Earthquakes

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LONDON POWER FORUM
CONNECTING INSURERS

Downtown San Francisco, before and after the Great San Francisco Earthquake of 1906

USGS

Scenario: M7.8, southeast of Los Angeles

Expert assessment from the 2008 ShakeOut utility panel

Impacts to the power grid and cascading effects:

- Power lost to >10 million people & businesses in southern California
- Short-term (hours) power loss to much of the western U.S.
- Power restoration delayed by damage to gas pipeline, transport, water and communication systems, and post-earthquake fires.
- In some counties, full power restoration takes 1-4 months.

Broader impacts

300,000 buildings damaged – 1 in 16

Widespread infrastructure damage (including major water delivery systems)

1,600 ignitions requiring response (200 million square feet burnt)

$213 billion total damages

Damage to Structures & Contents: $112.7b

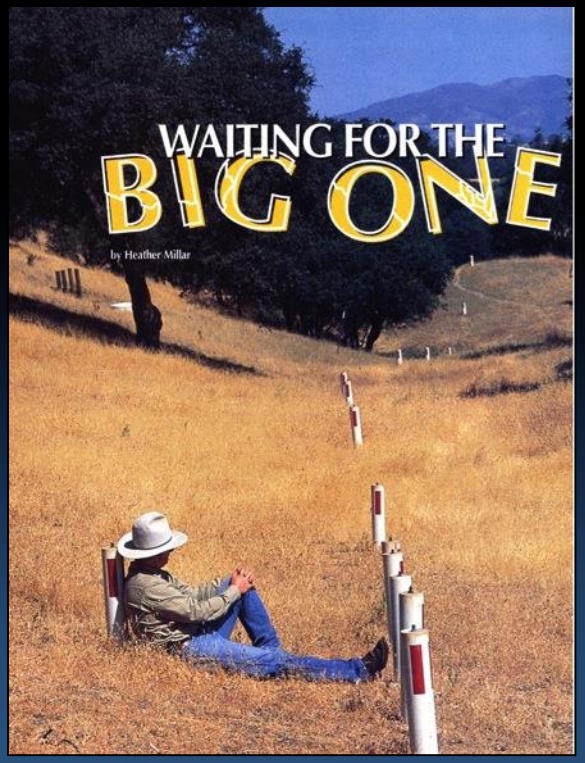
255,000 displaced– 1 in 60

53,000 injuries, **1,800** deaths

USGS

Earthquake Country **Alliance**

- Earthquakes, plates and faults
- What happens in earthquakes
- Earthquake probabilities, hazard and risk
  - Building codes, hazard assessments, mitigation
  - Forecasting, probabilities and prediction
- “Situational Awareness” during and following earthquakes
  - Monitoring networks, damage detection
  - ShakeMap, ShakeCast, PAGER
  - Earthquake early warning systems
- Scenarios to inform planning and mitigation
- Our work with power companies and insurers



USGS

The USGS role in earthquake loss reduction

- Provide earthquake monitoring and notifications,
- Assess seismic hazards,
- Conduct targeted research needed to reduce the risk from earthquake hazards nationwide, and
- with other NEHRP agencies and many other partners, support public awareness of earthquake hazards and impacts.

USGS National Earthquake Information Center

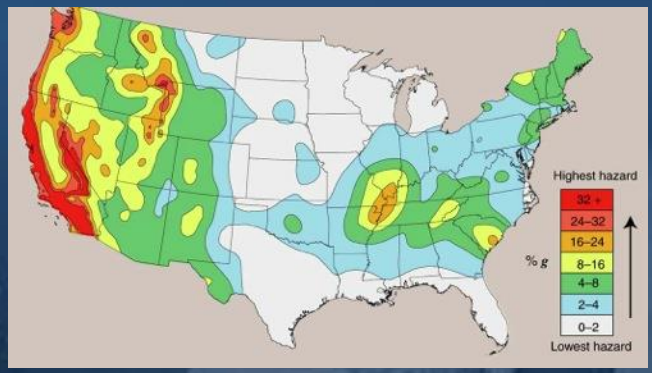
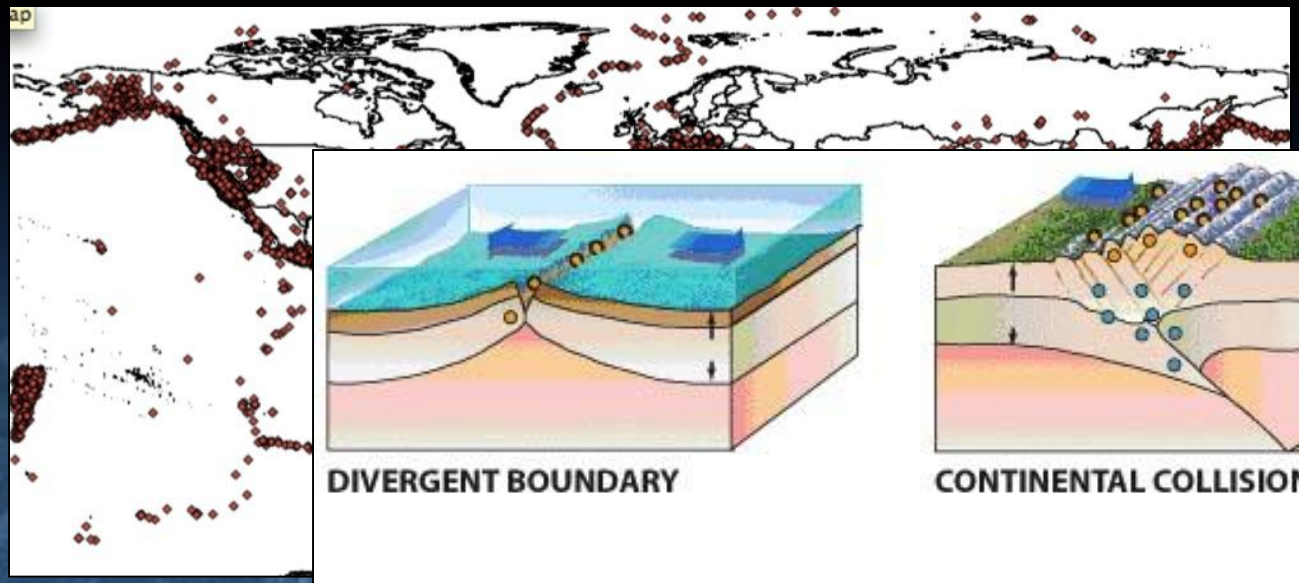


Plate Tectonics and earthquakes



USGS

Off-set Tire Tracks, Hector Mine Earthquake (M7.1, 1999)

Offset streams, San Andreas Fault, CA

USGS

Digging into earthquake histo

Tim Dawson trying to log a San Andreas trench

Earthquake Effects

- Strong shaking
- Ground fracture
- Landslides
- Liquefaction
- Levee breaks
- Roads & rails stopped
- Communication severed
- Hazmat spills
- Release of toxins
- Tsunami (M>7 submarine)

Earthquake Effects - Ground Shaking

Northridge, CA 1994

USGS

Earthquake Effects - Ground Shaking

Loma Prieta, CA 1989

USGS

KGO-TV News ABC-7

Earthquake Effects - Ground Shaking

USGS

Kobe, Japan 1995

Earthquake Effects - Tsunamis

Earthquake Effects - Liquefaction

Source: National Geophysical Data Center

USGS

Niigata, Japan 1964

Earthquake Effects - Landslides

USGS

Turnagain Heights,Alaska,1964

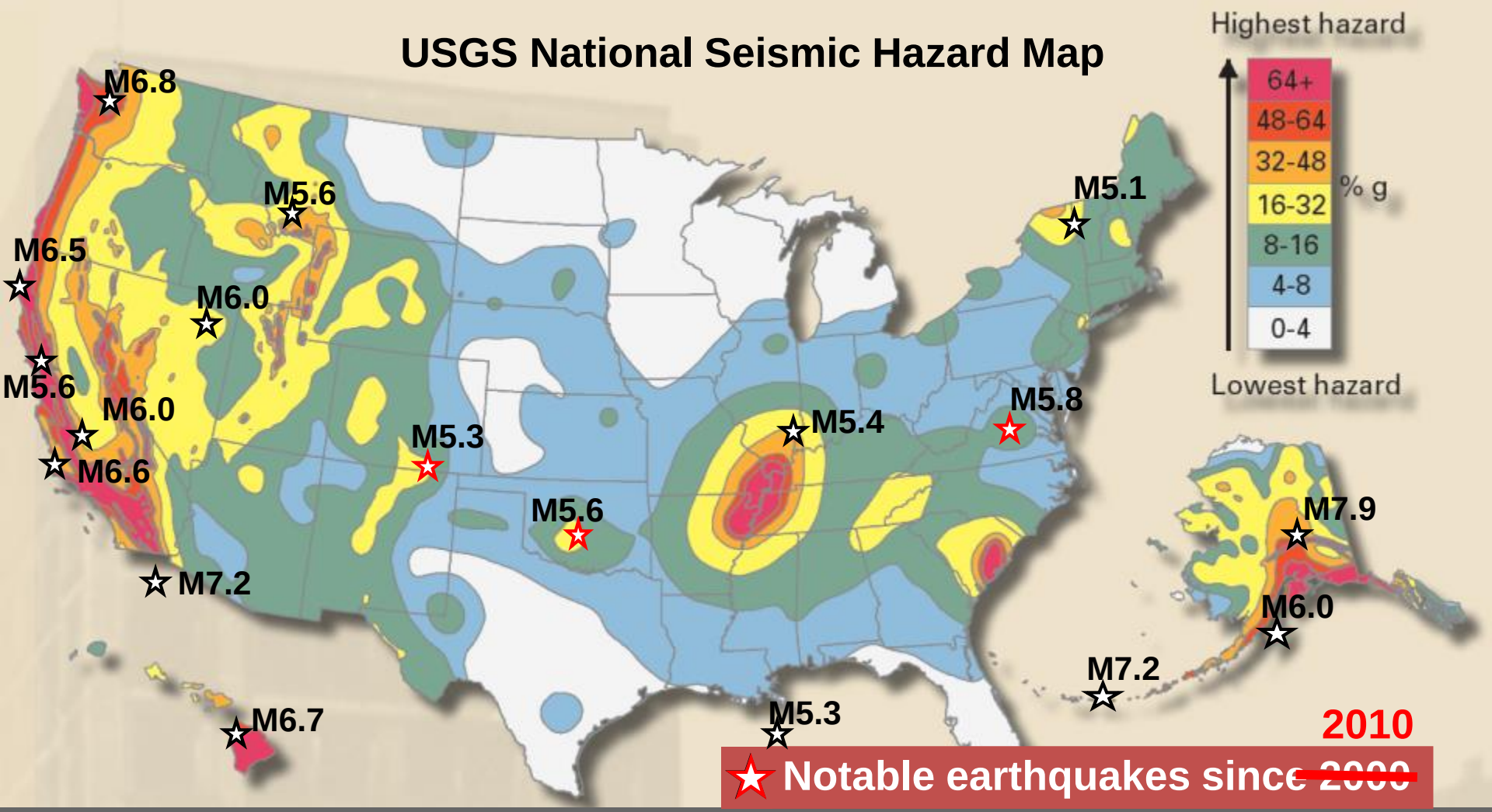
Earthquake Effects - Fires

Loma Prieta, CA 1989

USGS

Source: KGO-TV News ABC-7

Earthquakes are a National Hazard

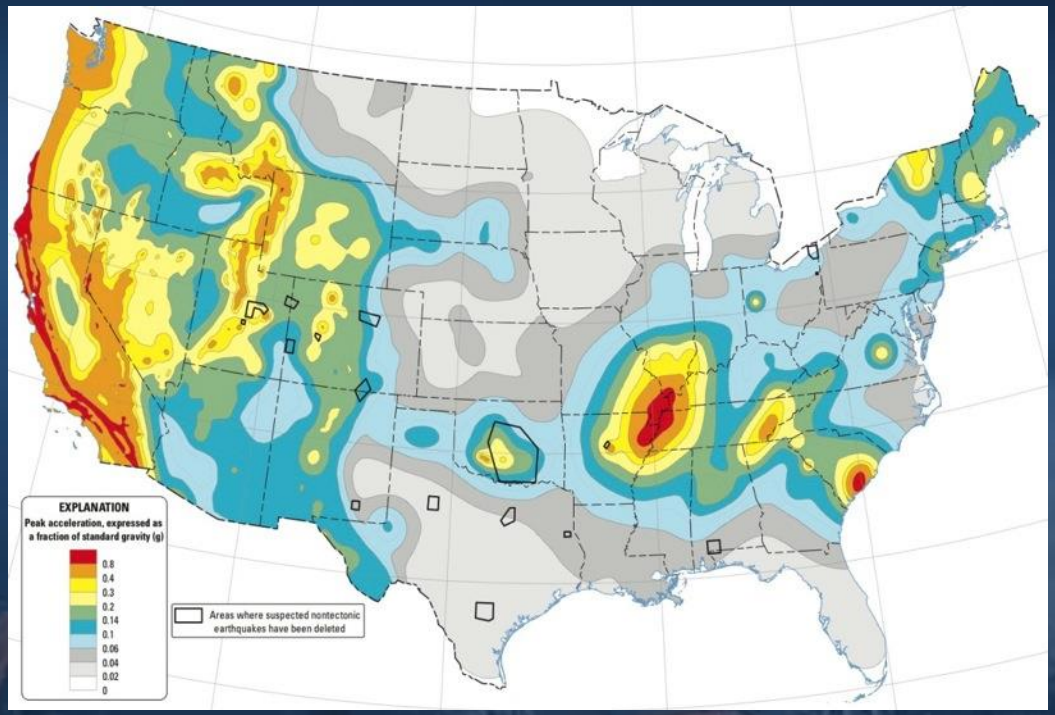


National Seismic Hazard Maps – 2014 revision

Updated every 6 years, these maps forecast the levels of earthquake shaking expected throughout the conterminous U.S. over long time periods. Form basis for seismic provisions in building codes used in most states and communities.

Those codes inform nearly one trillion dollars in new construction every year.

The data are heavily used by engineers, architects and designers, and by federal building owners.



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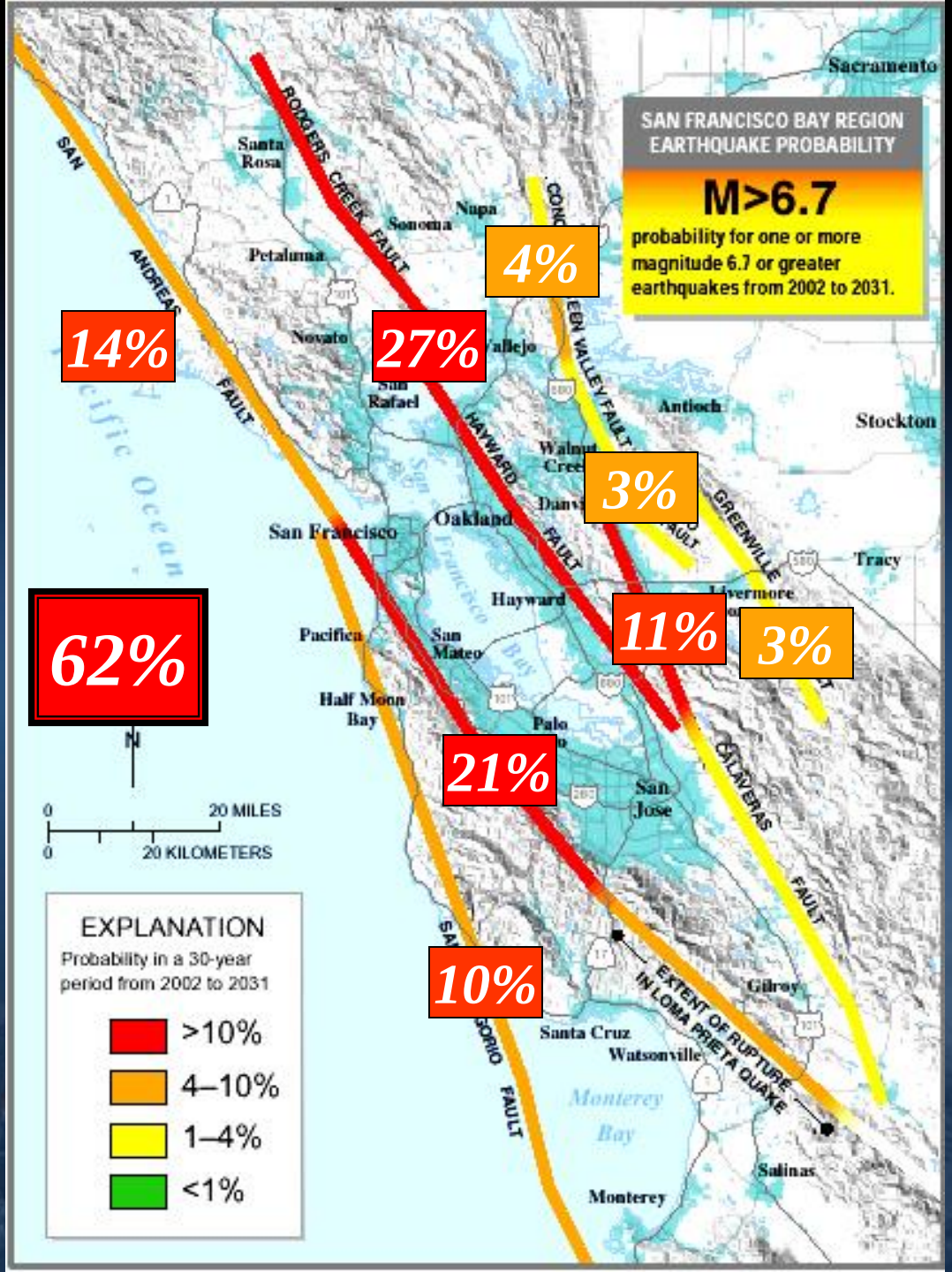
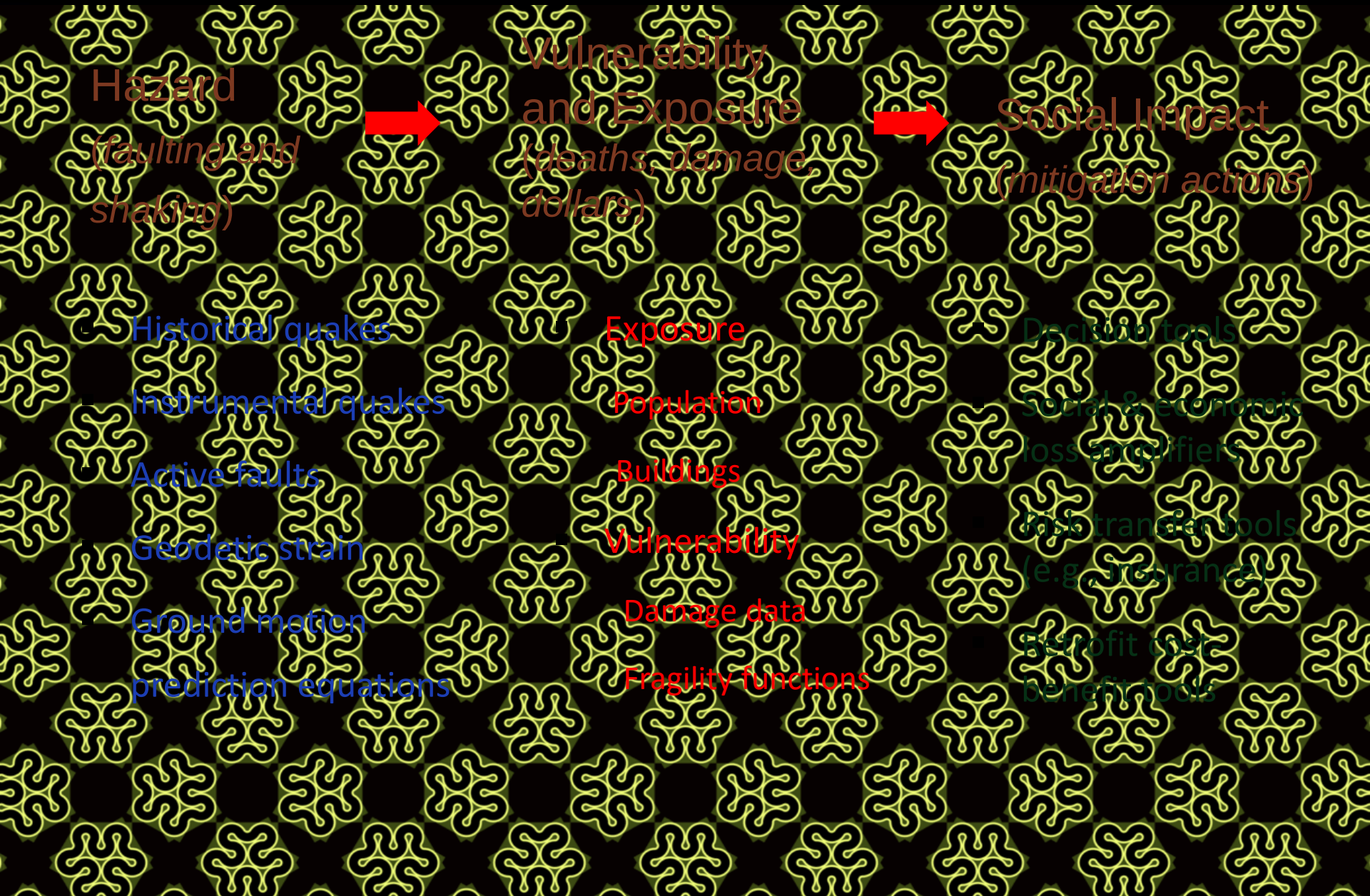
Regional Seismic Hazards: San Francisco Bay Area

30-year probabilities of M≥6.7 quakes in the SF Bay Area.



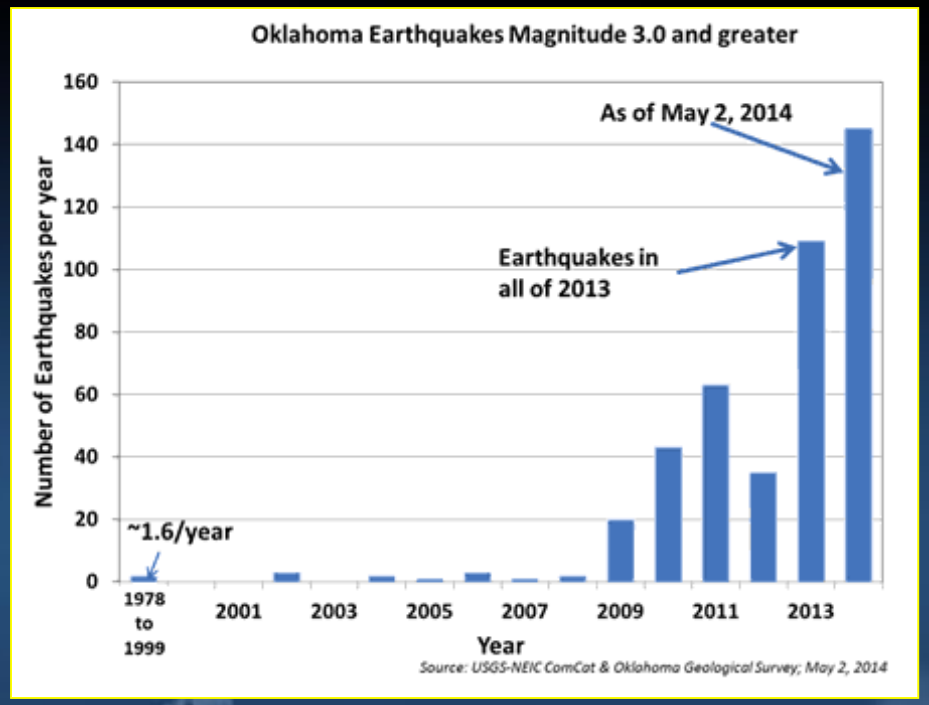
From Hazard to Risk/Vulnerability to *Impact*



Injection-Induced Earthquakes

Earthquakes can be induced by injection of wastewater from oil and gas production, in geothermal energy production, and in the geologic sequestration of carbon (CCS).

Most striking example: Oklahoma's seismic regions continue to expand, tied to the expansion in the number of wastewater disposal wells with high injected volumes.



Fracking is rarely the cause of felt earthquakes, but now several M>3 occurred.

New regulations for injection in Texas, Colorado and Ohio; seismic committee formed in Oklahoma. Wells have been shut down in several states.

USGS

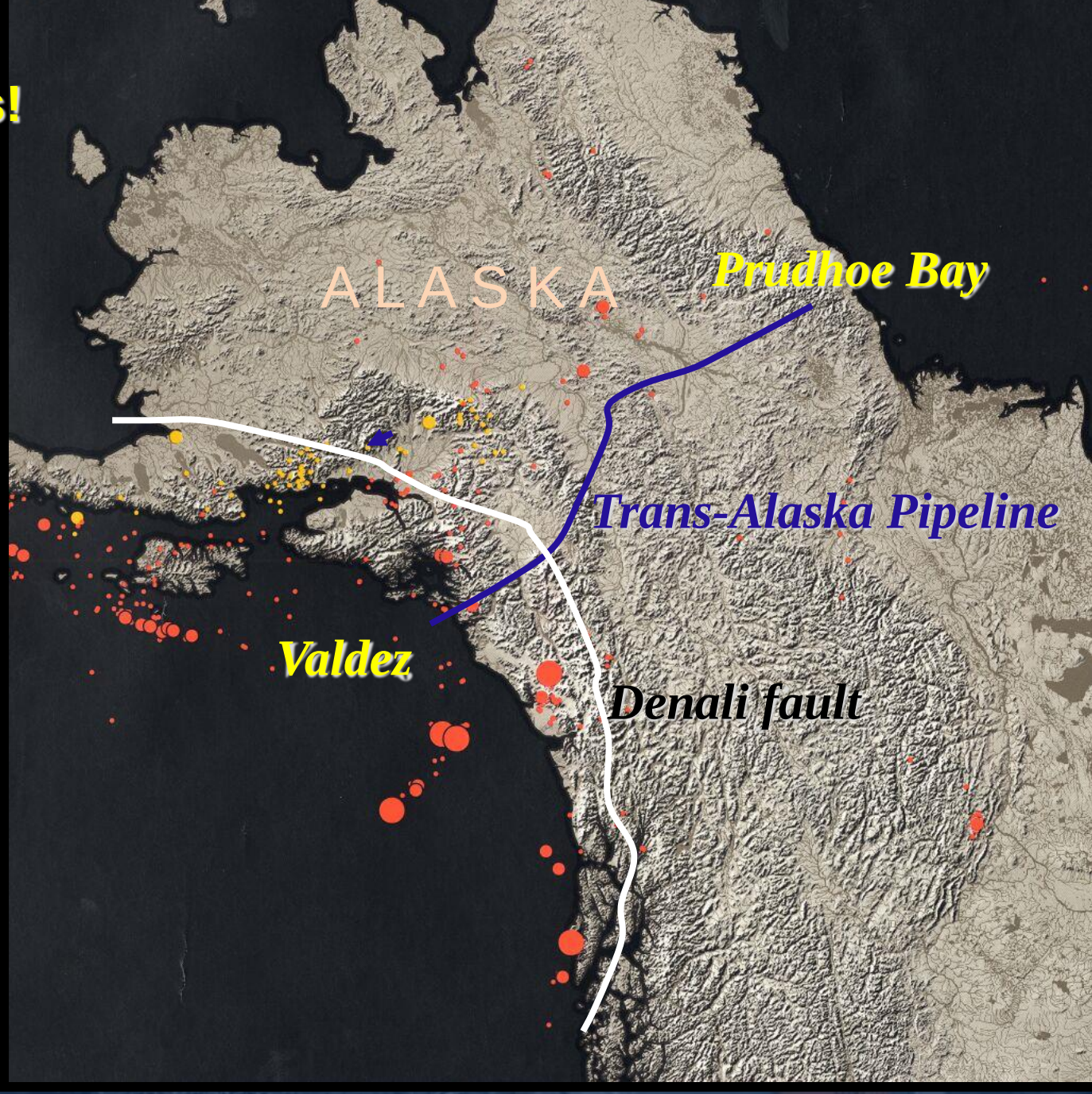
Mitigation works! Trans-Alaska Pipeline story

1 to 2 million barrels per day

17% of US crude oil

80% of Alaska's revenue

1977 to 2003, 14 billion barrels



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2002 M7.9 Denali earthquake: 18 feet of fault offset

USGS

After

Before

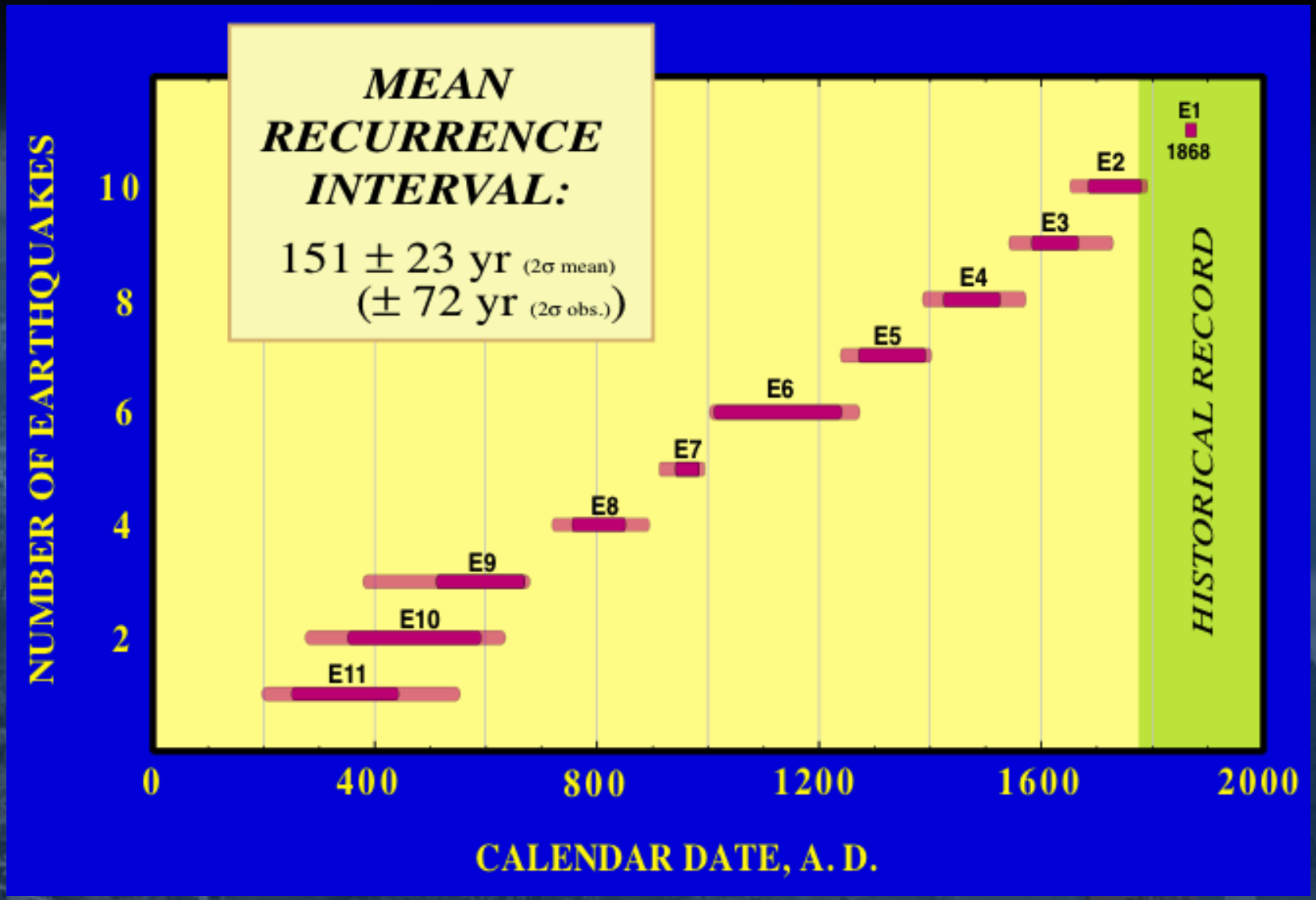
Earthquake Forecasting and Prediction

"Can the size, location, and time of a large earthquake be predicted a short time in advance?"

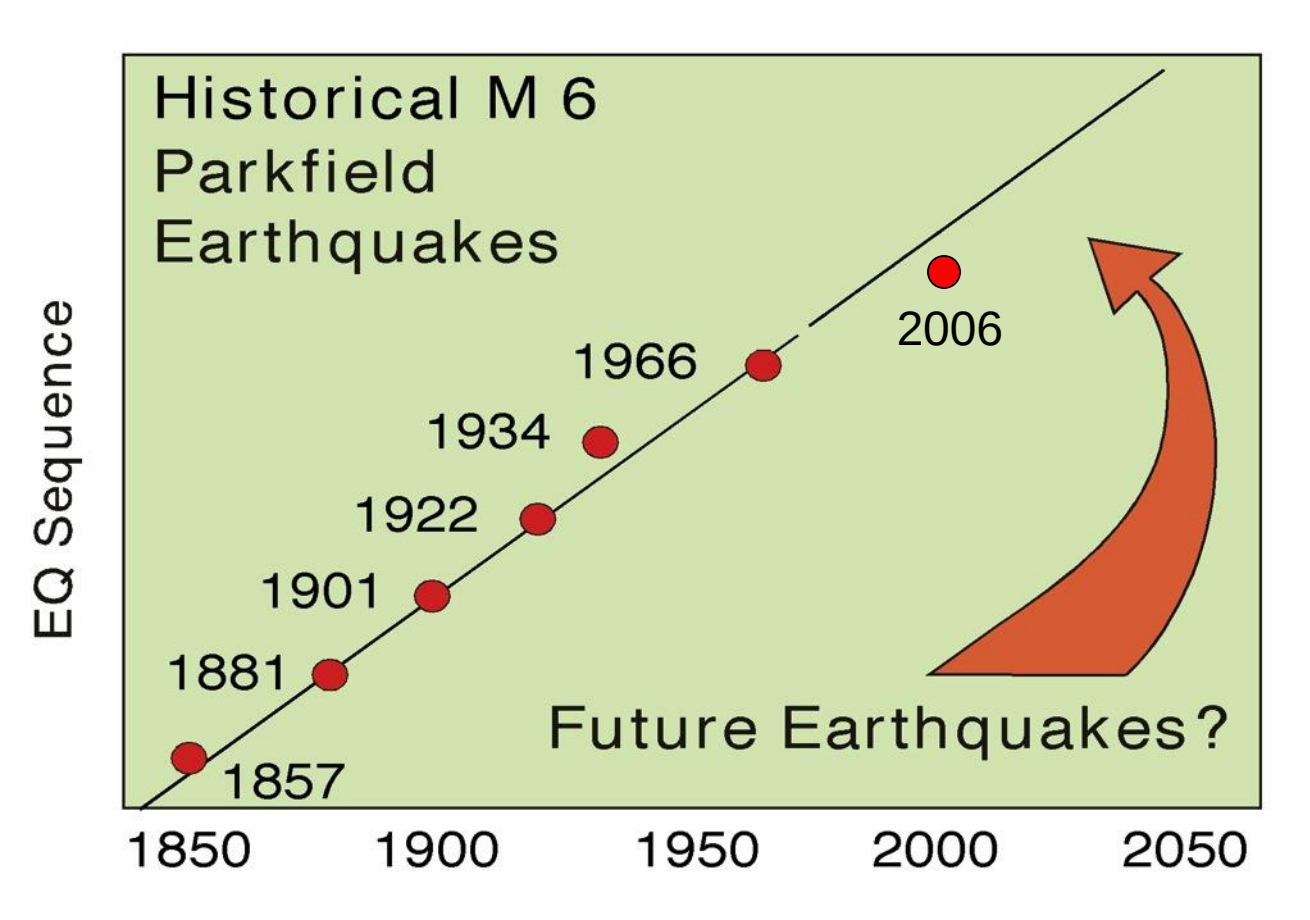
(…with enough confidence that action can be taken to reduce losses?)

USGS

Earthquake Forecasting: 1650 year history of the Hayward Fault



And then you wait…….



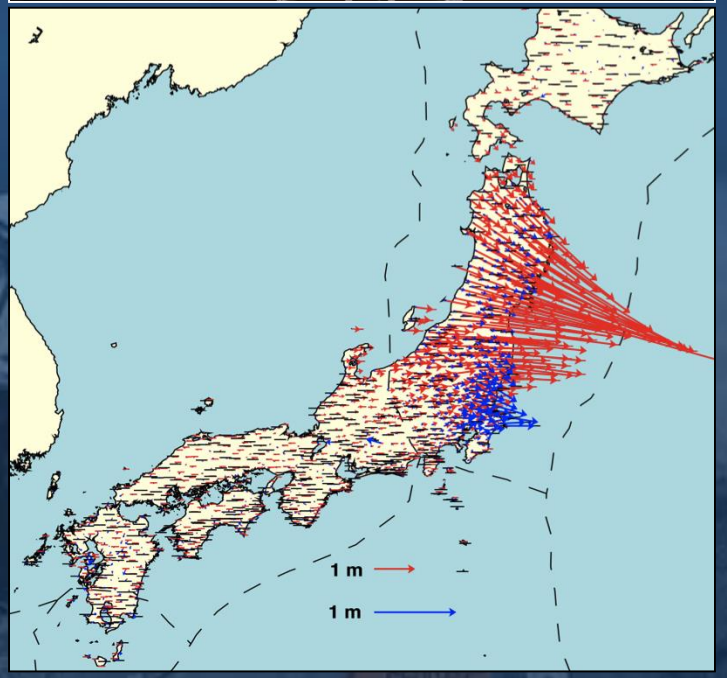
"Parkfield remains the best identified locale to trap an earthquake." – *Hager Committee Report (1994) to the National Earthquake Prediction Evaluation Council*

USGS

Networks provide rapid “situational awareness” for earthquakes worldwide

Station map for the USGS National Seismic Network

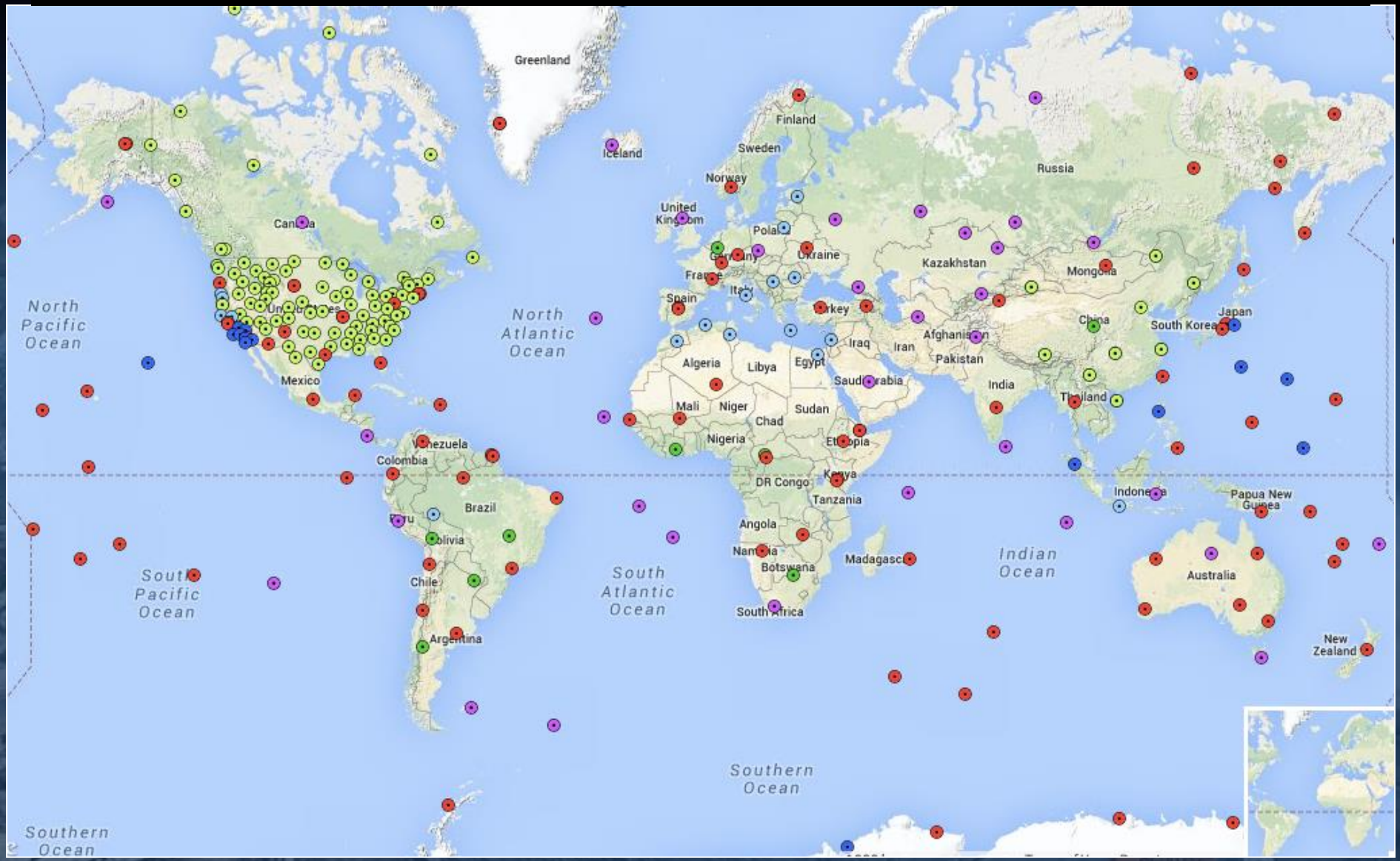
USGS *National Earthquake Information Center, Golden, Colorado*



Displacement vectors for Japanese GPS stations During the 2011 Tohoku Earthquake (M9.2)

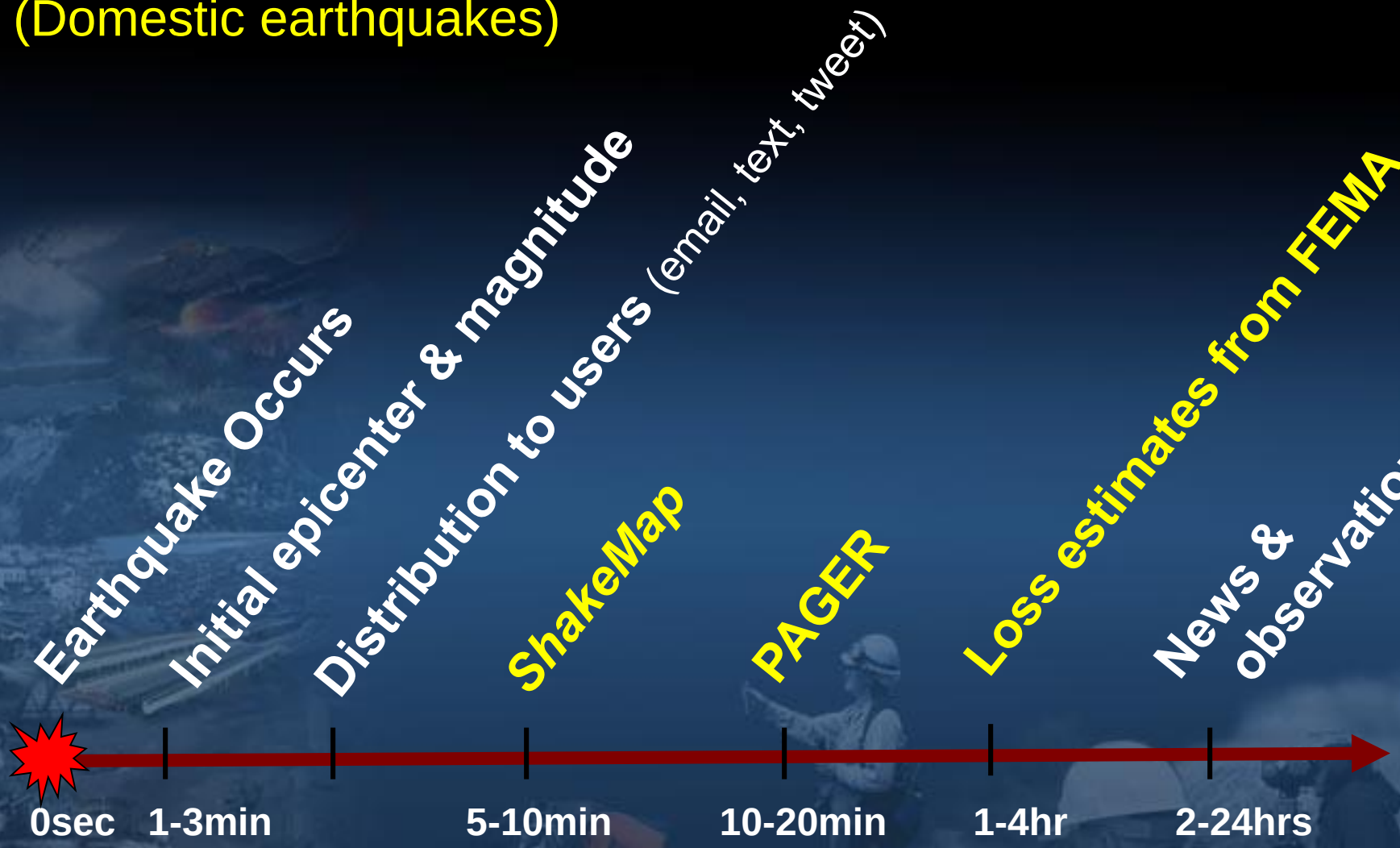
USGS

The Global Seismographic Network and Federation of Digital Seismic Networks



Earthquake Information Timeline

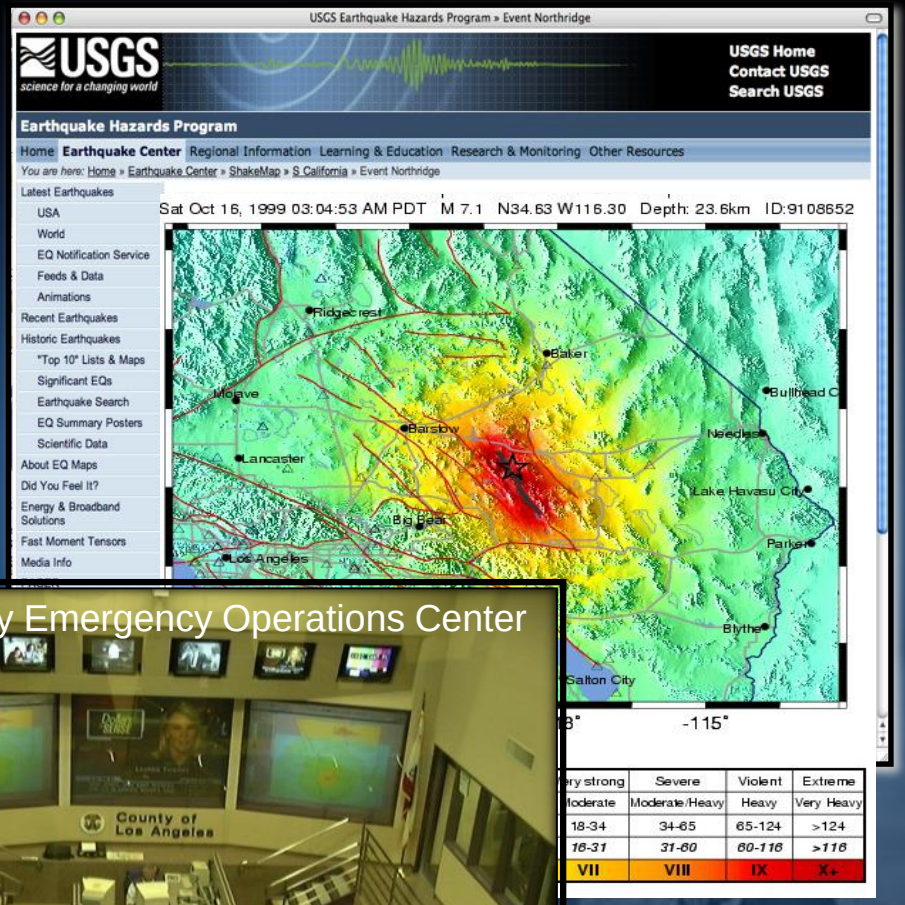
(Domestic earthquakes)



USGS

ShakeMap: A tool for rapid post-earthquake response, coordination, and situational awareness

Former California Governor Schwarzenegger pointing to ShakeMap at his press conference following the M5.4 Chino Hills earthquake that hit Los Angeles in 2008



ShakeCast

Rapidly delivered recordings or estimates of shaking intensity at **specific sites or critical facilities** in the strongly shaken region of an earthquake.

ShakeCast report to the IAEA following the 2011 Tohoku quake estimates that design values were exceeded for five reactors

IAEA.org International Atomic Energy Agency

ShakeCast Report

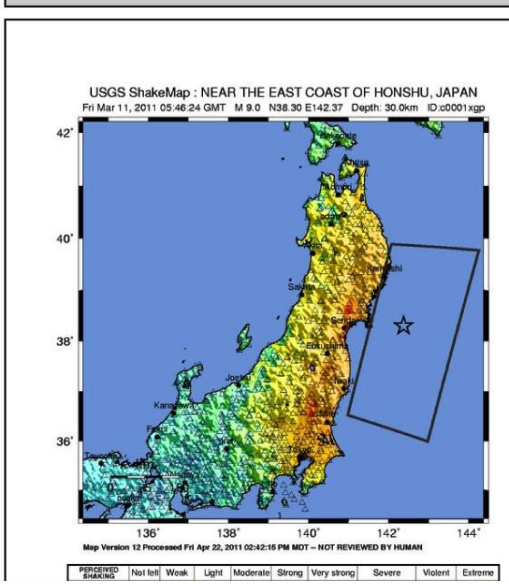
USGS science for a changing world

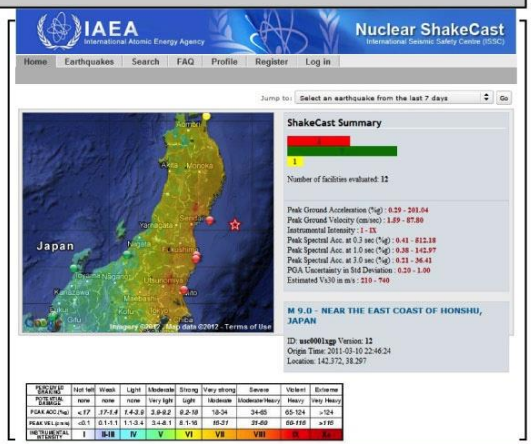
Magnitude 9.0 - NEAR THE EAST COAST OF HONSHU, JAPAN Version 12

Origin Time: 2011-03-11 05:46:24 GMT Created: 2012-06-15 20:42:09 GMT

Latitude: 38.297 Longitude: 142.372 Depth: 30.0 km

These results are from an automated system and users should consider the preliminary nature of this information when making decisions relating to public safety. ShakeCast results are often updated as additional or more accurate earthquake information is reported or derived.





Recent significant earthquakes in the region

- M9 NEAR THE EAST COAST OF HONSHU, JAPAN at 3/11/2011 5:46
- M7.7 Miyagi-Oki, Japan at 6/12/1978 8:14
- M7.4 NEAR THE EAST COAST OF HONSHU, JAPAN at

FACILITY_NAME	DIST	LATITUDE	LONGITUDE	PGA	SL1_OBE
Onagawa	76.99	38.3998	141.5010	34.0889	Exceeded
Fukushima Daiichi	152.67	37.4215	141.0340	31.0432	Exceeded
Fukushima Daini	161	37.3163	141.0250	31.2189	Exceeded
Tokai	256.43	36.4654	140.6070	35.2514	Exceeded
Higashi Dori	331.84	41.1880	141.3900	19.258	Exceeded

NUCLEAR	JPN8	Mihama	639.08	35.7018	135.9630	3.9994	Not Exceeded	Not Exceeded	V

RG1166
Exceeded
Exceeded
Exceeded
Exceeded
Exceeded
Exceeded
Exceeded
Exceeded
Exceeded

ShakeCast –

Initial reports delivered in 20-30 minutes

ShakeCast for the 2012 Virginia M5.8 earthquake.

Ground acceleration at the reactor was twice the design value

USGS

IAEA.org International Atomic Energy Agency

International Seismic Safety Centre

ShakeCast Report

USGS science for a changing world

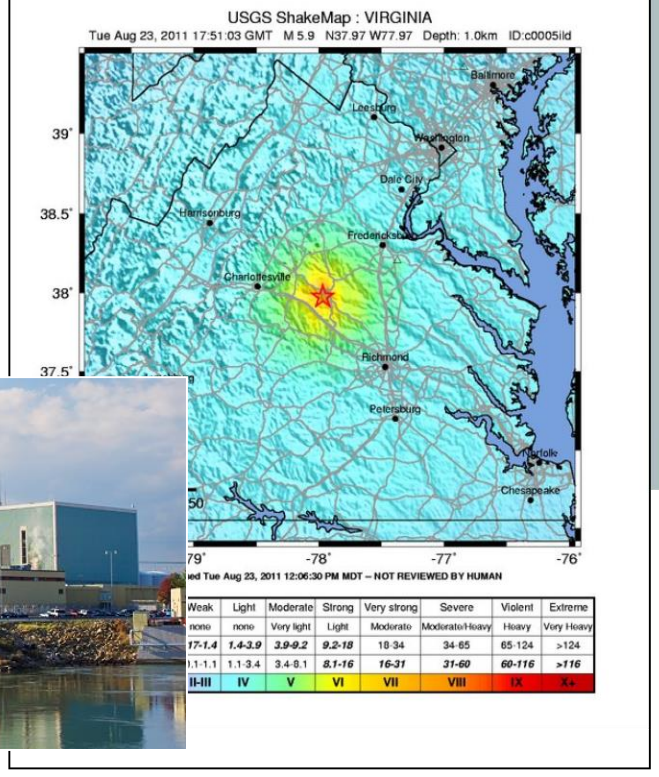
Magnitude 5.9 - VIRGINIA

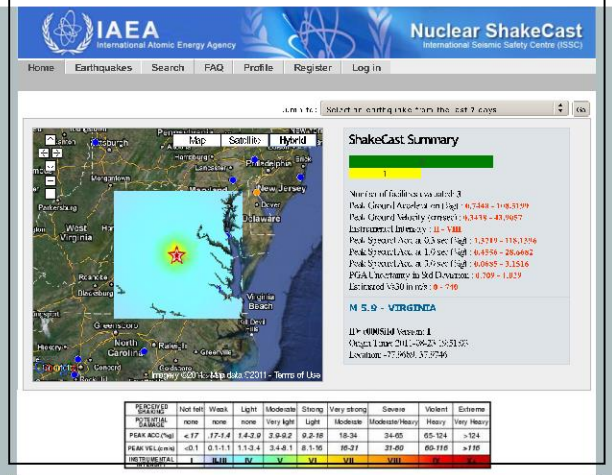
Time: 2011-08-23 17:51:03 GMT
Location: 37.97 N/ -77.97 W
Depth: 1.0 km

Version 1

Created: 2011-08-23 18:16:12 GMT
For more information and latest version see
http://nuclearshakecast.iaea.org

These results are from an automated system and users should consider the preliminary nature of this information when making decisions relating to public safety. ShakeCast results are often updated as addtional or more accurate earthquake information is reported or derived.





Recent significant earthquakes in the region

- M4.5 VIRGINIA at 12/9/2003 20:59
- M3.4 POTOMAC-SHENANDOAH REGION at 7/16/2010 9:04

FACILITY_TYPE	FACILITY_ID	FACILITY_NAME	LATITUDE	LONGITUDE	DAMAGE_LEVEL	MMI	PGA	PGV	PSA03	PSA10	PSA30
NPP	USA8	Calvert Cliffs	38.4319	-76.4424	GREEN	3.65	1.6502	0.8533	2.9634	0.8883	0.0974
NPP	USA37	North Anna	38.0573	-77.7956	YELLOW	5.53	16.6639	6.5376	21.4418	5.1476	0.5304
NPP	USA56	Surry	37.1633	-76.6942	GREEN	3.65	1.6397	0.8496	2.9455	0.885	0.0971

USGS
science for a changing world

Earthquake Shaking — Red Alert

Summary Alert = greater of Econ/Fatal Alert Levels

GSN ANSS — AID FROM THE AMERICAN PEOPLE

M 8.8, OFFSHORE MAULE, CHILE

Origin Time: Sat 2010-02-27 06:34:14 UTC (02:34:14 local)

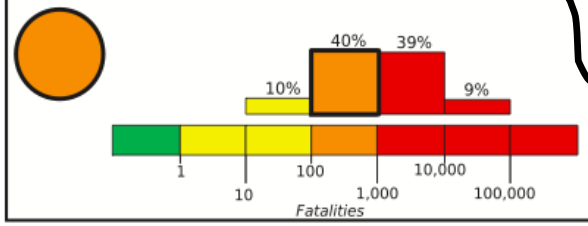
Location: 35.85°S 72.72°W Depth: 35 km

FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

PAGER Version 3

Created: 3 hours, 10 minutes after earthquake

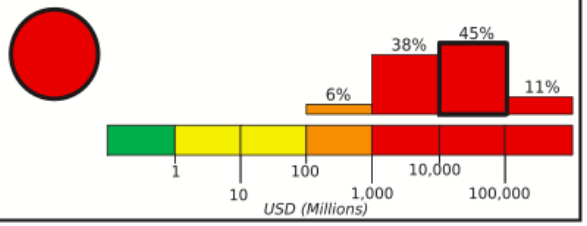
Estimated Fatalities



Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are 3-20% GDP of Chile. Past events with this alert level have required a national or international level response.

Orange alert level for shaking-related fatalities. Significant casualties are likely.

Estimated Economic Losses



Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	487k*	2,147k*	3,657k	6,405k	3,083k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

VIII	Arauco	25k
VIII	Lota	50k
VIII	Concepcion	215k
VIII	Constitucion	38k
VII	Bulnes	13k
VII	Cabrero	18k
VI	Temuco	238k
VI	Valparaiso	282k
VI	Santiago	4,837k
IV	Mendoza	877k
III	Neuquen	242k

bold cities appear on map (k = x1000)

PAGER content is automatically generated, and does not consider secondary hazards in loss calculations. Limitations of input data, shaking estimates, and loss models may add uncertainty.

http://earthquake.usgs.gov/pager

Event ID: us2010tfan

USGS

Some PAGER Alert Recipients

The World Bank
IBRD & IDA: Working for a World F

China's earthquake emergency rescue center

USAID
FROM THE AMERICAN PEOPLE

MercyCorps
Be the change

Australian Government
Geoscience Australia

AP Associated Press

GeoHazards International
A Nonprofit Working Toward Global Earthquake Safety

UPI.com
100 YEARS OF JOURNALISTIC EXCELLENCE

EERI Earthquake Engineering Research Institute

GDACS
Global Disaster Alert & Coordination System

REUTERS

Aid Agencies/NGO

International

THE WHITE HOUSE
PRESIDENT GEORGE W. BUSH

ANSS

Federal Government

U.S. DEPARTMENT of STATE

FEMA

Homeland Security

US AIR FORCE

AIR FORCE TECHNICAL APPLICATIONS CENTER

USNORTHCOM
DEFENDING OUR HOMELAND

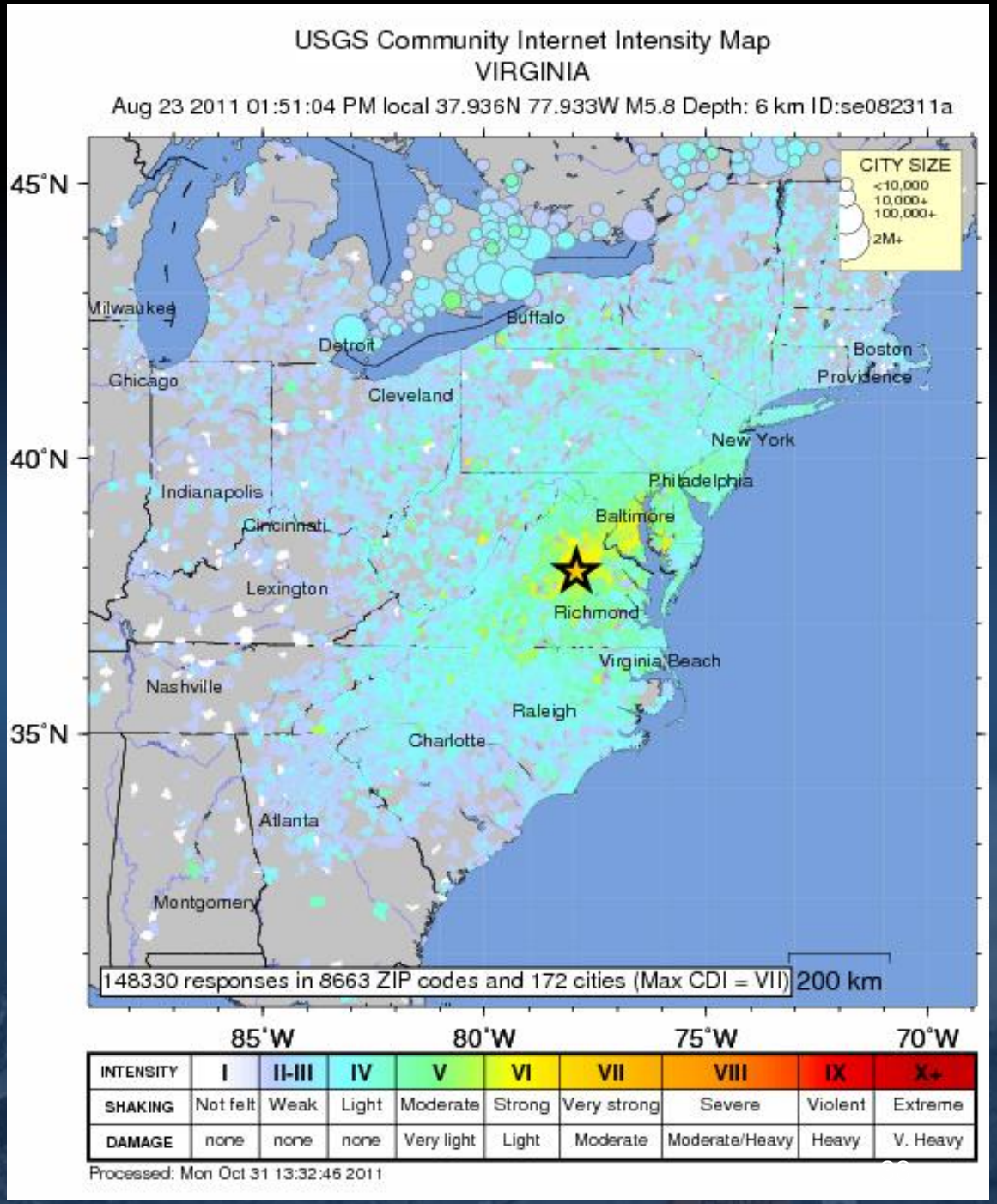
Office of Science and Technology Policy

Crowd-sourcing damage using “Did You Feel It?”

The USGS “Did You Feel It?” software collects observations from people who experienced the earthquake

- Anyone can report through a DYFI? web page
- The web page takes a person through a detailed set of questions that links their experience to ground-shaking intensity
- These reports are averaged by postal (zip) code, for domestic earthquakes, or city.
- **More than 140,000 felt reports were obtained for the 2011 Virginia quake**

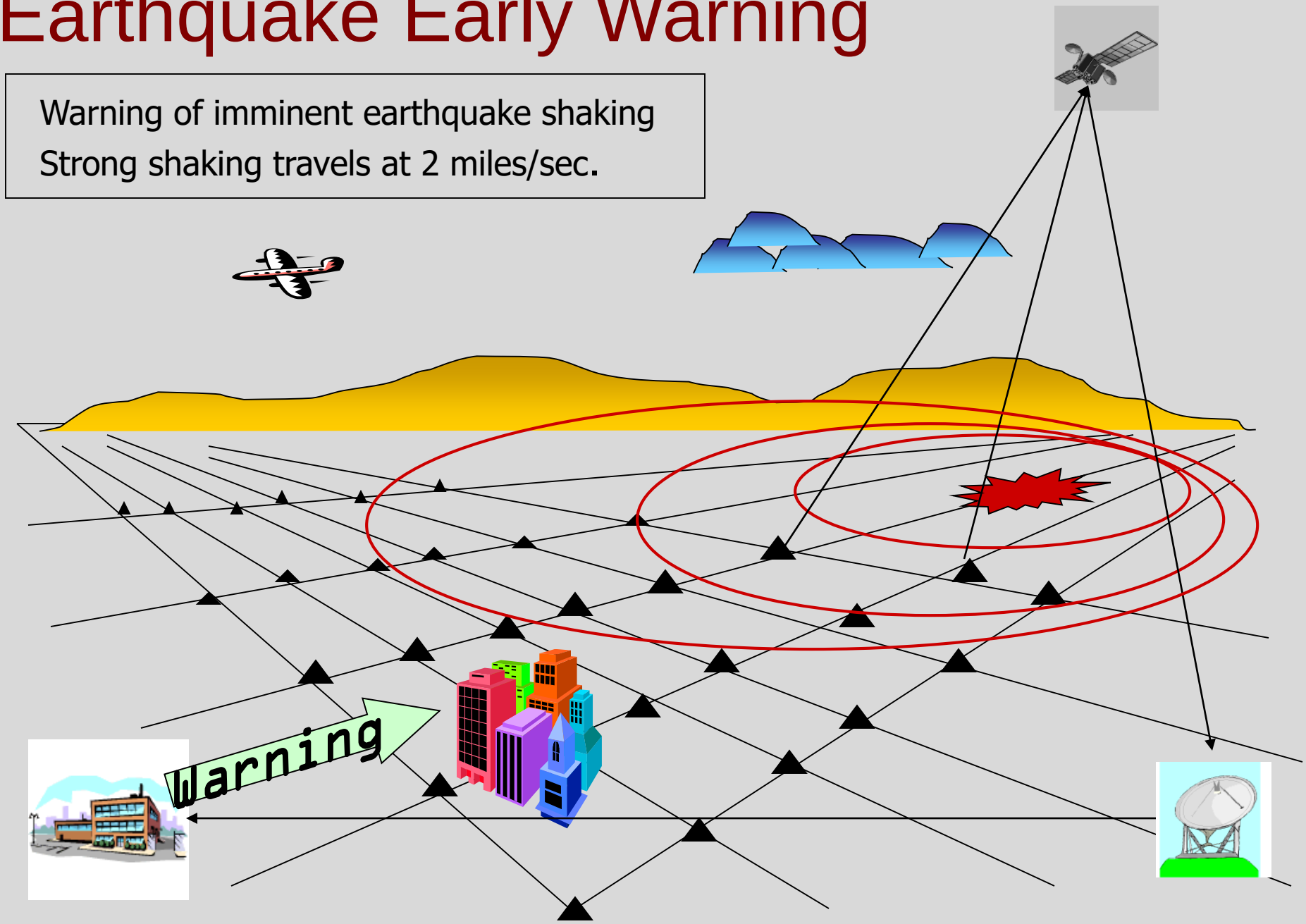
USGS



Earthquake Early Warning

Warning of imminent earthquake shaking

Strong shaking travels at 2 miles/sec.

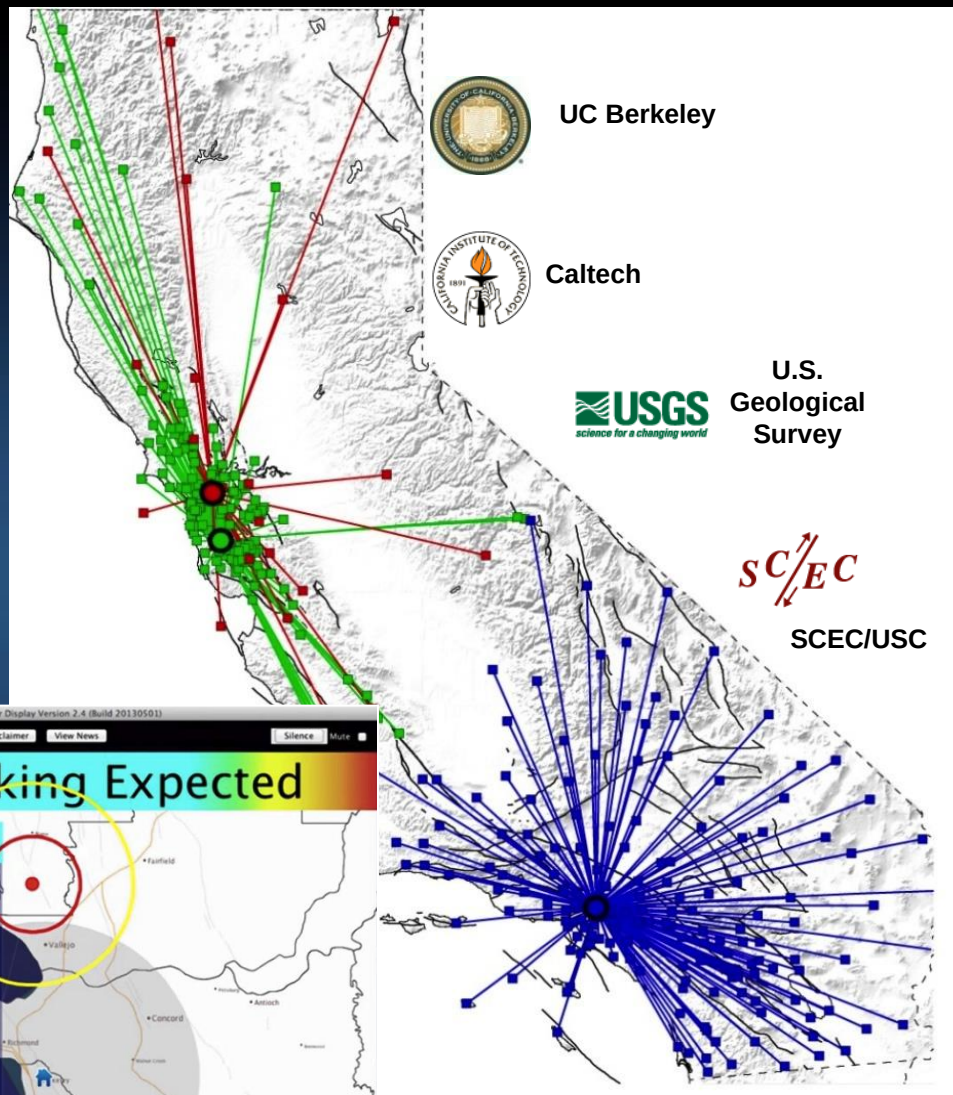


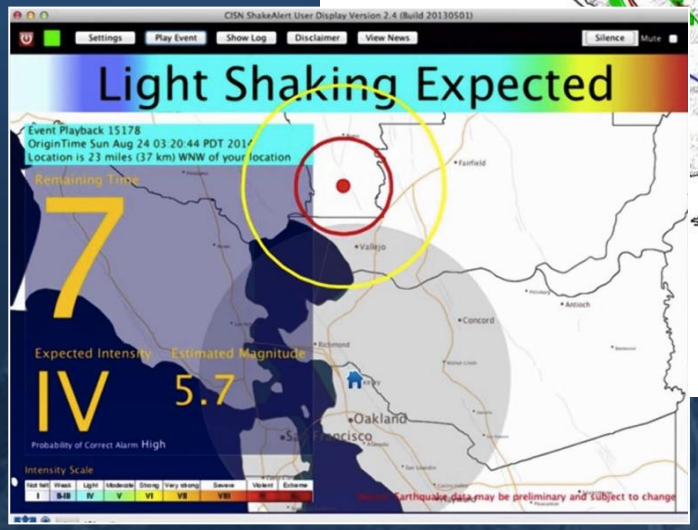
Earthquake early warning

Earthquake early warning systems are currently in use in Japan, Taiwan, Mexico and a number of other countries.

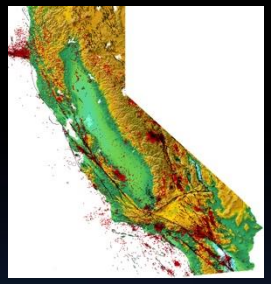
Magnitude-6.0 South Napa earthquake provided the first major and successful test of the prototype *ShakeAlert* system in California.

Potential to provide additional situational awareness for critical infrastructure operators.





USGS



CISN ShakeAlert

Earthquake Early Warning

Status today:

Prototype system issuing alerts

System expansion in Southern California [UASI funding]

Next two years:

Demonstration ➔ Prototype

Establish Federal-State-Private Partnership

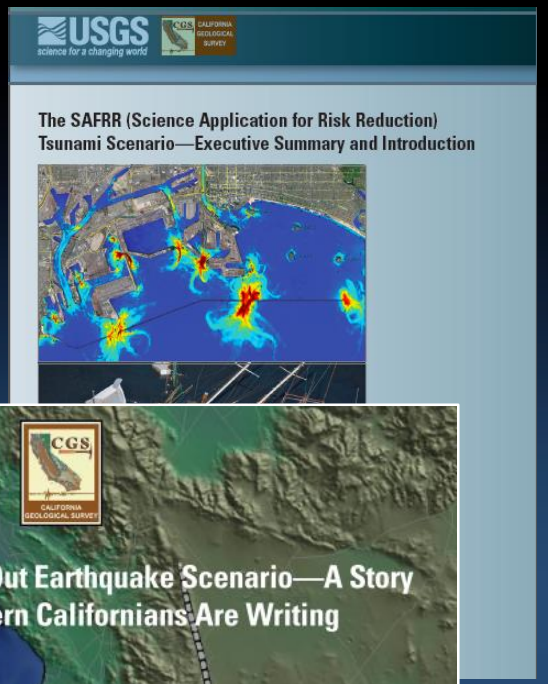
Receiving alerts today:

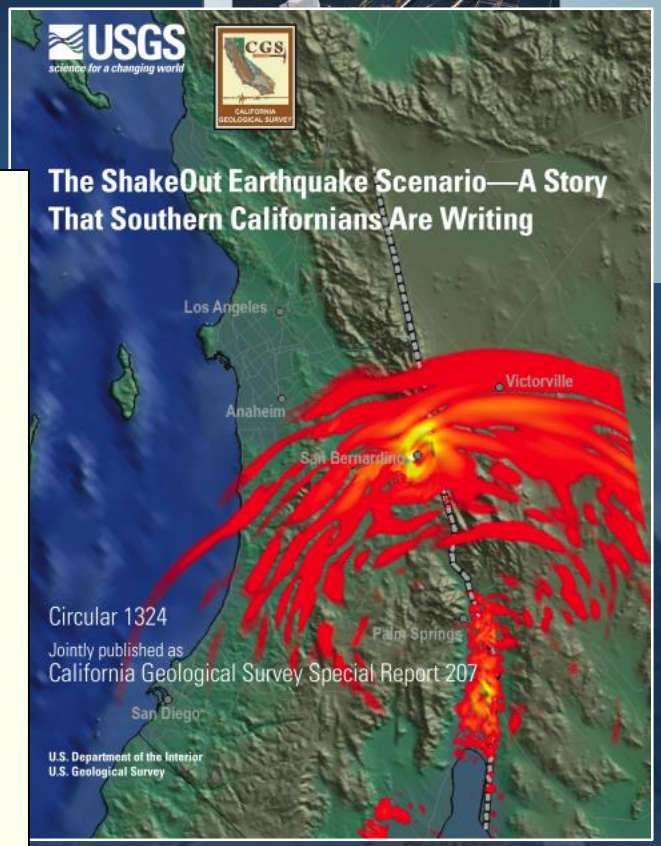
- **50 research scientists**
- **Google.org**
- **BART**
- **Metrolink**
- **Amgen**
- **So Cal Edison**
- **CalEMA**
- **SF DEM**
- **L.A. City**
- **L.A. County**
- **UC Berkeley OEP**
- *more…*

Using scenarios to inform planning and mitigation

USGS Science Application for Risk Reduction (SAFRR) project developed the ShakeOut, ARkStorm, and SAFRR Tsunami scenarios:

- A single, large but plausible event
- An event we need to be ready for
- Craft study with community partners
- Consensus among leading experts





Utility Performance Panels in the ShakeOut Scenario

Keith A. Porter[a] M.EERI and Rachel Sherrill[b]

The ShakeOut Scenario assessed earth-science impacts, physical damage, and socioeconomic impacts of a hypothetical M7.8 southern San Andreas Fault earthquake. Among many detailed studies were special studies of 12 lifelines, 7 of which were performed by panels of employees of the utilities at risk. Panels met for four hours. Panelists were presented with the scenario's earth science impacts and previously estimated damage to "upstream" lifelines. They then hypothesized a realistic outcome of the earthquake on damage and service restoration, identifying research needs and mitigation options. The panel process worked well: panelists were well qualified and seemed to fairly assess realistic earthquake impacts and restoration, probably more realistically than an outside consultant would have been able to do, thus improving the ShakeOut. Panelists gained insight into lifeline interaction, mutual-aid needs, communication capabilities, and backup supplies. Southern California Edison, for example, enhanced its planning and preparedness

Power restoration times for the ShakeOut scenario (**Porter and Sherrill, 2011**)

Table 2. Percent of services restored (of those capable of receiving power), by time after earthquake

County	1 day	2 days	3 days	7 days	14 days	1 mo	18 mo	36 mo
Riverside	0%	0%	0%	1%	30%	60%		95%
San Bernardino	0	0	0	1	30	60		95
Los Angeles	0	0	0	30	60	80	95	
Santa Barbara, Ventura	0	0	5–10	30	60		95	
Orange	0	0	0	30	60	~100		
Tulare, Kern	0	60	100					
Imperial	0			25–30	60		95	

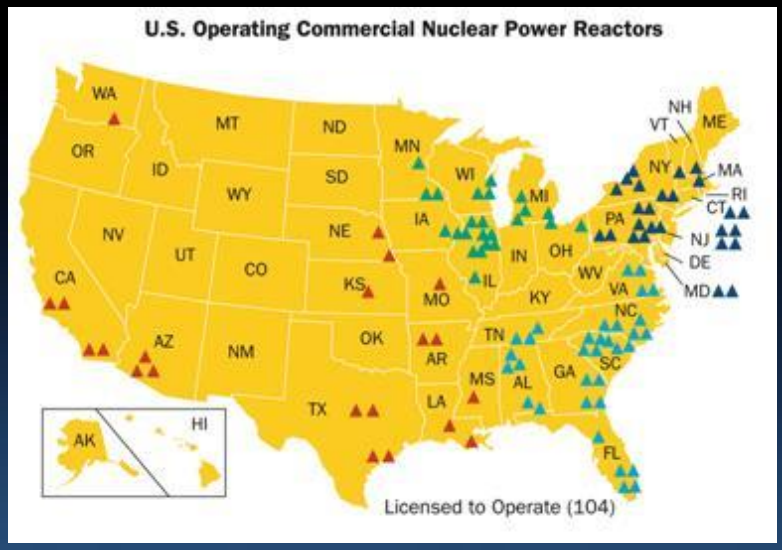
Table 3. Key activities of power restoration

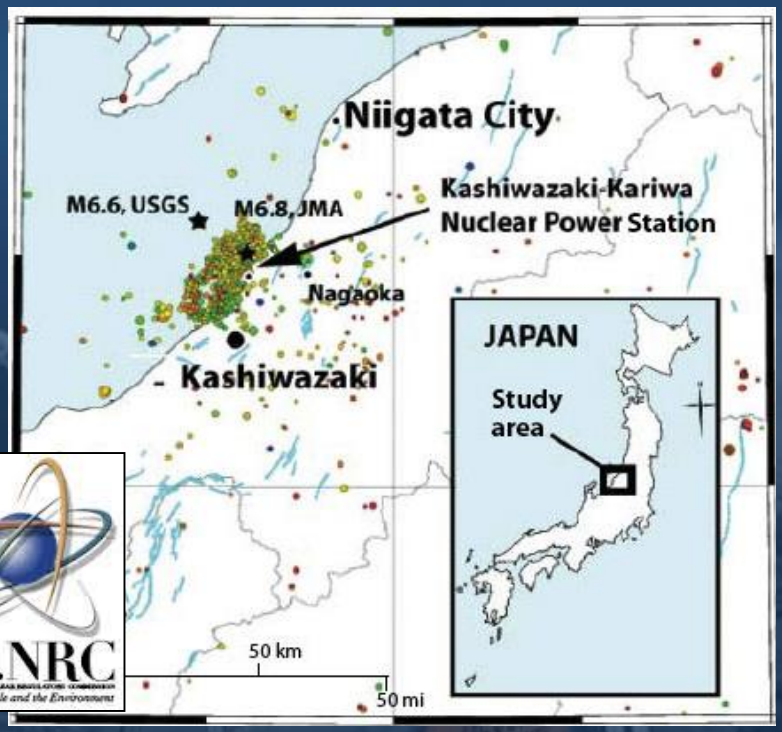
County	Activities
Riverside	Days 1–3 trying to fire up generators; Day 7 repairs to generation and transmission
San Bernardino	Same as Riverside County
Los Angeles	Days 1–3 trying to bring power down to LA basin; days 7–14 repairs to transmission and distribution substations
Santa Barbara, Ventura	Damage because equipment is old and undergoes long duration of shaking; Days 7–14 repairs to transmission and distribution substations; Day 7 rerouting power from San Onofre
Orange	Days 7–14 repairs to transmission and distribution substations;
Tulare, Kern	No panelist notes
Imperial	Transmission lines damaged; impacts power to Mexico.

USGS

Cooperation with Regulators: USNRC and IAEA

- Seismic hazard analyses for new and renewal license applications
- *ShakeCast* earthquake alerting for ground motion at U.S. foreign nuclear plants
- Evaluation of seismic monitoring needs in Central and Eastern U.S.
- Research on ground motion variability and uncertainties
- Tsunami hazard assessment and post-tsunami studies





USGS

U.S.NRC
Protecting People and the Environment

Cooperation with Utilities: Example of Pacific Gas & Electric

- USGS CRADA – Cooperative Research and Development Agreement
  - Established in 1992
  - Products over the last 5 years include >100 papers, abstracts, workshops, field trips
- Recent cooperative research includes:
  - Central CA coast seismic hazards & geodesy
  - Northeastern CA hazards, geology & geodesy
  - Northern CA geodesy & crustal deformation
  - Ground motion modeling & estimation
  - PG&E seismic network data-sharing

USGS

Support for Insurers

- In the U.S., most earthquake insurance premiums are based on USGS earthquake probability models
- Numerous financial-sector players use hazard models, *ShakeMaps*, and *PAGER* to trigger insurance payouts, contingency loans, Cat bonds and other products
- Some major loss modeling firms use USGS hazard data and models for loss estimation, risk assessment and scenario planning.
- Earthquake catalog data are also used for “Cat in a box” payouts (e.g., World Bank); more sophisticated products are possible

WORLD BANK

IABD
Inter-American
Development Bank

Munich RE

Swiss Re

Willis Re

R M S

GUY CARPENTER

EQECAT

VALIDUS
GROUP

USGS

TRAVELERS

FM Global

ZURICH

ZELLE HOFMANN

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Earthquakes and Insurance – Claims, Underwriting and Wording Issues

Limitations on Earthquake Coverage

- Exclusions
- Low Sublimits
- High deductibles
- High premiums
  - California
  - Nature of earthquake risk

Causation

- Earthquake (excluded) and another (covered) peril
  - Example: improper construction
  - Anti-concurrent causation clauses
    - Enforceable
    - Efficient proximate cause rule

Causation

"My loss wasn't caused by the Earthquake, it was caused by [insert covered peril.]"

When are Earthquake "Effects" a new peril:

…ground shaking vs tsunami vs liquefaction vs landslide vs fire…

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Anti-concurrent Causation

Peril excluded "regardless of any other cause or event contributing in any sequence"

Majority rule – allocate (Miss.) (partially enforceable)

Minority rule (CA/W.Va) – **unenforceable**

Minority rule – (5th Cir. Tx / English law) – fully enforceable

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Causation (cont.)

- Special rule in California
  - No coverage for any loss caused by earthquake
  - Compare: where earthquake coverage exists


I SEE YOUR EARTHQUAKE EXCLUSION AND
RAISE YOU A FIRE
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Ensuing Losses

- Ensuing loss provisions
- Fire / water damage
  - Fire losses not affected by special causation rule in California

Ensuing Losses

Clauses create exceptions to exclusions when a covered peril results from an excluded peril

Typical language:

> "We do not insure for loss caused by any of the following, but if loss or damage not excluded by any other provision in this policy ensues, such resulting loss or damage is insured."

"Ensuing Loss" is usually not defined.

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Ensuing Loss – Analytical Chain

Excluded Peril ----- **Property damage directly caused by**
(earthquake) **the excluded peril (gas main rupture)**

]
] resulting separate/independent peril
] **(fire)**

Ensuing Loss from covered peril
(fire damage)

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Required Offer of Earthquake Insurance in California

Must be offered in residential property insurance

Form and content of offer

Private right of action for failure to offer

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72 Hours Clause

If a series and/or several losses occur which are attributable directly to one accident or event, all such losses shall be added together and the total amount of such losses shall be treated as one occurrence

(a) The Insured may elect the moment from which each of the aforesaid periods of seventy-two (72) hours shall begin for any one specific peril . . . .

72 Hours Clause?

If a series and/or several losses occur which are attributable directly to one accident or event, all such losses shall be added together and the total amount of such losses shall be treated as one occurrence

(a) The Insured may elect the moment from which each of the aforesaid periods of one-hundred-twenty-eight (128) hours shall begin for any one specific peril . . . .

Earthquake Sublimits

The following Sublimits apply:

A. ✓ $500 million per occurrence as respects loss or damage resulting from the peril of Earthquake except:

✓ $10 million per occurrence as respects property situated in Japan, Chile, California and Mexico.

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Contingent Business Interruption

The following Sublimits apply:

A. $500 million per occurrence as respects loss or damage resulting from the peril of Earthquake except:

$10 million per occurrence as respects property situated in Japan, Chile, California and Mexico.

Earthquake Deductibles

The following Deductibles apply to all locations as respects Earthquake Shock at location(s) in High Hazard Earth Movements Zones, except Mexico:

Five percent (5%) of the one hundred percent (100%) value of the property insured at location(s) involved for Property Damage; and

Five percent (5%) of the full twelve (12) months Time Element that would have been earned in the 12 month period following the Occurrence at location(s) involved for Time Element.

The combined deductible for Property Damage and Time Element shall be subject to a minimum of USD15,000,000 per occurrence.

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Contingent Business Interruption

The following Deductibles apply to all locations as respects Earthquake Shock at location(s) in High Hazard Earth Movements Zones, except Mexico:

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Not just about prices

Words matter