Improving GNSS for Future Natural Disaster Reduction:

Earthquakes

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U. S. Geological Survey

GNSS Science & Technology Applications

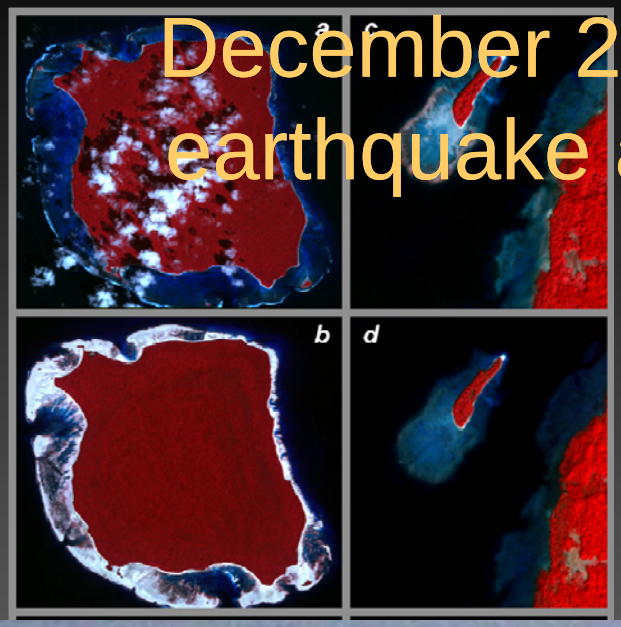
ICG-3

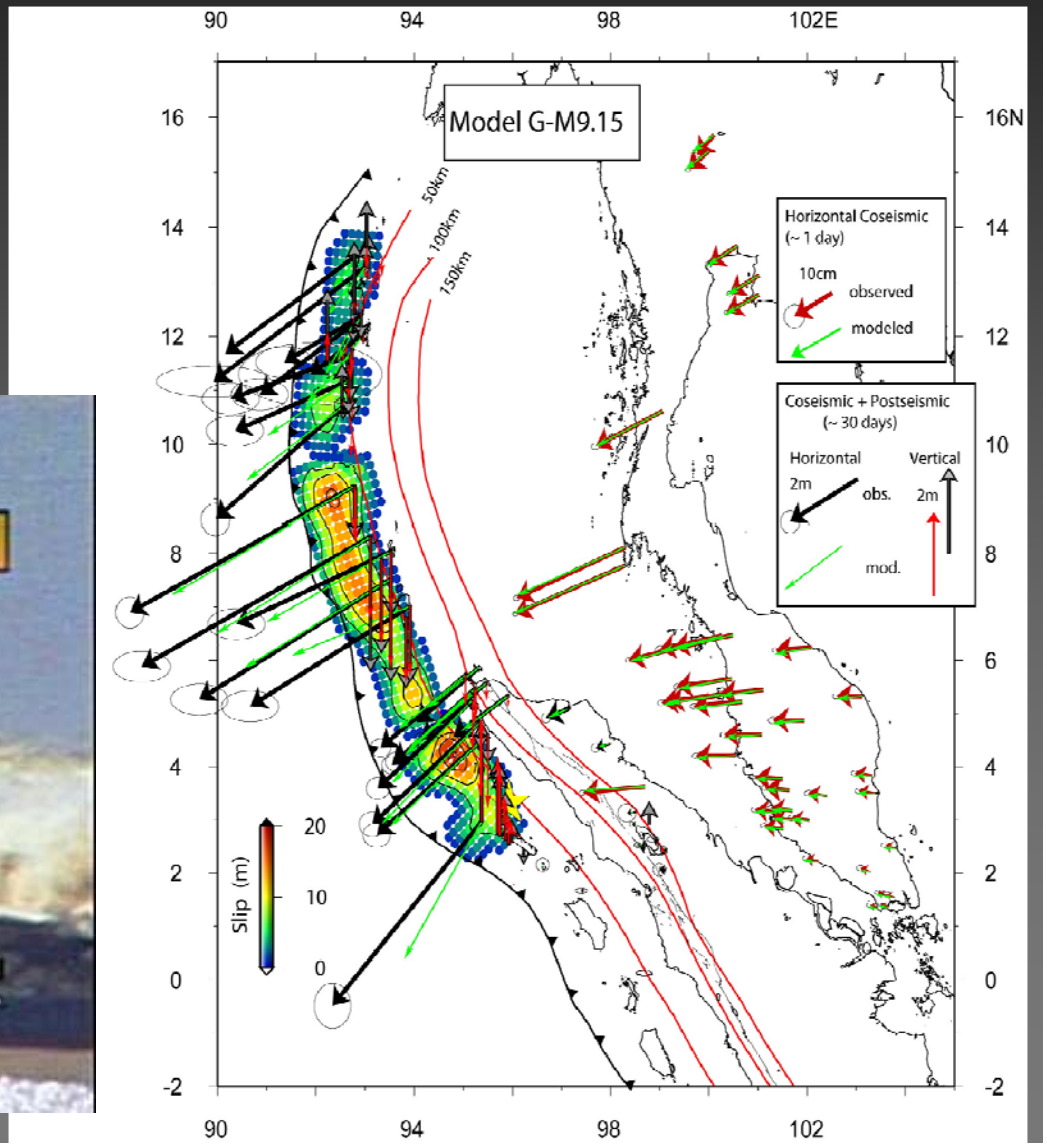
December 9, 2008
Pasadena, California

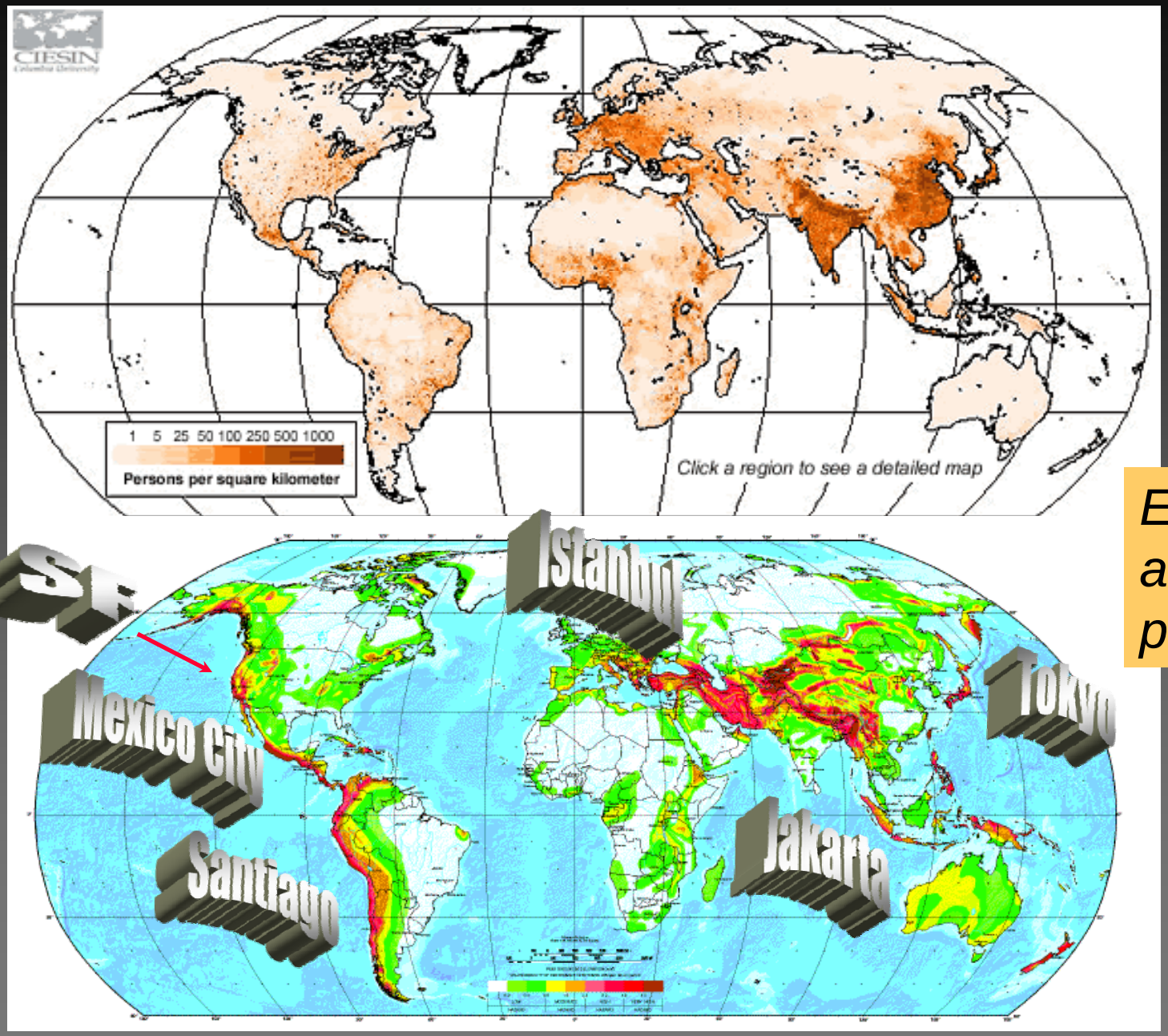
GPS & broadband seismic station on the San Andreas fault

USGS
science for a changing world

December 26, 2004 Sumatra-Andaman earthquake and Indian Ocean Tsunami

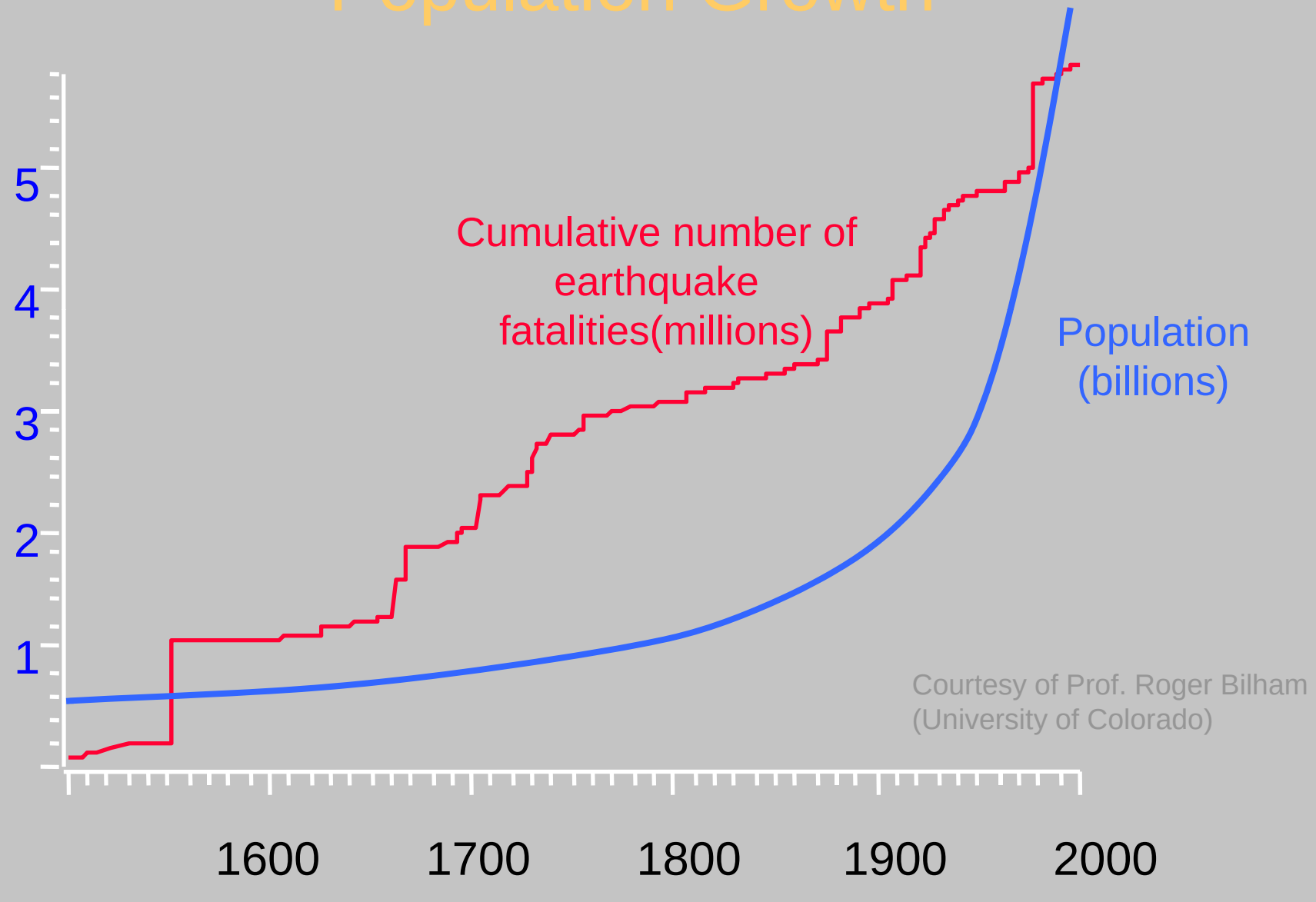






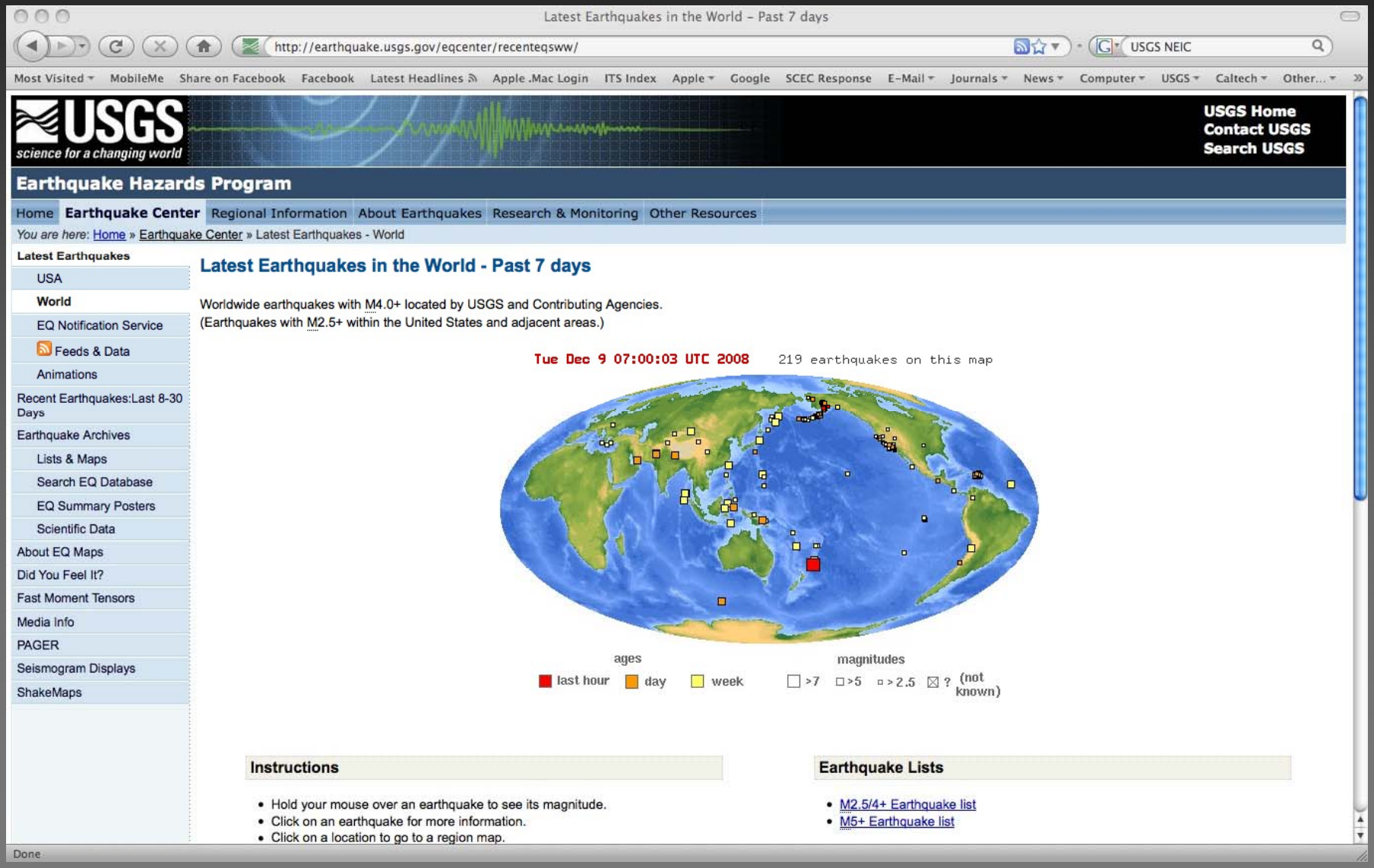
Earthquakes are a global problem

Earthquake Fatalities and Population Growth



Courtesy of Prof. Roger Bilham
(University of Colorado)

GNSS timing for precise earthquake location worldwide - also vital for tsunami alerts



Courtesy of Prof. Tanya Atwater, UCSB

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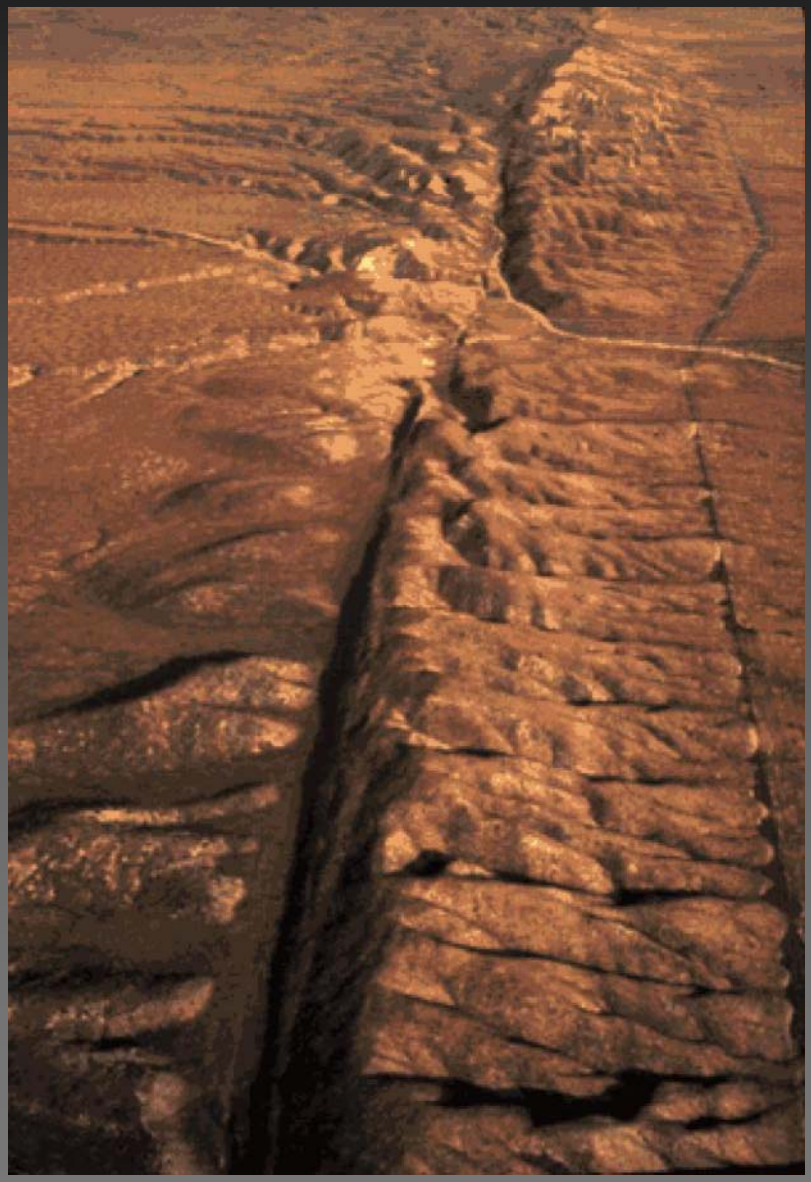
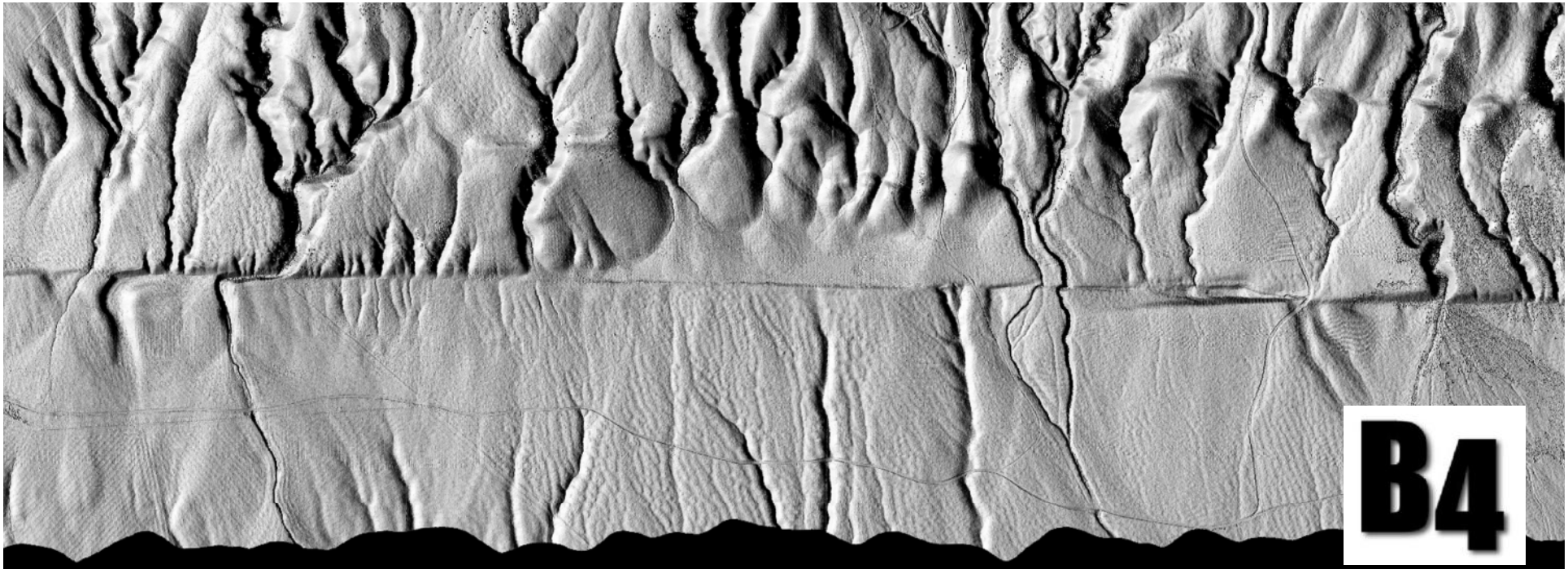
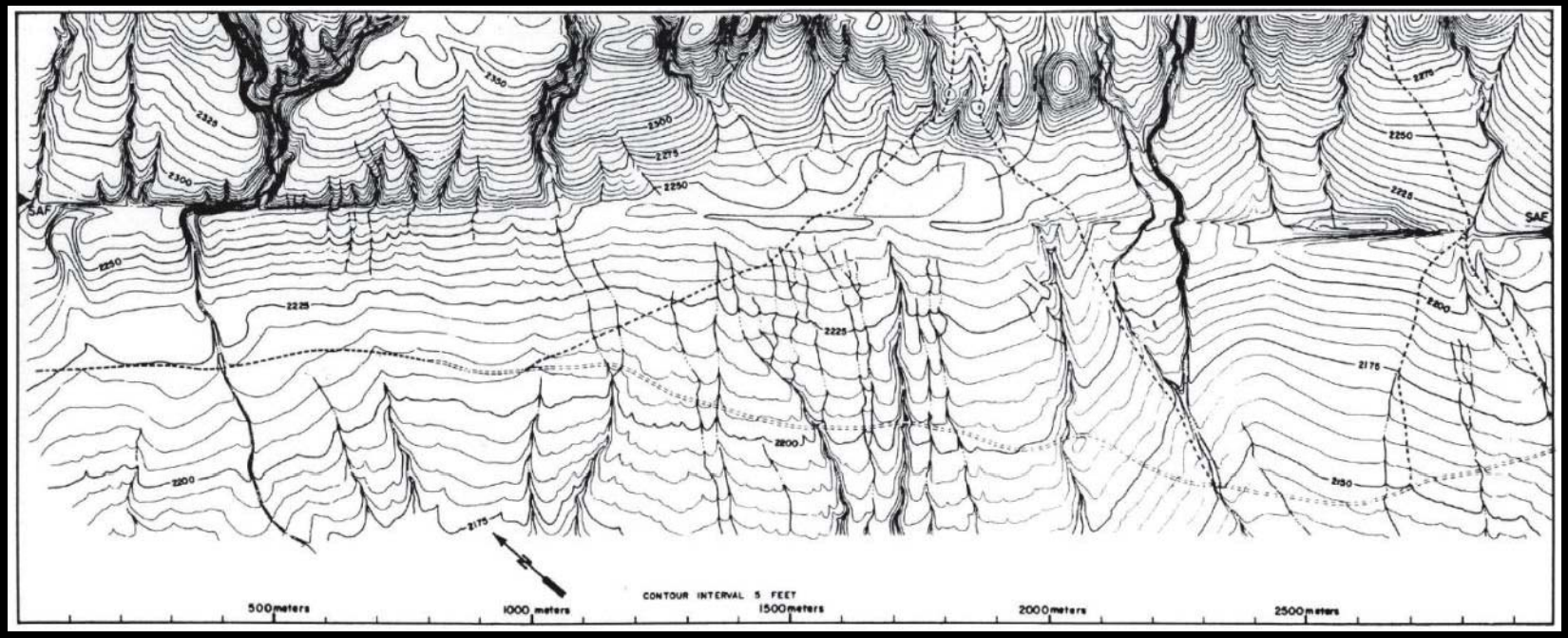
San Andreas fault

- 35 mm/yr slip rate;
  - >70% of plate motion
  - 1685, 1812, 1857 eq's
- Big Bend compression
  - 1971 Sylmar (M 6.7)
  - 1994 Northridge (M 6.7)
- California is now very heavily 'wired' with many GPS stations
- GPS measures plate motion strain accumulation and large earthquake displacements
- 'Natural laboratory' to study future 'Big Ones'
- B4 - Imaged by airborne LiDAR - *GPS was crucial!*



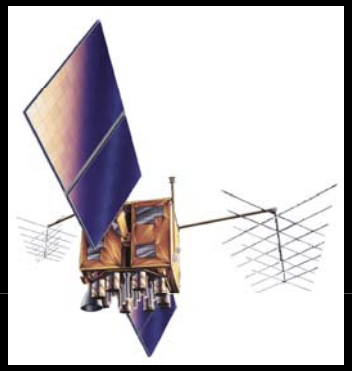


B4


SAF
SAF
2350
2325
2300
2275
2250
2225
2200
2175
2200
2225
2250
2275
2200
2175
2150
CONTOUR INTERVAL 5 FEET
500 meters
1000 meters
1500 meters
2000 meters
2500 meters

SCIGN
SOUTHERN CALIFORNIA INTEGRATED GPS NETWORK

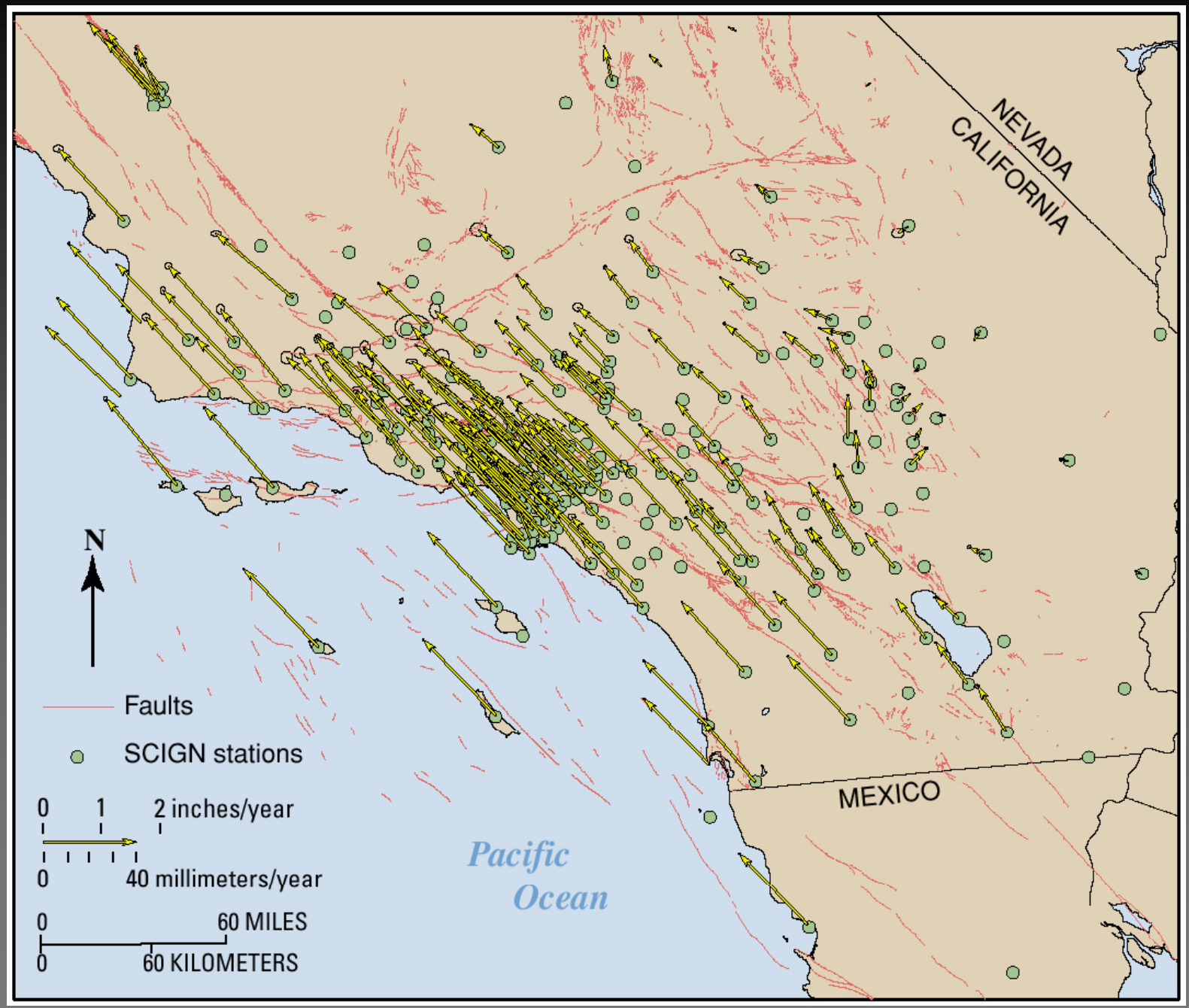
GPS

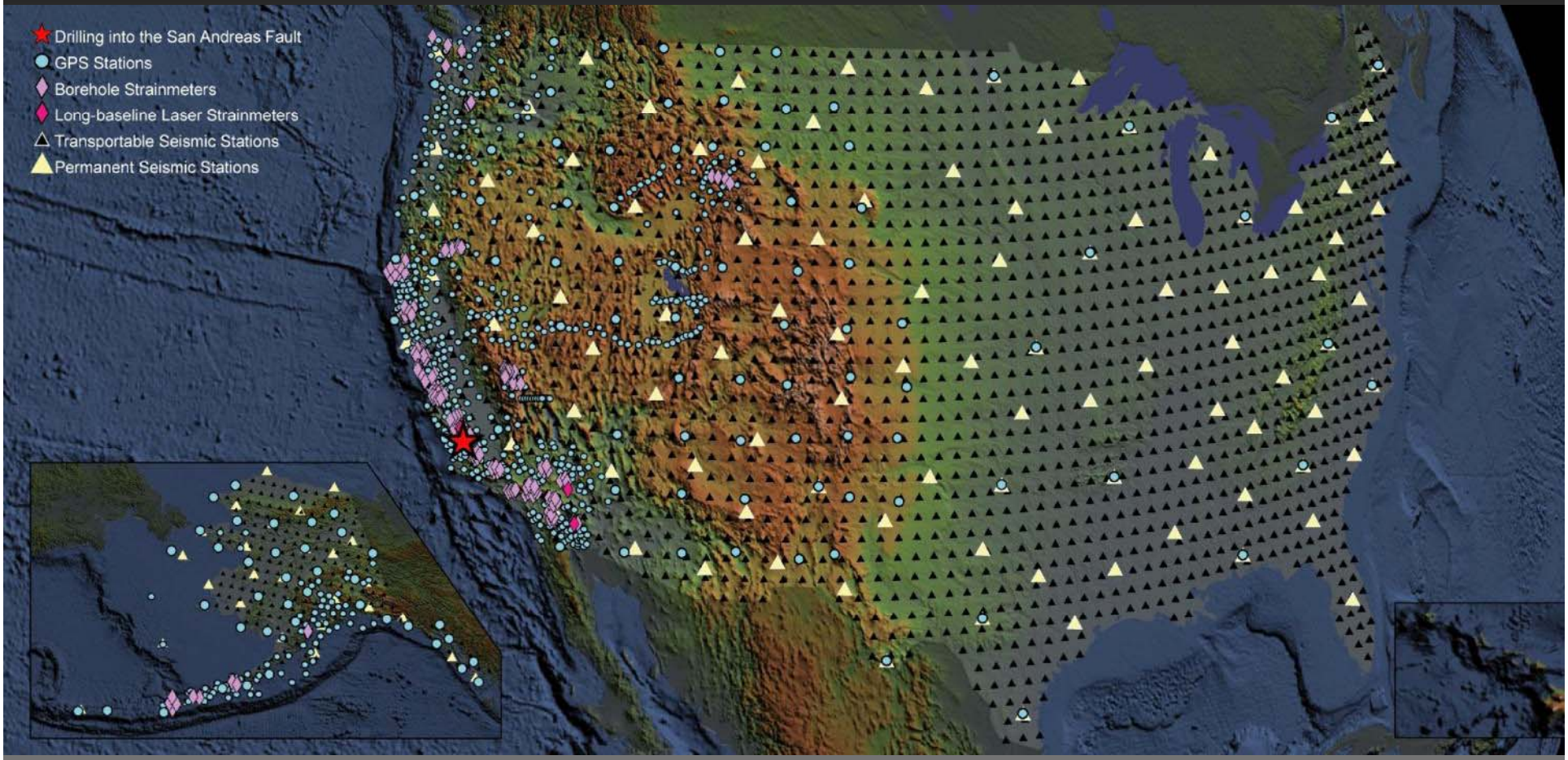


GPS network measures plate tectonic motions to an accuracy of better than 1 mm/yr

We can see whether the motion is ‘slow and steady,’ or perhaps more interestingly it may sometimes accelerate or decelerate

W. M. Keck Foundation
NASA
NSF
USGS
science for a changing world


NEVADA
CALIFORNIA
MEXICO
N
Faults
SCIGN stations
0 1 2 inches/year
0 40 millimeters/year
0 60 MILES
0 60 KILOMETERS
Pacific Ocean

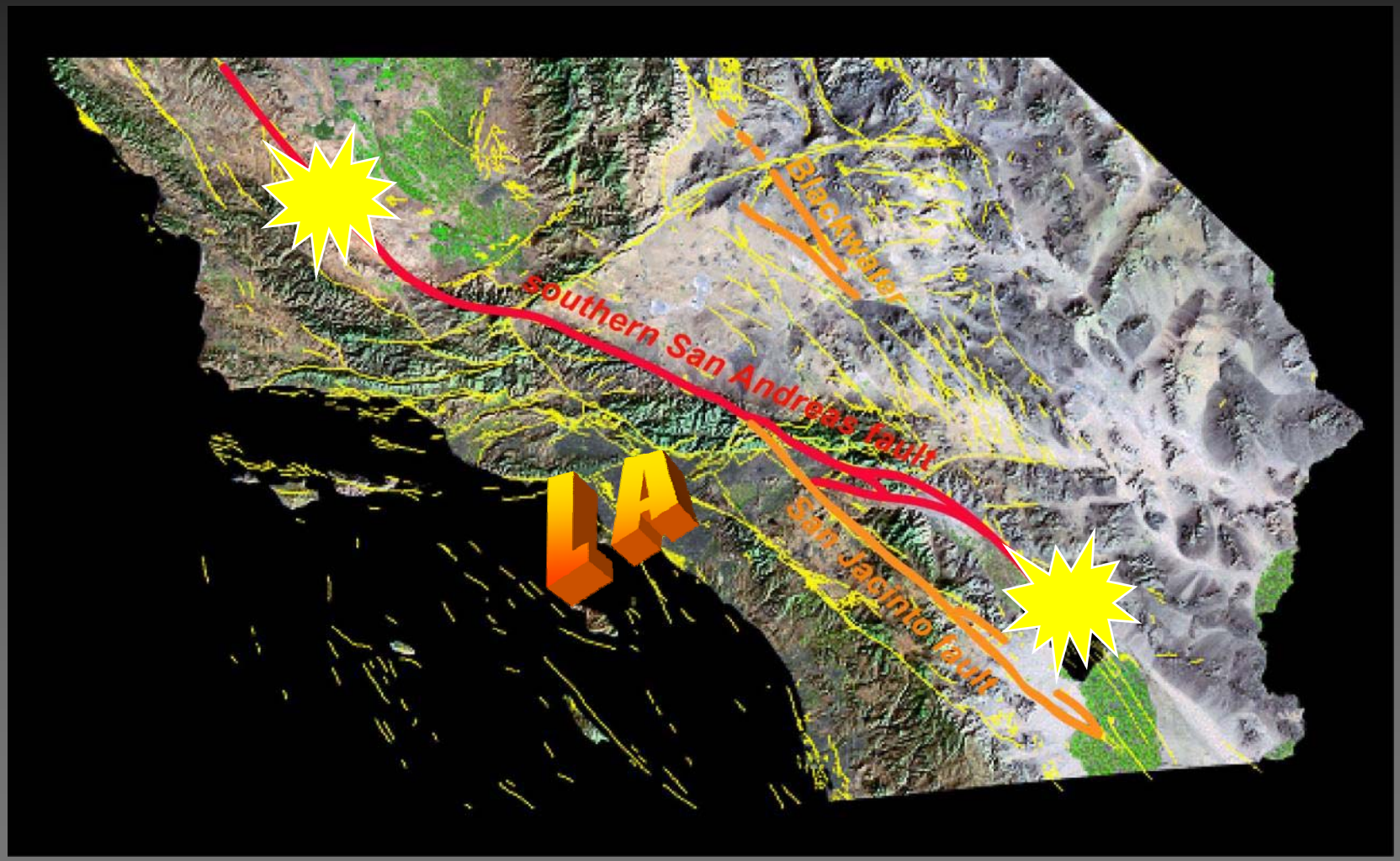


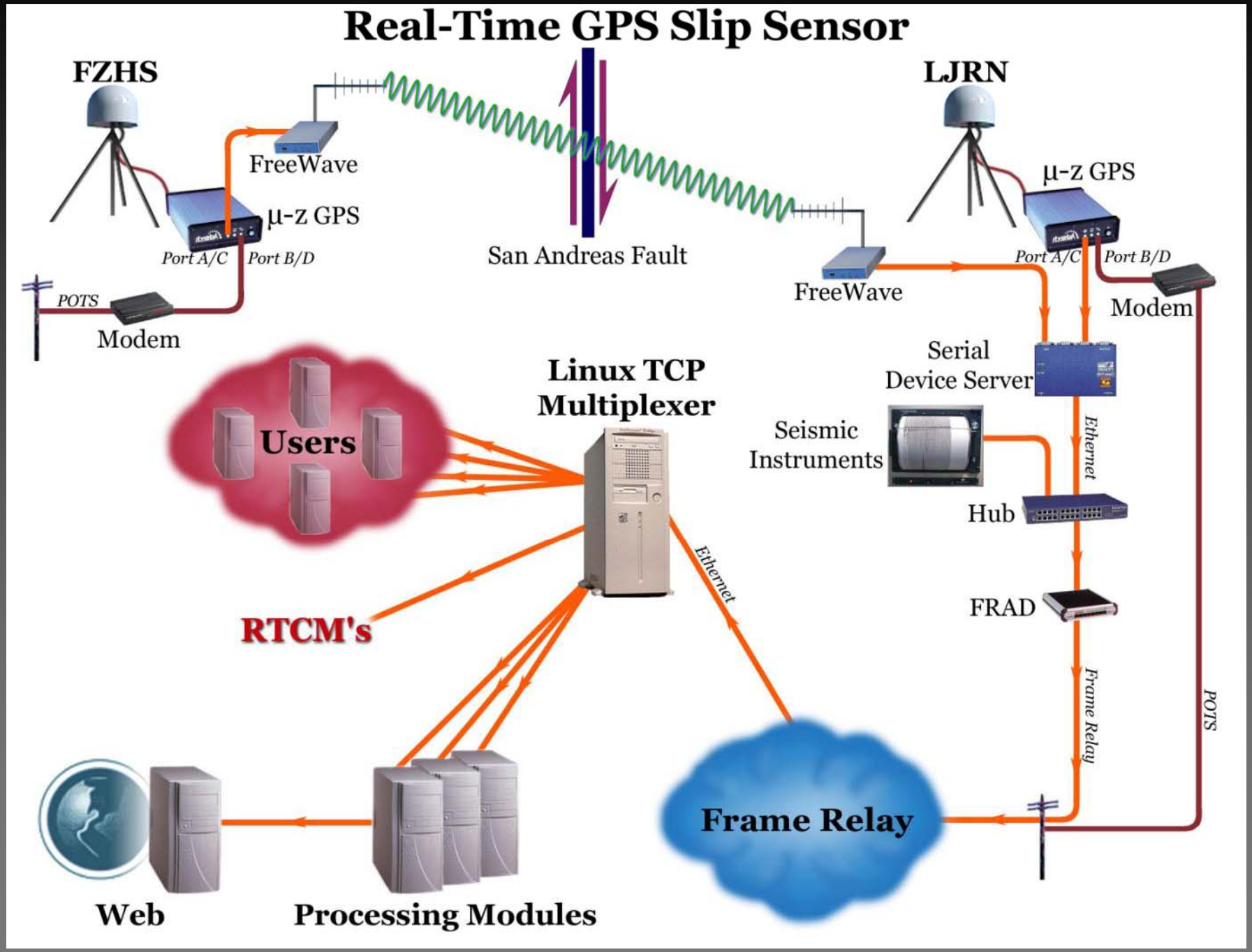
earth scope PROJECT

National Science Foundation
WHERE DISCOVERIES BEGIN

San Andreas - place two bets

both ~120 km from Los Angeles (LA)



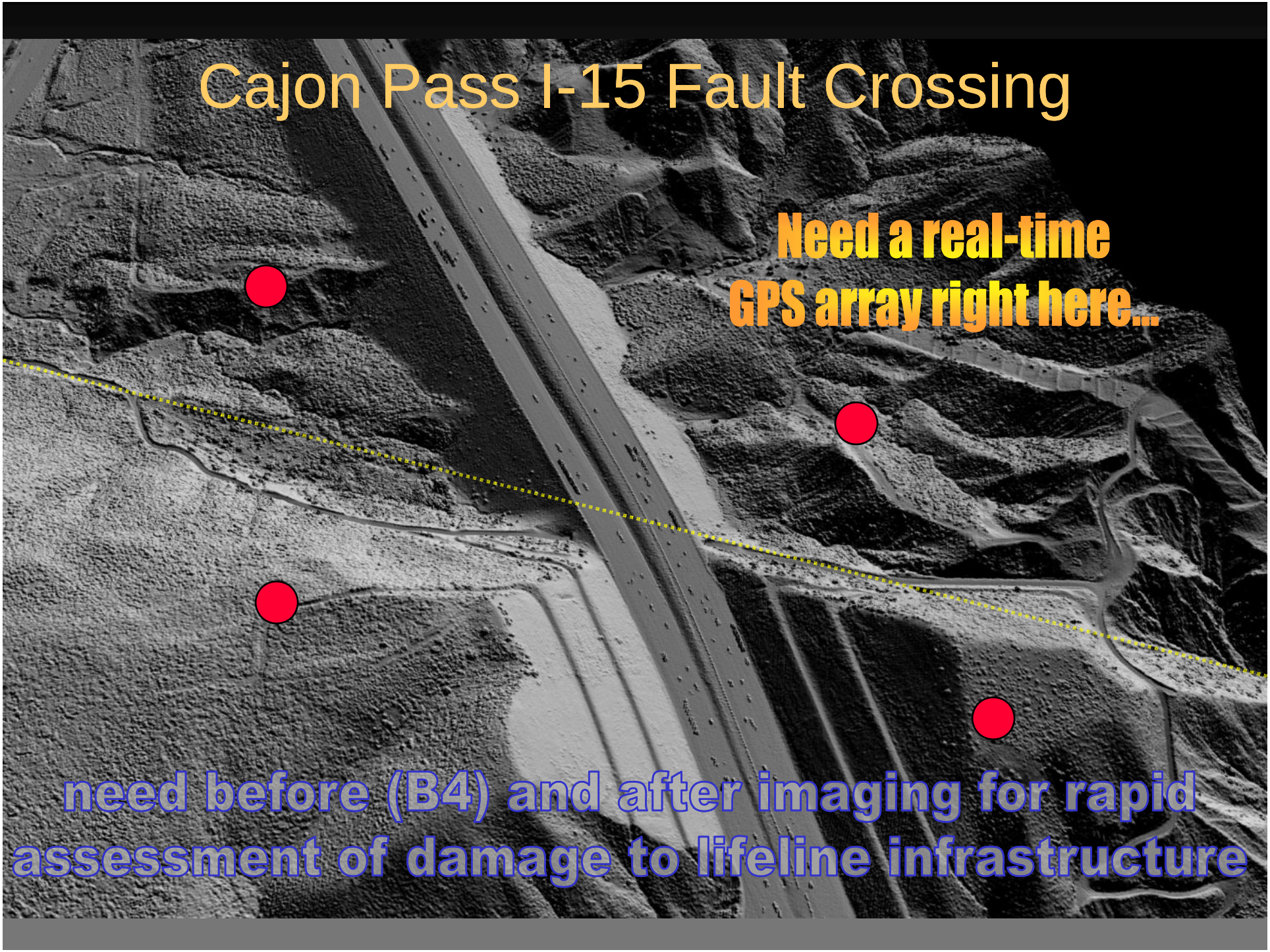

Real-Time GPS Slip Sensor
FZHS
FreeWave
µ-z GPS
Port A/C
Port B/D
POTS
Modem
San Andreas Fault
LJRN
FreeWave
µ-z GPS
Port A/C
Port B/D
Modem
Serial
Device Server
Seismic
Instruments
Ethernet
Hub
FRAD
Frame Relay
POTS
Linux TCP
Multiplexer
Users
RTCM's
Ethernet
Frame Relay
Web
Processing Modules

Lone Juniper Ranch and Frazier Park High School

Prototype GPS fault slip sensor; up to 10 Hz

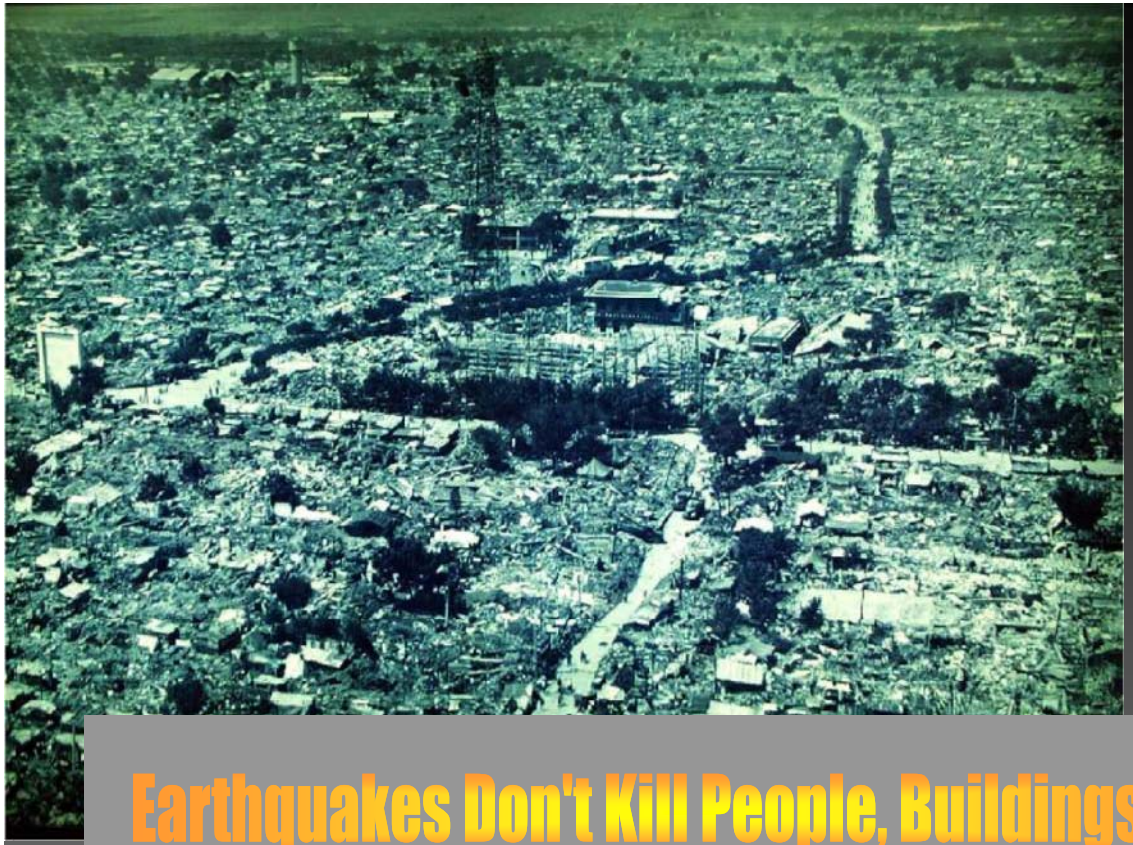
Spans the San Andreas fault near Gorman, California

San Andreas - instrument major lifeline infrastructure crossings


Cajon Pass I-15 Fault Crossing
Need a real-time
GPS array right here...
need before (B4) and after imaging for rapid
assessment of damage to lifeline infrastructure

ShakeOut M 7.8 Simulation - San Andreas

QuickTime™ and a
H.264 decompressor
are needed to see this picture.



Tangshan, China

1976 - M 7.5

255,000

people died

(official)

Northridge, CA
1994 - it *can* happen here

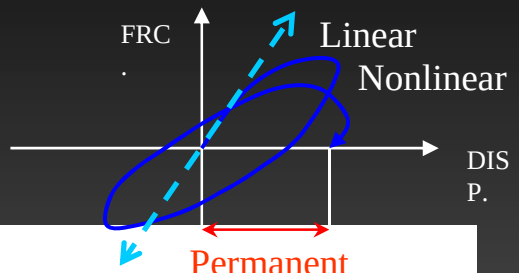
Earthquakes Don't Kill People, Buildings Do...

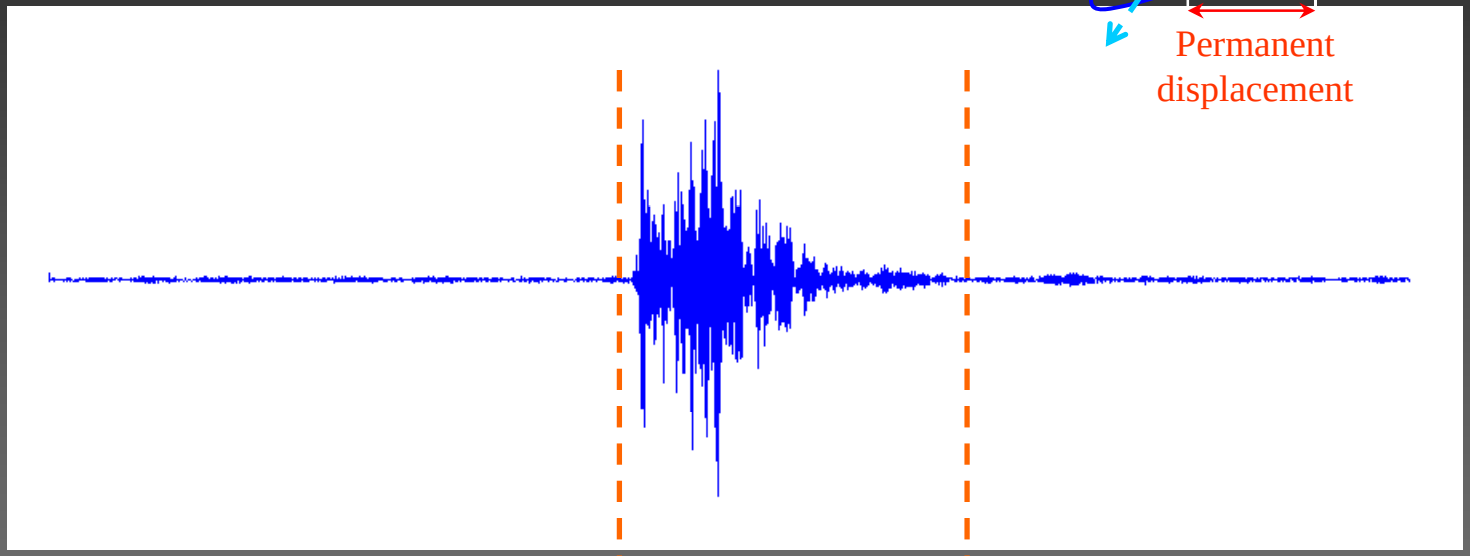
Turkey 1999

Automated Tagging and Real-Time Damage Distribution Maps

Multiple sensor package:

- Acceleration / Velocity
- Displacement (GPS)
- Rotation (tilt-meter)





Pre-earthquake:

- ➢Reference static displacement
- ➢Reference static rotation
- ➢Mean and variance of dynamic characteristics

During earthquake:

- ➢Changes in dynamic characteristics
- ➢Hysteretic behavior
- ➢Damage initiation

Post-earthquake:

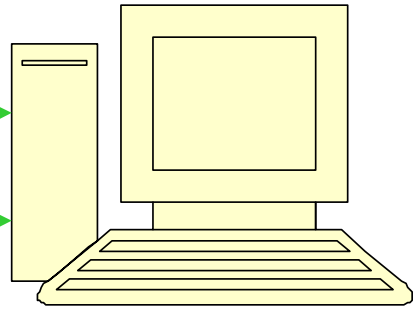
- ➢Permanent static displacement
- ➢Permanent static rotation
- ➢Mean and variance of dynamic characteristics

REAL-TIME DAMAGE ASSESSMENT

•Satellite

•Telemetry

•Internet



Courtesy of
Erdal Safak (USGS)

SENSOR PACKAGE

-Accelerometer

-Tiltmeter

-GPS sensor

GNSS Benefiting Humanity: Earthquake and Tsunami safety

- Global earthquake observation and tsunami alerts (ANSS)
- Airborne imagery positioning for fault zone characterization and damage assessment (B4)
- Tracking plates and strain accumulation and release (PBO)
- Earthquake early warning & rapid slip observation at lifeline fault crossings (Gorman SAF)
- Building monitoring and damage assessment; automatic ‘tagging’ (Factor Building)
- Fault displacement (SuGAr) and tsunami buoy measurement (MBARI)

Nearly everything we do is helped by GNSS

- GNSS will become even better than it is currently for these applications:
  - GPS L2C, L5 and L1C will improve over current capabilities (e.g., tri-laning)
  - GLONASS, QZSS, Galileo and other GNSS will help (e.g., increased coverage)
- GNSS could be improved beyond currently planned system enhancements:
  - Aiding through internet or wireless will enhance real-time precise results
  - Added signals could nearly eliminate the real-time ambiguity resolution problem