIGN real-time acquisition and processing system
  - Currently testing and implementing sub-daily processing (4 hr) for most SCIGN stations (down from 24 hr)
  - Implementing multiple real-time streaming GPS processors (commercial software)

SCIGN station upgrade to DSL real-time system

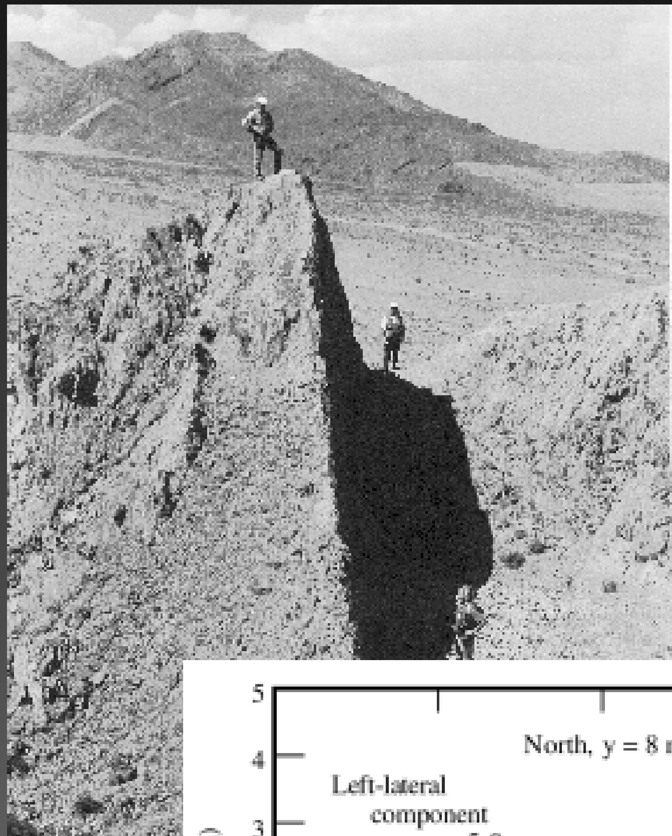


GPS can help with…

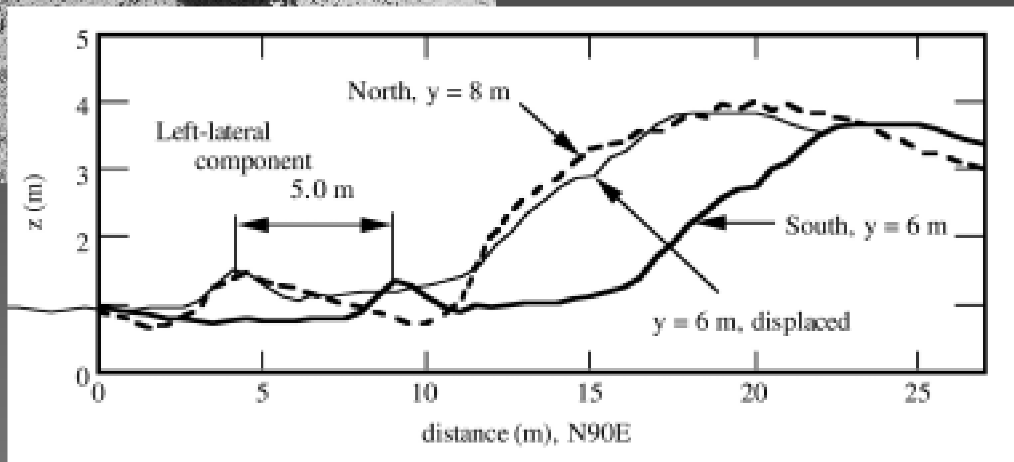
- Earthquake response information
- Damage estimation
- Basic positioning infrastructure
  - Remote sensing
    - Example: Hector Mine earthquake - high resolution topographic mapping using airborne laser scanner and digital imaging
    - Precise trajectory and orientation for airborne imaging platforms (as well as for satellites)
  - Field data collection
    - Example: PDA's for ATC-20 forms
    - Field data collection by geologists, seismologists, others

New methods and data integration

- Precise topographic mapping of surface ruptures and active fault scarps
  - slip models for prehistoric events
  - rapid assessment of surface slip and damage patterns after large events
  - Requires precise integration of GPS & INS for flight navigation



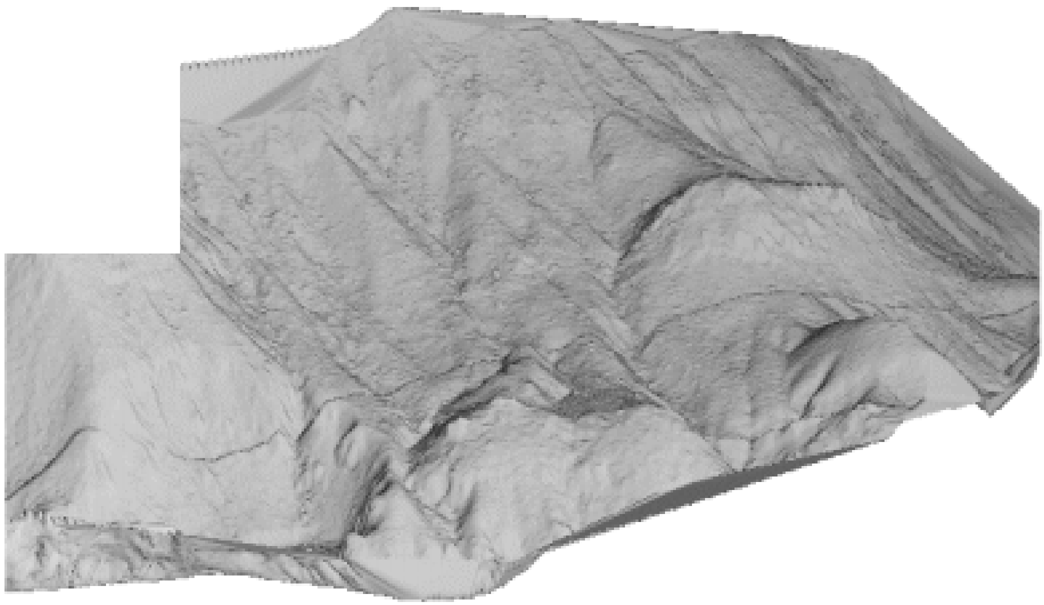
1957 Gobi-Altai earthquake surface rupture



Surface Rupture

- Mapped by Thomas Dibblee, while at USGS
- Lavic Lake fault in recognition of breaks through dry lake bed
- Up to 5.5 m of right-lateral motion
- Over 45 km overall length of surface rupture
- Only ruptured once previously through 50,000 year-old soils
- Old fault looked harmless, but produced a big earthquake
- May 2002 is the *BSSA* special issue

Estimating slip on ‘max. slip’ segment of the fault



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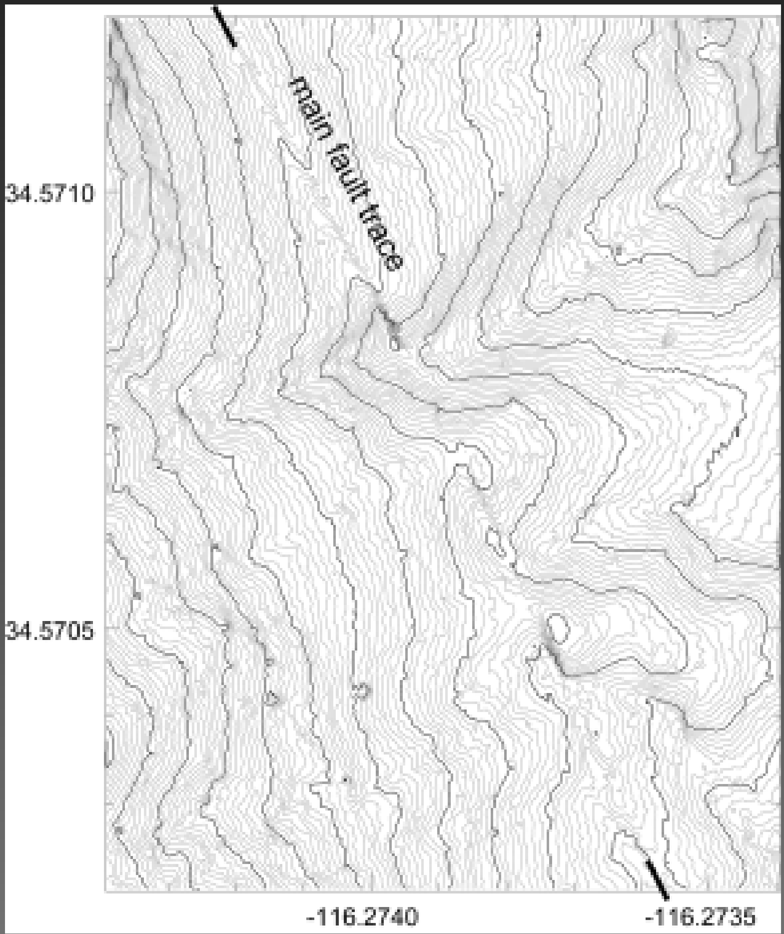
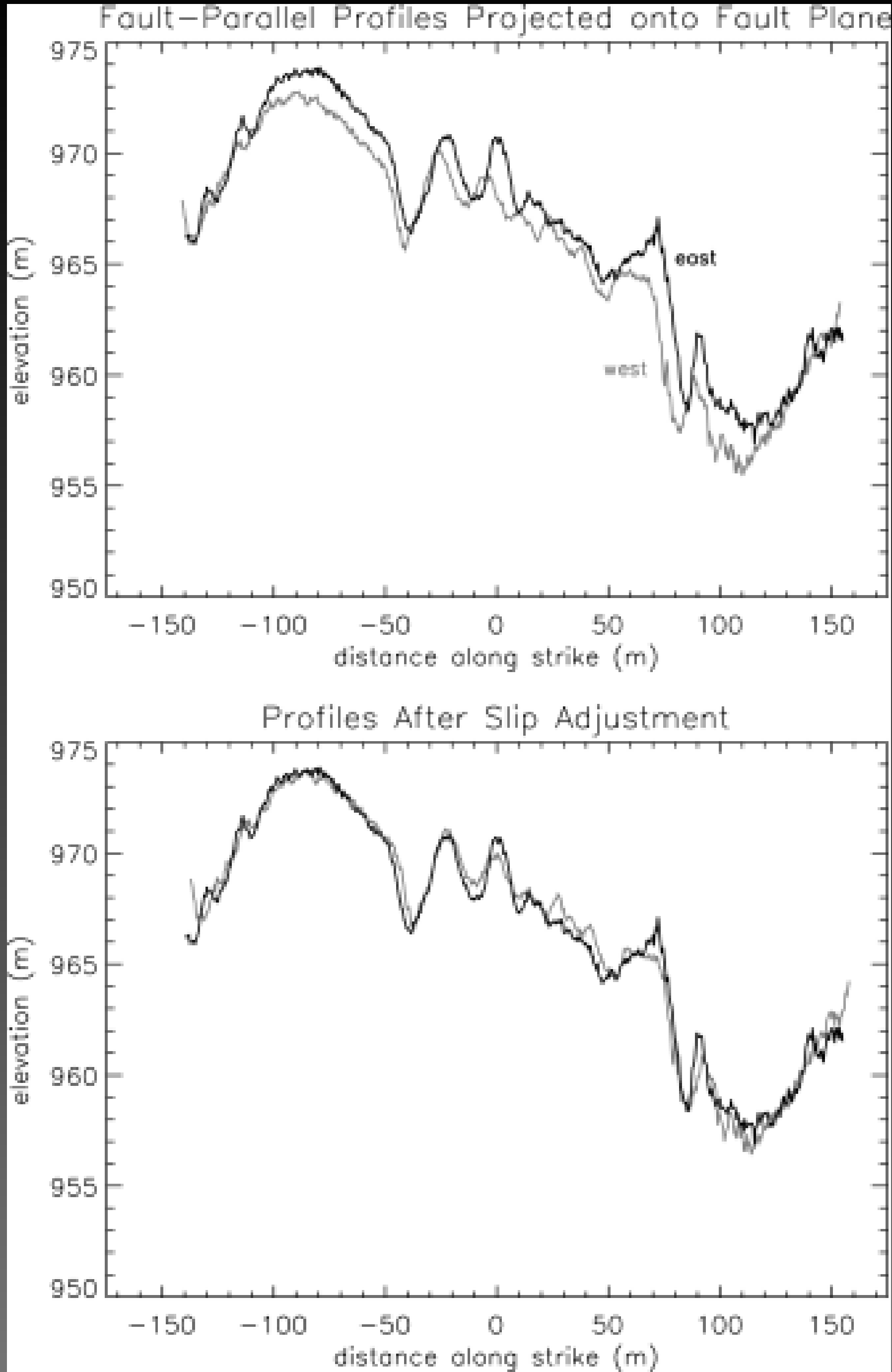
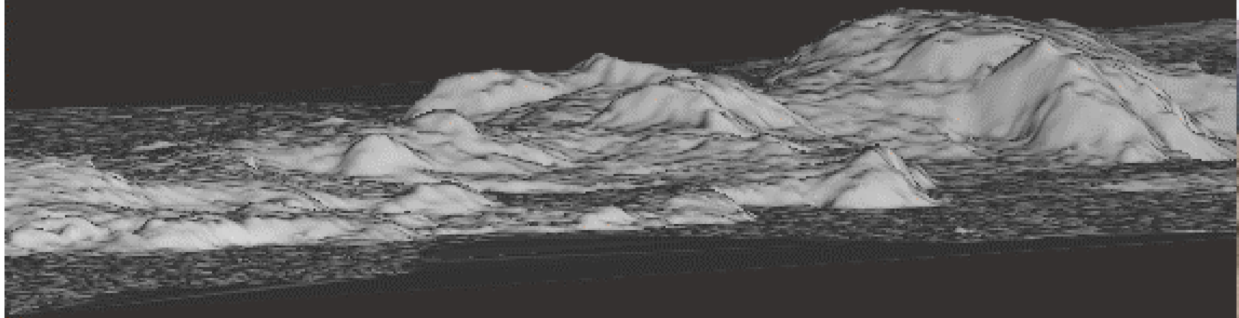




New methods and data integration

- precise topographic mapping of surface ruptures and active fault scarps

Airborne platform navigation must be highly precise and requires high-rate GPS data



- representation of actual fault ruptures recorded and preserved in unprecedented detail for use by future earthquake researchers

Concluding remarks

- State-of-the-art GPS networks and technology development have become vital infrastructure for earthquake research and response:
  - Static deformation field data; source models & rapid tilt and strain mapping
  - Monitoring of large engineered structures (e.g., dams, buildings)

- New enhancements to telemetry support wider range of applications
  - Real-time GPS sub-networks of SCIGN
    - Precise RTK positioning for surveying, AVL and GIS applications
  - InSAR, Airborne Laser Swath Mapping (ALSM) and digital photography
    - SCIGN provides ground control for airborne imaging and surveys
    - Mapping and imaging for rapid assessment of damage to buildings, lifeline infrastructure, etc. (The National Map; Homeland Security)

- Collaboration between Scientific, Surveying, GIS, Engineering and Transportation communities has mutual benefits - this is expected to help with funding our scientific projects in the future

Arthur C. Clarke's 2nd Law:
"The only way of discovering the limits of the possible
is to venture a little way past them into the impossible."
For additional information –
hudnut@usgs.gov
http://pasadena.wr.usgs.gov/
http://www.scign.org/
http://www.trinet.org/
USGS photo
by John Galetzka