Stuart Nishenko

Senior Seismologist
Pacific Gas and Electric Company
San Francisco, CA

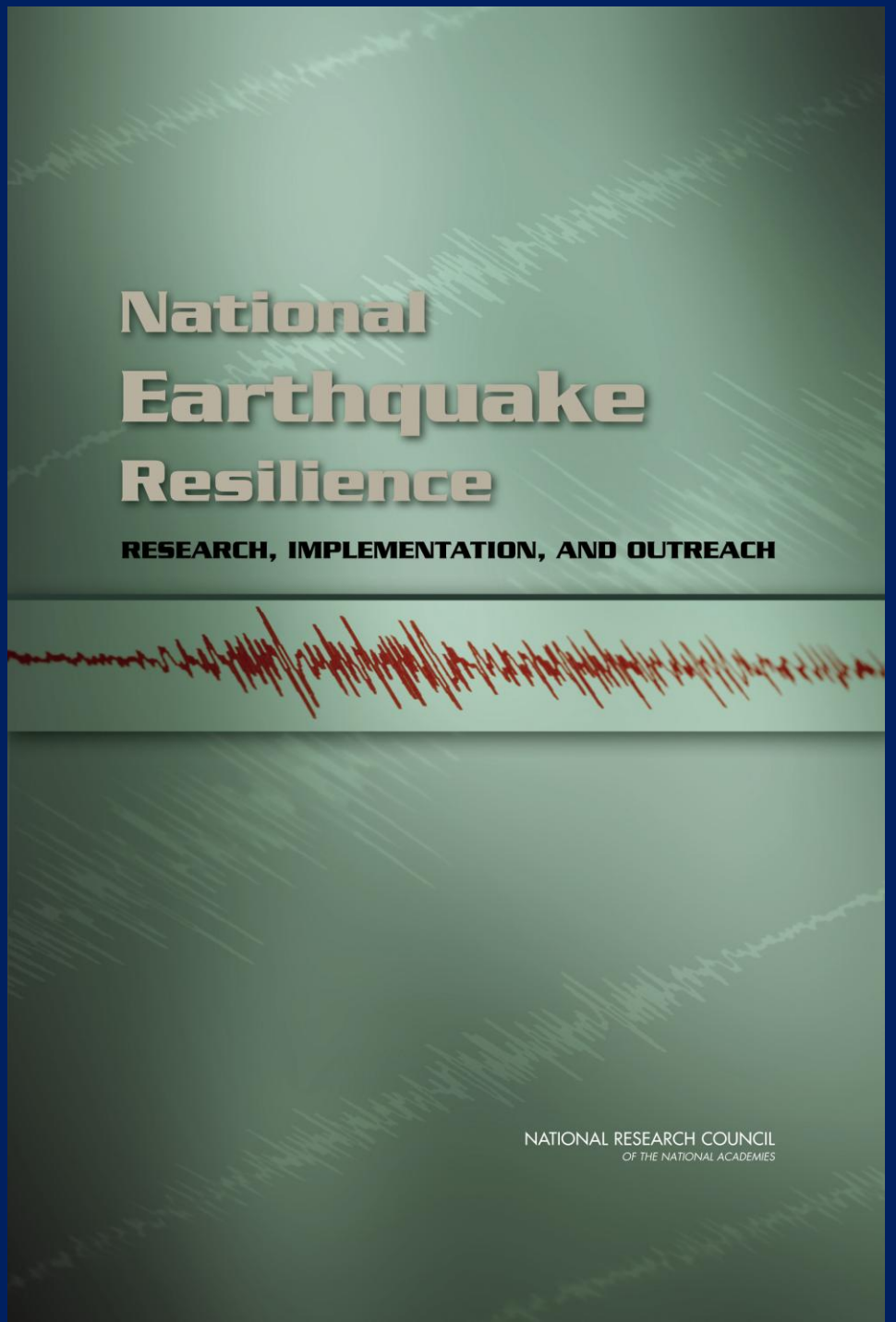
NRC Committee on Seismology and Geodynamics liaison to the Committee on National Earthquake Resilience

Tom Tobin

Tobin and Associates
Mill Valley, CA

Member, Committee on National Earthquake Resilience

Presentation to the Advisory Committee for Earthquake Hazards Reduction
Washington DC November 8, 2011



NRC Committee commissioned by
National Institute of Standards and Technology (NIST)
on behalf of the NEHRP agencies

NRC Report released April 2011

Committee Task

A National Research Council committee will develop a roadmap for earthquake hazard and risk reduction in the United States. The committee will frame the road map around the goals and objectives for achieving national earthquake resilience in public safety and economic security stated in the current strategic plan of the National Earthquake Hazard Reduction Program (NEHRP) submitted to Congress in 2008. This roadmap will be based on an analysis of what will be required to realize the strategic plan's major technical goals for earthquake resilience within 20 years.

In particular, the committee will:

Committee Task (cont.)

- Host a national workshop focused on assessing the basic and applied research, seismic monitoring, knowledge transfer, implementation, education, and outreach activities needed to achieve national earthquake resilience over a twenty-year period.
- Estimate program costs, on an annual basis, that will be required to implement the roadmap.
- Describe the future sustained activities, such as earthquake monitoring (both for research and for warning), education, and public outreach, which should continue following the 20-year period.

National Earthquake Resilience
Research, Implementation, and Outreach

Robert M. Hamilton, *Chair*, Zelienople, Pennsylvania

Richard A. Andrews, Independent Consultant, Redlands, California

Robert A. Bauer, Illinois State Geological Survey, Champaign

Jane A. Bullock, Bullock and Haddow, LLC, Reston, Virginia

Stephanie E. Chang, University of British Columbia, Vancouver, Canada

William T. Holmes, Rutherford & Chekene, San Francisco, California

Laurie A. Johnson, Laurie Johnson Consulting and Research, San Francisco, California

Thomas H. Jordan (NAS), University of Southern California, Los Angeles

Gary A. Kreps, College of William and Mary *(emeritus)*, Williamsburg, Virginia

Adam Z. Rose, University of Southern California, Los Angeles

L. Thomas Tobin, Tobin & Associates, Mill Valley, California

Andrew S. Whittaker, State University of New York, Buffalo

Liaison from the Board on Earth Sciences and Resources:

Stuart P. Nishenko, Pacific Gas and Electric Company, San Francisco, California

National Research Council :

David A. Feary, Study Director

PREFACE ADDITION

The recent, disastrous, magnitude-9 earthquake that struck northern Japan demonstrates the threat that earthquakes pose, and the tragic impacts are especially striking because Japan is an acknowledged leader in implementing earthquake-resilient measures.

Moreover, the cascading nature of impacts—the earthquake causing a tsunami, cutting electrical power supplies, and stopping the pumps needed to cool nuclear reactors—demonstrates the potential complexity of an earthquake disaster.

Such types of compound disaster can strike *any* earthquake-prone populated area

Defining Earthquake Resilience

- The committee interpreted resilience broadly, to incorporate engineering/science (physical), social/economic (behavioral), and institutional (governing) dimensions.
- Resilience was interpreted to encompass both pre- and post-disaster actions to enhance community robustness so that all earthquake-vulnerable regions can function adequately following damaging earthquakes.
- The committee also recognized that it is cost-prohibitive to achieve a completely seismically-resistant nation.

Earthquake Resilience

A disaster-resilient nation is one in which its communities, through mitigation and pre-disaster preparation, develop the adaptive capacity to maintain important community functions and recover quickly when major disasters occur.

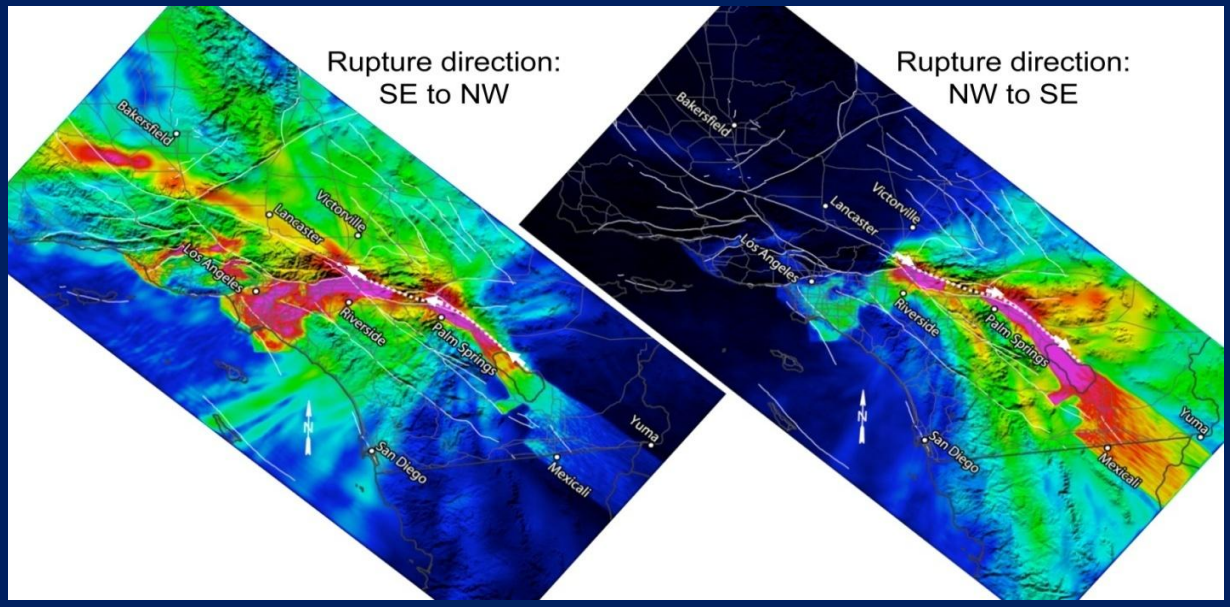
Elements and Costs of a Resilience Roadmap

The committee endorses the 2008 NEHRP Strategic Plan, and identifies 18 specific task elements required to implement that plan and materially improve national earthquake resilience.

1. Physics of Earthquake Processes

Conduct additional research to advance the understanding of earthquake phenomena and earthquake generation processes and to improve the predictive capabilities of earthquake science

5-year annualized cost of $27 million/year, for a total 20-year cost of $585 million

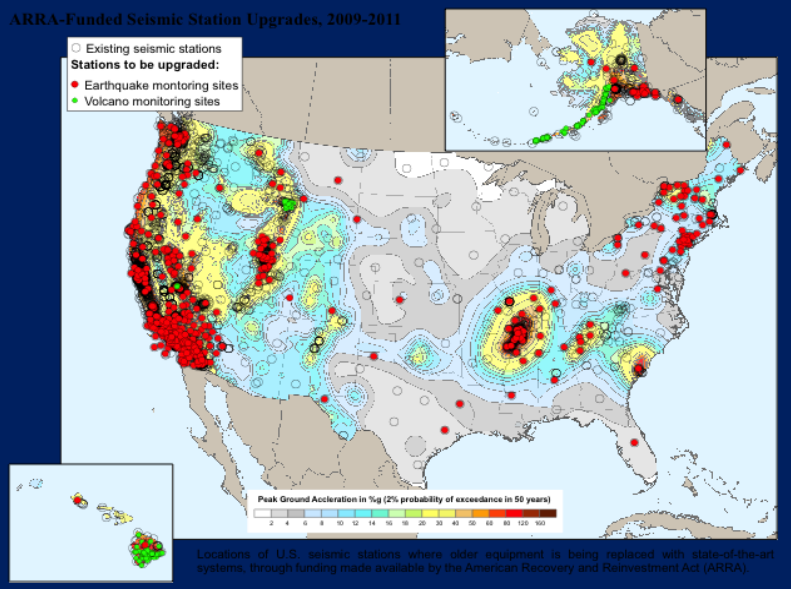


2. Advanced National Seismic System

Complete deployment of the remaining 75 percent of the Advanced National Seismic System

5-year annualized cost of $66.8 million/year, for a total 20-year cost of $1.3 billion

On-going operations and maintenance costs after the initial 20-year period of $50 million/year



Locations of U.S. seismic stations where older equipment is being replaced with state-of-the-art systems, through funding made available by the American Recovery and Reinvestment Act (ARRA).

3. Earthquake Early Warning

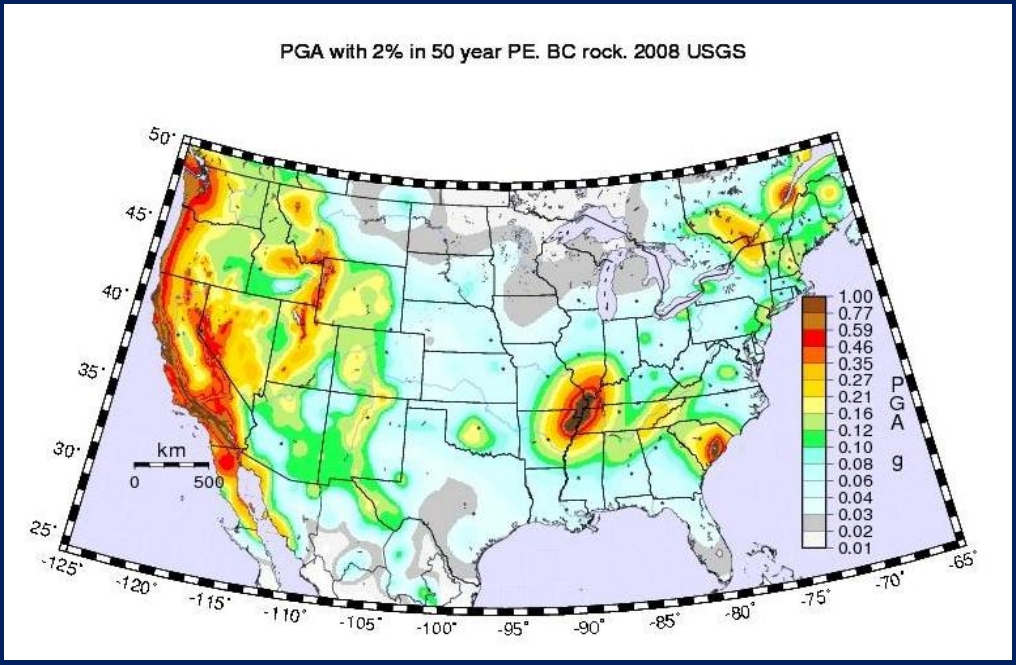
Evaluation, testing, and deployment of earthquake early warning systems

5-year annualized cost of $20.6 million/year, for a total 20-year cost of $283 million

4. National Seismic Hazard Model

Complete the national coverage of seismic hazard maps and create urban seismic hazard maps and seismic risk maps for at-risk communities

5-year annualized cost of $50.1 million/year, for a total 20-year cost of $946.5 million

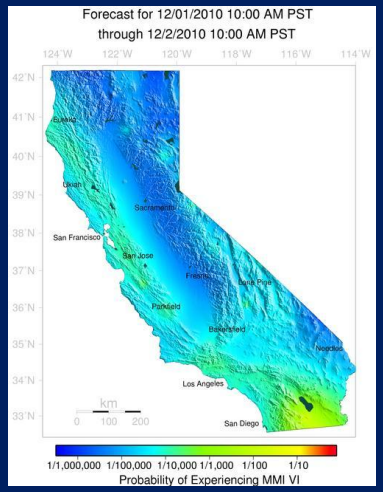


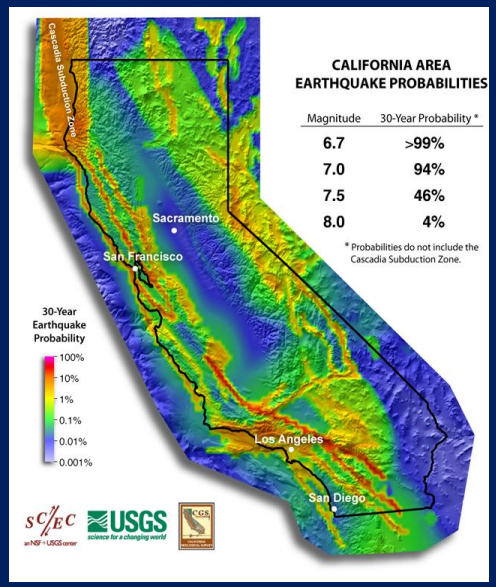
5. Operational Earthquake Forecasting

Develop and implement operational earthquake forecasting, in coordination with state and local agencies

5-year annualized cost of $5 million/year, for a total 20-year cost of $85 million

On-going operations and maintenance costs after the initial 20-year period are *unknown*

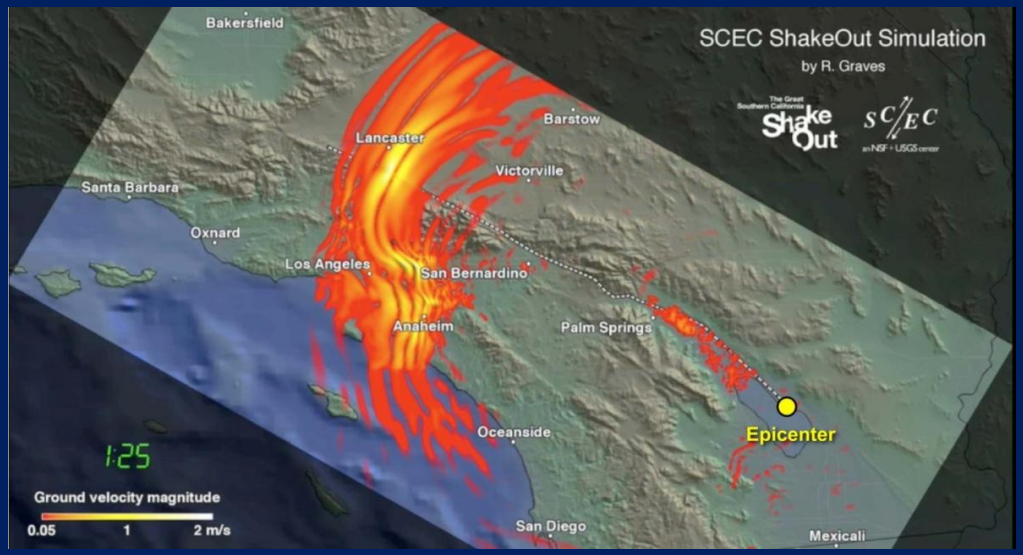


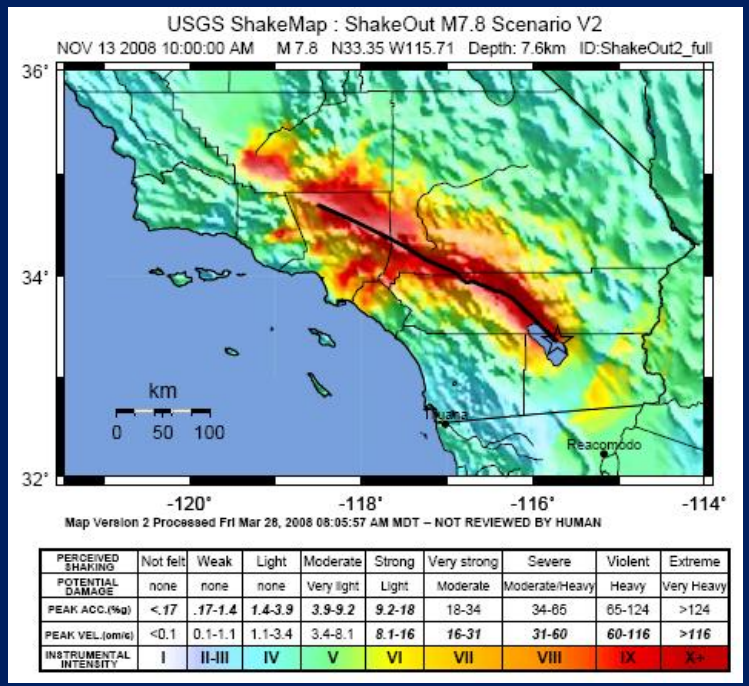


6. Earthquake Scenarios

Develop scenarios that integrate earth science, engineering, and social science information so that communities can visualize earthquake and tsunami impacts and mitigate potential effects

5-year annualized cost of $10 million/year, for a total 20-year cost of $200 million





PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

7. Earthquake Risk Assessments

Integrate science, engineering, and social science information in an advanced GIS-based loss estimation platform to improve earthquake risk assessments and loss estimations

5-year annualized cost of $5 million/year, for a total 20-year cost of $100 million

Rank	State	AEL ($ Million)	Rank	State	AELR ($/Million $)
1	Los Angeles-Long Beach-Santa Ana, CA	1,312.3	1	San Francisco-Oakland-Fremont, CA	2,049.44
2	San Francisco-Oakland-Fremont, CA	781.0	2	Riverside-San Bernardino-Ontario, CA	2,021.57
3	Riverside-San Bernardino-Ontario, CA	396.5	3	El Centro, CA	1,973.77
4	San Jose-Sunnyvale-Santa Clara, CA	276.7	4	Oxnard-Thousand Oaks-Ventura, CA	1,963.00
5	Seattle-Tacoma-Bellevue, WA	243.9	5	San Jose-Sunnyvale-Santa Clara, CA	1,837.58
6	San Diego-Carlsbad-San Marcos, CA	155.2	6	Santa Rosa-Petaluma, CA	1,662.57
7	Portland-Vancouver-Beaverton, OR-WA	137.1	7	Santa Cruz-Watsonville, CA	1,580.97
8	Oxnard-Thousand Oaks-Ventura, CA	111.0	8	Los Angeles-Long Beach-Santa Ana, CA	1,574.85
9	Santa Rosa-Petaluma, CA	68.6	9	Napa, CA	1,398.18
10	St. Louis, MO-IL	58.5	10	Vallejo-Fairfield, CA	1,375.94
11	Salt Lake City, UT	52.3	11	Anchorage, AK	1,238.56
12	Sacramento-Arden-Arcade--Roseville, CA	52.0	12	Santa Barbara-Santa Maria-Goleta, CA	1,207.93
13	Vallejo-Fairfield, CA	39.8	13	Reno-Sparks, NV	1,150.40
14	Memphis, TN-MS-AR	38.2	14	Bremerton-Silverdale, WA	1,110.13
15	Santa Cruz-Watsonville, CA	36.2	15	Salinas, CA	1,075.54
16	Anchorage, AK	34.8	16	Seattle-Tacoma-Bellevue, WA	1,052.43
17	Santa Barbara-Santa Maria-Goleta, CA	34.4	17	Salt Lake City, UT	984.61
18	Las Vegas-Paradise, NV	33.1	18	Olympia, WA	969.50
19	Honolulu, HI	32.0	19	Portland-Vancouver-Beaverton, OR-WA	942.62
20	Bakersfield, CA	30.3	20	Bakersfield, CA	870.43
21	New York-Northern New Jersey-Long Island, NY-NJ-PA	29.9	21	San Luis Obispo-Paso Robles, CA	848.65
22	Salinas, CA	29.2	22	Ogden-Clearfield, UT	826.52
23	Reno-Sparks, NV	29.0	23	Salem, OR	797.50
24	Charleston-North Charleston, SC	22.3	24	San Diego-Carlsbad-San Marcos, CA	770.20
25	Columbia, SC	21.6	25	Charleston-North Charleston, SC	766.01
26	Stockton, CA	20.9	26	Eugene-Springfield, OR	701.95
27	Atlanta-Sandy Springs-Marietta, GA	19.1	27	Provo-Orem, UT	683.30
28	Bremerton-Silverdale, WA	17.7	28	Stockton, CA	597.79
29	Ogden-Clearfield, UT	17.5	29	Memphis, TN-MS-AR	509.13
30	Salem, OR	17.4	30	Evansville, IN-KY	485.60
31	Eugene-Springfield, OR	16.5	31	Columbia, SC	478.05
32	Napa, CA	15.9	32	Modesto, CA	473.60
33	San Luis Obispo-Paso Robles, CA	15.7	33	Las Vegas-Paradise, NV	390.28
34	Nashville-Davidson--Murfreesboro, TN	15.4	34	Sacramento--Arden-Arcade--Roseville, CA	374.73
35	Albuquerque, NM	14.7	35	St. Louis, MO-IL	337.23
36	Olympia, WA	13.7	36	Albuquerque, NM	322.20
37	Modesto, CA	13.0	37	Honolulu, HI	311.12
38	Fresno, CA	12.6	38	Fresno, CA	283.13
39	Evansville, IN-KY	11.7	39	Little Rock-North Little Rock, AR	248.74
40	Birmingham-Hoover, AL	11.3	40	Nashville-Davidson-Murfreesboro, TN	167.26
41	El Centro, CA	10.7	41	Birmingham-Hoover, AL	115.54
42	Little Rock-North Little Rock, AR	10.5	42	Atlanta-Sandy Springs-Marietta, GA	65.39
43	Provo-Orem, UT	10.4	43	New York-Northern New Jersey-Long Island, NY-NJ-PA	20.90

8. Post-earthquake Social Science Response and Recovery Research

Document and model the mix of expected and improvised emergency response and recovery activities and outcomes to improve pre-disaster mitigation and preparedness practices at household, organizational, community, and regional levels

5-year annualized cost of $2.3 million/year, reviewed after the initial 5-years

9. Post-earthquake Information Management

Capture, distill, and disseminate information about the geological, structural, institutional, and socioeconomic impacts of specific earthquakes, as well as post-disaster response, and create and maintain a repository for post-earthquake reconnaissance data

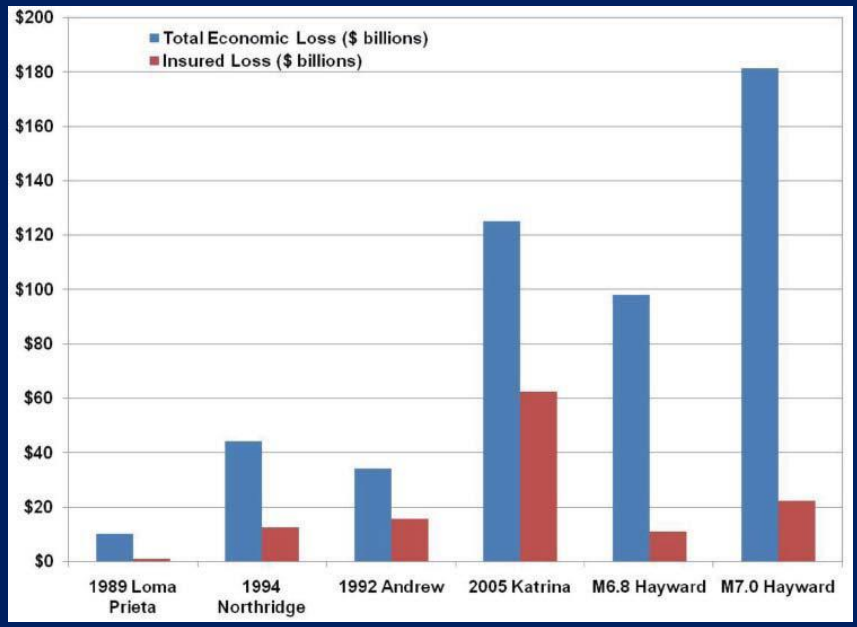
5-year annualized cost of $1 million/year, for a total 20-year cost of $14.6 million

On-going operations and maintenance costs after the initial 20-year period are *unknown*, but are likely to be small

10. Socio-economic Research on Hazard Mitigation and Recovery

Support basic and applied research in the social sciences to examine individual and organizational motivations to promote resilience, the feasibility and cost of resilience actions, and the removal of barriers to successful implementation

5-year annualized cost of $3.0 million/year, for a total 20-year cost of $60 million



11. Observatory Network on Community Resilience and Vulnerability

Establish an observatory network to measure, monitor, and model the disaster vulnerability and resilience of communities, with a focus on resilience and vulnerability; risk assessment, perception, and management strategies; mitigation activities; and reconstruction and recovery

5-year annualized cost of $2.9 million/year, for a total 20-year cost of $57.3 million

On-going operations and maintenance costs after the initial 20-year period are *unknown*

12. Physics-based Simulations of Earthquake Damage and Loss

Integrate knowledge gained in Tasks 1, 13, 14 and 16

- Physics of the Earthquake Process
- Evaluation and Retrofit of Existing Buildings
- Performance Based Engineering for Buildings and Lifelines
- Next Generation Sustainable Materials, Components and Systems

to enable robust, fully coupled simulations of fault rupture, seismic wave propagation through bedrock, and soil-structure response to compute reliable estimates of financial loss, business interruption and casualties

5-year annualized cost of $6 million/year, for a total 20-year cost of $120 million

13. Techniques for Evaluation and Retrofit of Existing Buildings

Develop analytical methods that predict the response of existing buildings with known levels of reliability based on integrated laboratory research and numerical simulations, and improve consensus standards for seismic evaluation and rehabilitation

5-year annualized cost of $22.9 million/year, for a total 20-year cost of $543.6 million

14. Performance-based Earthquake Engineering for Buildings

Advance performance-based earthquake engineering knowledge and develop implementation tools to improve design practice, inform decision makers, and revise codes and standards for buildings, lifelines and geo-structures

5-year annualized cost of $46.7 million/year, for a total 20-year cost of $891.5 million

15. Guidelines for Earthquake-Resilient Lifeline Systems

Conduct lifelines-focused collaborative research to better characterize infrastructure network vulnerability and resilience as the basis for the systematic review and updating of existing lifelines standards and guidelines, with targeted pilot programs and demonstration projects

5-year annualized cost of $5 million/year, for a total 20-year cost of $100 million

16. Next Generation Sustainable Materials, Components, and Systems

Develop and deploy new high-performance materials, components and framing systems that are green and/or adaptive

5-year annualized cost of $8.2 million/year, for a total 20-year cost of $334.4 million

17. Knowledge, Tools, and Technology Transfer to/from the Private Sector

Initiate a program to encourage and coordinate technology transfer across the NEHRP domain to ensure the deployment of state-of-art mitigation techniques across the nation, particularly in regions of moderate seismic hazard

5-year annualized cost of $8.4 million/year, for a total 20-year cost of $168 million

18. Earthquake Resilient Community and Regional Demonstration Projects

Support and guide community-based earthquake resiliency pilot projects to apply NEHRP-generated and other knowledge to improve awareness, reduce risk, and improve emergency preparedness and recovery capacity

5-year annualized cost of $15.6 million/year, for a total 20-year cost of $1 billion

Summary Totals

The annualized cost for the first 5 years of the roadmap for national earthquake resilience is **$306.5 million/year** ($2009)

Actual NEHRP appropriations in 2009 were $129.7 million

Factor of 2.4 increase in annual budget

The total 20-year estimate is $6.8 billion ($2009)

In Context

2008 Great California ShakeOut exercise in southern California was a scenario study for a magnitude-7.8 earthquake on the southernmost 300 km of the San Andreas Fault -- 1800 fatalities, $113 billion in damages to buildings and lifelines, and nearly $70 billion in business interruption

Proposed *20 year* NEHRP Budget represents ~ 3% Potential Losses in a *single* catastrophic earthquake

Thank You !

Questions?