SCEC

Southern California Earthquake Center

1994 Annual Meeting

September 23-25, 1994

Temecula Creek Inn
Temecula, California

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1994 SCEC ANNUAL MEETING AGENDA

Friday, September 23

9:00 a.m. **Field Trip to Pinon Flat, San Jacinto Fault and Garner Valley**

Field Trip Leaders: **Duncan Agnew**
Frank Wyatt
Tom Rockwell
Ralph Archuleta

7:30 p.m. **Poster Session and Icebreaker**

Saturday, September 24

7:30 p.m. **Breakfast Meeting of Advisory Council and Steering Committee**

9:00 a.m. **Session I: Plenary Session**

Welcome and Introduction	Henyey
Statement from NSF	Whitcomb
Statement from USGS	Mori
Phase II/Phase III Report	Aki
Phase IV	Jackson
GPS Initiative	Henyey
Los Angeles Basin Earthquake Scenarios	Sieh
Education and Outreach Developments	Abdouch/Johnson

We will break for lunch @ noon.

Session II: Working Group Meetings

1:00 to 4:00 p.m.	Group A:	Aki
4:00 to 6:30 p.m.	Groups B & H:	Day/Martin
	Group C:	Sieh
	Group D:	Clayton
Dinner at 6 to 7:30 p.m.		
7:30 to 10:00 p.m.	Group E:	Agnew
	Group F:	Hauksson
	Group G:	Knopoff
	Education and Outreach:	Abdouch/Johnson

Sunday, September 25

7:30 a.m. **Breakfast Meeting of GPS Coordinating Committee**

9:00 a.m. **Session III: Reports on Future Plans from Group Leaders**

Education and Outreach	Abdouch/Johnson
Engineering Applications Group Report	Martin
Group G (Earthquake Physics)	Knopoff
Group F (Regional Seismicity)	Hauksson
Group E (Crustal Deformation)	Agnew
Group D (Subsurface Imaging)	Clayton
Group C (Earthquake Geology)	Sieh
Group B (Strong Motion)	Day
Group A (Master Model)	Aki
Meeting Summary	Henyey

End of SCEC Meeting

Lunch **Lunch meeting of Advisory Council and Steering Committee**

Note: Steering Committee will meet at conclusion of session for preparation of RFP.

1994 SCEC ANNUAL MEETING AND PROPOSAL SCHEDULE

ANNUAL MEETING SEPTEMBER 23-25, 1994	REVIEW OF 1994 SCEC ACTIVITIES
	GROUP MEETINGS - REVIEW AND PLANNING FOR YEAR 5
	CONSENSUS REPORTS ON YEAR 5 PLANS PRESENTED BY GROUP LEADERS
	MEETING OF ADVISORY COUNCIL
	GROUP LEADERS PROVIDE WRITTEN SUMMARIES OF GROUP PLANS TO AKI
EARLY OCTOBER, 1994	CALL FOR PROPOSALS FOR YEAR 5
NOVEMBER 8, 1994	YEAR 4 PROGRESS REPORTS AND 1995 PROPOSALS DUE AT SCEC
NOVEMBER 15, 1994	PROPOSAL PACKETS SENT TO GROUP LEADERS FOR REVIEW
DECEMBER 1, 1994	GROUP LEADERS SEND RECOMMENDATIONS TO AKI
	GROUP LEADERS PROVIDE SUMMARIES FOR ANNUAL REPORT
	AKI REVIEWS TOTAL PROGRAM
MID-DECEMBER, 1994	SCEC STEERING COMMITTEE REVIEWS AKI RECOMMENDATIONS
	SCEC ANNUAL REPORT DUE TO NSF/USGS
EARLY JANUARY, 1995	1995 AWARDS ANNOUNCED AFTER BOARD VOTE
	NSF/USGS NOTIFIED OF AWARDS
FEBRUARY-MARCH, 1995	SUBCONTRACTS ISSUED

1994 SCEC ANNUAL MEETING PARTICIPANTS

Curt Abdouch	USC
Rachel Abercrombie	USC
Duncan Agnew	UC-San Diego
Ralph Archuleta	UC-Santa Barbara
Kei Aki	USC
John Anderson	Nevada-Reno
Thora Arnadottir	UC-Santa Barbara
Mark Benthien	UC-Los Angeles
Yehuda Ben-Zion	Harvard
Yehuda Bock	UC-San Diego
Ron Blom	JPL
Ann Blythe	USC
John Chen	Oregon St.
James Chin	USC
Rob Clayton	Caltech
Cheryl Contopulos	Caltech
Allin Cornell	Stanford
Bob Coutts	CAPSE
Paul Davis	UC-Los Angeles
Steve Day	San Diego State
Jishu Deng	Lamont
Jim Dieterich	USGS-Menlo Park
Jim Dolan	Caltech/USC
Danan Dong	JPL
Andrea Donnellan	JPL
Geoff Ely	UC-Santa Barbara
Kurt Feigl	Paris
Ned Field	USC/Lamont
Mike Forrest	USC
Dan Francis	Cal State-Long Beach
Bob Ge	UC-Los Angeles
Lisa Grant	Woodward-Clyde
Katrin Hafner	Caltech
Brad Hager	MIT
Toni Hanson	USC
Ruth Harris	USGS-Menlo Park
Egill Hauksson	Caltech
Tom Heaton	USGS-Pasadena
Mike Hedlin	UC-San Diego
Don Helmberger	Caltech
Tom Henyey	USC

Scott Hornafius	UC-Santa Barbara
Bill Holt	SUNY-Stony Brook
Sue Hough	USGS-Pasadena
Ken Hudnut	USGS-Pasadena
Gary Huftile	Oregon State
Gene Humphreys	Oregon
Ken Hurst	JPL
Gene Ichinose	San Diego State
Dave Jackson	UC-Los Angeles
Anshu Jin	USC
Laurie Johnson	USC/Spangle
Lucy Jones	USGS-Pasadena
Tom Jordan	MIT
Marc Kamerling	UC-Santa Barbara
Stacy Kerkela	Caltech
Mercedes Kim	UC-Los Angeles
Bob King	MIT
Leon Knopoff	UC-Los Angeles
Mark Legg	ACTA
Eric Lehmer	USC/UC-Riverside
Yong-gang Li	USC
Scott Lindvall	Lindvall, Richter, Benuska
Bruce Luyendyk	UC-Santa Barbara
Harold Magistrale	San Diego State
Mehrdad Mahdyiar	Vortex Rock Consultants
Geoff Martin	USC
Sally McGill	Cal State-San Bernardino
Keith McLaughlin	S-Cubed
John McRaney	USC
Erick McWayne	UC-Santa Barbara
Dennis Mileti	Colorado
Bernard Minster	UC-San Diego
Jim Mori	USGS-Pasadena
Karl Mueller	Princeton
Danny Natawidjaja	Caltech
Stefan Nielsen	UC-Los Angeles
Craig Nicholson	UC-Santa Barbara
David Oglesby	UC-Santa Barbara
David Okaya	USC
Kim Olsen	UC-Santa Barbara
Steve Park	UC-Riverside
Guang-yu Pei	UC-Los Angeles
Bill Petak	USC

Mark Petersen	CDMG
Bob Pizzi	UC-Santa Barbara
Dan Ponti	USGS-Menlo Park
Dave Potter	UC-Los Angeles
Helen Qian	Caltech
Matthew Ragan	USC
Cliff Roblee	Caltrans
Barbara Romanowicz	UC-Berkeley
Mike Reichle	CDMG
Tom Rockwell	San Diego State
John Rundle	Colorado
Steve Salyards	UC-Los Angeles
Charlie Sammis	USC
Jennifer Scott	Caltech
Craig Scrivner	Caltech
Nano Seeber	Lamont
Kaye Shedlock	USGS-Denver
Kerry Sieh	Caltech
Lois Slavkin	USC
Bob Smith	Utah
Jamie Steidl	UC-Santa Barbara
Ross Stein	USGS-Menlo Park
Mark Stirling	Nevada-Reno
Joann Stock	Caltech
Li-yu Sung	UC-Los Angeles
John Suppe	Princeton
Chris Sykes	San Diego State
Mary Templeton	Cal State-Fullerton
Tony Thatcher	Oregon State
Hong-Kie Thio	Caltech
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Alexei Tumarkin	UC-Santa Barbara
Gianluca Valensise	UC-Santa Cruz
Frank Vernon	UC-San Diego
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Steve Wesnousky	Nevada-Reno
Jim Whitcomb	NSF
Tom Wright	Consultant
Bob Yeats	Oregon State
Guang Yu	San Diego State
Yuehua Zeng	Nevada-Reno
Dapeng Zhao	Caltech

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Rachel Abercrombie	USC
Duncan Agnew	UC-San Diego
Kei Aki	USC
Ralph Archuleta	UC-Santa Barbara
Thora Arnadottir	UC-Santa Barbara
Yehuda Ben-Zion	Harvard
Ann Blythe	USC
Rob Clayton	Caltech
Cheryl Contopulos	Caltech
Paul Davis	UC-Los Angeles
Jishu Deng	Lamont
Jim Dolan	Caltech/USC
Andrea Donnellan	JPL
Kurt Feigl	Paris
Ned Field	USC/Lamont
Bob Ge	UC-Los Angeles
Lisa Grant	Woodward-Clyde
Katrin Hafner	Caltech
Brad Hager	MIT
Bill Holt	SUNY-Stony Brook
Sue Hough	USGS-Pasadena
Gene Humphreys	Oregon
Ken Hurst	JPL
Anshu Jin	USC
Malcolm Johnston	USGS-Menlo Park
Mercedes Kim	UC-Los Angeles
Bob King	MIT
Mark Legg	ACTA
Eric Lehmer	USC/UC-Riverside
Yong-Gang Li	USC
Bruce Luyendyk	UC-Santa Barbara
Mehrdad Mahdyiar	Vortex Rock Consultants
Sally McGill	Cal State-San Bernardino
John McRaney	USC
Karl Mueller	Princeton
Stefan Nielsen	UCLA
David Oglesby	UC-Santa Barbara
David Okaya	USC
Kim Olsen	UC-Santa Barbara
Guang-Yu Pei	UC-Los Angeles
Mark Petersen	CDMG

Dave Potter	UC-Los Angeles
Helen Qian	Caltech
Mike Reichle	CDMG
Cliff Roblee	Caltrans
Tom Rockwell	San Diego State
Steve Salyards	UC-Los Angeles
Bruce Shaw	Lamont
Li-Hong Sheng	Caltrans
Jamie Steidl	UC-Santa Barbara
Ross Stein	USGS-Menlo Park
Mark Stirling	Nevada-Reno
John Suppe	Princeton
Alexei Tumarkin	UC-Santa Barbara
Alla Tumarkin	UC-Santa Barbara
Gianluca Valensise	UC-Santa Cruz
Frank Vernon	UC-San Diego
Steve Ward	UC-Santa Cruz
Frank Wyatt	UC-San Diego
Bob Yeats	Oregon State
Guang Yu	San Diego State

POSTER SESSION PARTICIPANTS

Abercrombie, Rachel and Ragan, Matthew, Microseismicity in the Vicinity of the Cajon Pass Borehole.

Barry, R., Hauser, R., Lehmer, E. and Park, S. K., SCEC Contributions to USGS Digital Fault Map Project.

Benthien, Mark and Pei, Guang-Yu, Crustal Tomography of Southern California.

Ben-Zion, Yehuda and James Rice, Statistics of Earthquakes Along Different Classes of Fault Systems.

Blom, R., Crippen, R. and Pletzer, G., Topographic and Satellite Data for Seismic Hazard Evaluation and Deformation Measurement.

Bryant, W. A., Petersen, M. D. and Kramer, C. H., Paleoseismic Data and Probabilistic Seismic Hazard Maps, Los Angeles, Orange, and Ventura Counties, California.

Chin, James and Aki, K., Strong Motion Simulation for the 1992 Landers Earthquake.

Deng, Jishu and Sykes, L. R., Evolution of the Stress Field in Southern California: Triggering of 1812 Santa Barbara Earthquake by a Great San Andreas Shock.

Dolan, James and Sieh, Kerry, Prospects for Larger and More Frequent Earthquakes in the Los Angeles Metropolitan Region, California.

Dong, D., Herring, T. A., and R. W. King, Methodology of Estimating Regional Deformation Geodetic Data.

Donnellan, Andrea and Lyzenga, Greg, Current Results from GPS Measurements Collected Following the Northridge Earthquake.

Ely, Geoffrey, and Craig Nicholson, Analysis of the SCEC Portable and Regional Data for the 1992 Joshua Tree Sequence.

Forrest, M. R. and Abercrombie, Rachel, Can We Use Microseismicity Rates to Quantify Large Earthquake Hazard? -- Examples From Reverse Faults in Southern California.

Francis, Robert D., David Sigurdson, Michael Morgan, and William Mah, High Resolution Seismic Reflection Investigation of the Palos Verdes Fault Zone in Los Angeles Harbor.

Ge, Xiaobin Bob, Shen, Zheng-kang, Cline, Michael, Feng, Yanjie, Potter, David and Jackson, David D., Static Focal Mechanism of 1994 Northridge Earthquake Determined by GPS.

Hafner, K. and R. Clayton, The SCEC Data Center.

Hedlin, Michael, Minster, J. B., Vernon, F. L. and Orcutt, J. A., A Deep Crustal Scatterer Near the San Andreas at the Northern End of the Coachella Valley.

Holt, Bill, Relative Velocities in Southern California Estimated From the Inversion of Quaternary Strain Rates.

Hong, L., Gao, S. and Davis, P., NEAR 94.

Huftile, Gary and Yeats, Bob, Cross Sections Through the Northridge Aftershock Zone.

Humphreys, Gene, A Kinematic Model of Southern California Deformation.

Hurst, Ken, An Empirical Study of GPS Monument Stability in the Southern California Dense GPS Array and FLINN GPS Network.

Ichinose, Gene, Magistrale, Harold, Steve Day, and Keith McLaughlin, Visualizing 3D Elastic Seismic Wave Simulations of the Los Angeles and San Fernando Basin.

Kamerling, Marc and Craig Nicholson, The Oak Ridge Fault in the Central Santa Barbara Channel.

Kerkela, Stacy and Stock, Joann, Stress Directions North of the San Fernando Valley Determined from Borehole Breakouts.

Legg, Mark, Active Faulting in the Inner Continental Borderland.

Li, Y. G., Beltas, Periklis and Aki, K., Observations of f_{max} and f_{corner} from Landers Aftershocks Using Reftek Instruments.

Lindvall, Scott and Walls, Chris, Tectonic Geomorphology of the Sierra Madre Fault Zone in the Sylmar Basin.

Magistrale, Harold, J. Scott, and E. Hauksson, Three Dimensional P-Wave Velocities of the Los Angeles Basin: Integrating Forward and Tomographic Models.

Mahdyiar, Mehrdad (Computer Demonstration)

Martin, Aaron J., Rodgers, Peter W. and Archuleta, Ralph J., The SCEC Portable Broadband Instrument Center 1993-94 Projects and Activities.

McGill, Sally, Variability in Surficial Slip Along a Portion of the Emerson Fault During the 1992 Landers Earthquake.

McWayne, Erick, History of Faulting and Folding in the Western Santa Barbara Channel, California.

Mori, J., R. Wesson, and D. Wald, Overlapping Fault Planes of the 1971 San Fernando and 1994 Northridge Earthquake.

Mueller, Karl and Suppe, John, Paleoseismology of Blind Thrusts Through Analysis of Their Fault-Related Folds.

Nicholson, Craig, Christopher C. Sorlien, Tanya Atwater, John C. Crowell and Bruce P. Luyendyk, Microplate Capture, Rotation of the Western Transverse Ranges, and Initiation of the San Andreas Transform as a Low-Angle Fault System.

Nielsen, Stefan, Periodicity in a Model of Recurrent Dynamic Faulting.

Okaya, David, Wright, Tom, Henyey, Tom, Suppe, John, and Yeats, Bob, Status of Industry Data Acquisition.

Park, S. K. and Lehmer, E., Correlation of Damage and Geotechnical Parameters with Quaternary Geology.

Pei, G., Benthien, M. and the LARSE Working Group, Passive Array Experiment.

Potter, David and Jackson, David, Determination of Strain Fields From the Numerical Inversion of Southern California GPS, VLBI and Trilateration Data.

Rice, James, Ben-Zion, Yehuda and Zheng, Elastodynamics of Rupture Propagation and Arrest.

Rogers, Peter W. and Martin, Aaron J., Signal Coil Calibration of Electro-Magnetic Seismometers.

Qian, Helen, Marquis, John, Sullivan, Damien and Hauksson, E., Interactive Tutorial in Seismicity, Including the Northridge Earthquake.

Salyards, Steve, GPS Data Archiving.

Sammis, Charles and Sornette, Didier, Universal Log-Periodic Correction to Renormalization Group Scaling for Regional Seismicity: Implications for Earthquake Predictions.

Scott, Jennifer S. Hauksson, E., Vernon, Frank, and Edelman, A., Los Angeles Basin Structure from Waveform Modeling of Aftershocks of the January 17, 1994 Northridge Earthquake.

Scrivner, Craig, Wen, Lianxing and Helmberger, Donald V., Potential for an Early Warning Program in Los Angeles Based on Sparse Broadband Network Data.

Seeber, Nano (Computer Demonstration)

Sorlien, C. C., Luyendyk, B. P. and Hornafuis, J. S., Unfolding the Top Monterey Formation in Offshore Ventura Basin, California.

Steidl, J., et al., SCEC Portable Deployment Following the 1994 Northridge Earthquake.

Stirling, Mark, Fault Trace Complexity, Cumulative Slip and the Shape of the Magnitude-Frequency Distribution for Strike-Slip Faults: Implications to Seismic Hazard Assessment in Southern California.

Sykes, Chris, Paleoseismic Studies in the Los Angeles Region.

Templeton, Mary, Refining High-Resolution Seismic Reflection as a Tool for Paleoseismology.

Thatcher, Tony, Kimerling, Jon and Yeats, Bob, Digitizing the Well-Base Map and Structure Contour Maps of Northern LA Basin.

Thio, Hong-Kei, Source Complexity of 1994 Northridge Earthquake and Its Relation to Aftershock Mechanisms.

Thorup, Kim, Paleoseismic Studies in the Los Angeles Basin and on Santa Rosa Island.

Toppozada, T. R., et al., Planning Scenario for a Major Earthquake on the San Jacinto Fault Zone in the San Bernardino Area.

Ward, Steve and Valensise, Luca, Progressive Growth of San Clemente Island, California, by Blind Thrust Faulting: Implications for Fault Slip Partitioning in the California Continental Borderland.

Working Group D, The October 1994 LARSE Experiment.

Zhao, Dapeng, Teleseismic Evidence for Lateral Heterogeneities in the Northeastern Japan Area.

Zhao, Dapeng and Kanamori, Hiroo, Relation Between Crustal Structure, Mechanism and Dynamic Rupture of the 1994 Northridge Earthquake.

Zhao, Dapeng and Kanamori, Hiroo, Simultaneous Inversion of Local and Teleseismic Data for the Crust and Mantle Structure in Southern California.

SCEC ORGANIZATION-1994

Management

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Executive Director:	Thomas Henyey University of Southern California
Assistant Director for Engineering Applications:	Geoffrey Martin University of Southern California
Assistant Director for Administration:	John McRaney University of Southern California
Assistant Director for Knowledge Transfer:	Laurie Johnson University of Southern California/ Spangle Associates
Assistant Director for Education:	Curt Abdouch University of Southern California/ Southern California Academy of Sciences

Board of Directors

Chair:	Keiiti Aki University of Southern California
Vice-Chair:	Bernard Minster University of California, San Diego
Members:	Robert Clayton California Institute of Technology
	Ralph Archuleta University of California, Santa Barbara
	Bernard Minster University of California, San Diego
	Leonardo Seeber Columbia University
	James Mori United States Geological Survey
Ex-officio:	Thomas Henyey University of Southern California

Research Group Leaders

A:	Master Model:	Keiiti Aki University of Southern California
B:	Ground Motion Prediction:	Steve Day San Diego State University
C:	Earthquake Geology	Kerry Sieh California Institute of Technology
D:	Tectonics and Subsurface Imaging:	Robert Clayton California Institute of Technology
E:	Crustal Deformation:	Duncan Agnew University of California, San Diego
F:	Seismicity and Source Parameters:	Egill Hauksson California Institute of Technology
G:	Earthquake Source Physics:	Leon Knopoff University of California, Los Angeles
H:	Engineering Applications:	Geoffrey Martin University of Southern California

SCEC ADVISORY COUNCIL

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Dr. Robert (Bob) SMITH, University of Utah, Department of Geology and Geophysics, Salt Lake City, UT 84112-1183

Report on the
meeting of the Advisory Council
to the Southern California Earthquake Center
March 25, 1994
University of Southern California.

The 5th meeting of the SCEC Advisory Council was held at USC on March 25, 1994. The Council welcomed new member K. Shedlock. Members present were J. Dietrich, D. Miletti, W. Petak, B. Romanowicz (Chair), J. Rundle and K. Shedlock.

The Advisory Council is pleased to see the progress made in the last year towards the development of the Outreach Program. Dr Karen McNally's efforts have now resulted in the creation of a capable, enthusiastic and energetic team, with an ambitious program for outreach towards both the public and professional organisations. We welcome Laurie Johnson and Curtis Abdouch and wish them good luck with their endeavors. The Outreach Program seems now well underway and we particularly encourage Curt to follow up on his plan to tune the activities of the educational outreach with those of the SCEC scientists.

The Advisory Council congratulates SCEC for their completion of the Phase I report and hopes that the Center will be able to adhere to its schedule and timely publish the Phase 2 report this summer. We have observed, once again, an increasing level of integration between the disciplinary groups towards the Center's goal of the Master Model. The symbiosis created by the Center's monthly meetings and cooperative projects is working.

The membership in SCEC seems to be evolving in a natural manner for a dynamic organisation. We welcome JPL as a new member institution. At this time of chamge, we take the opportunity to affirm our conviction that essential aspects of the Center's success depend upon the open cooperative style of member institution participation and firm rulews for sharing of data bases.

The Council is pleased to see the evolution of relations with oil companies. The availability of the wealth of subsurface imaging data raises an obvious question. Should the Center continue to plan and execute experiments in this domain or focus on the interpretation of the existing data and other activities? We urge the Center to undertake a reexamination of the subsurface imaging activities in light of this important development.

In the wake of the Northridge earthquake, we recommend that the Center take a look back and assess how well it has performed in coordinating scientific and media response to the earthquake. We strongly recommend discussion with Caltech and the USGS so that a plan can be prepared to develop a Public Information Office for southern California that would involve all relevant organisations and complement but not compete with the existing efforts of the Caltech Media Center. This center might prepare ongoing summaries of the efforts underway at SCEC to continually evaluate the risk posed by earthquakes in southern California; update the public on scientific progress in earthquake studies; and act as an emergency information source.

We applaud the news that strong motion data for the Landers earthquakes have been made available to SCEC and hope that the Northridge earthquake strong motion data will likewise be made available in a timely manner.

The Council feels that too much time has elapsed between this and the last meeting (almost one year) to be able to follow the SCEC developments closely. To meet once every six months seem necessary and the Advisory Committee needs at least one full day to meet. The next meeting of the Advisory Council is planned for September 23-25, 1994, in conjunction with a SCEC Annual Meeting.

SCEC Steering Committee

Kei Aki

August 4, 1994

Response to the Advisory Council Report

Attached is a copy of report on the Advisory Council meeting of March 25, 1994. The report recommends that the center take a look back and assess how well it has performed in coordinating scientific and media response to the Northridge earthquake.

As you may remember, the first significant earthquake after the formation of SCEC was the Sierra Madre earthquake of June, 1991, and we had a meeting to discuss the role of SCEC in response to an earthquake. In that meeting, we decided that the short-term response should be done at the USGS-Caltech office in Pasadena, and the long-term response by SCEC. As a result, we published a newsletter, in a month or so.

Similarly, the short-term response to the Landers earthquake of 1992 was taken care of by the Pasadena office, and SCEC organized a one-day workshop two weeks after the earthquake where we decided to publish the Phase-I and Phase-II report.

After the Northridge earthquake, Tom Henyey and Jim Mori organized a meeting at the USGS Pasadena office one week after the earthquake, and we discussed publishing a report which did not materialize. Instead, Lucy Jones took initiative in editing a Science paper authored by USGS and SCEC scientists. The paper was submitted to Science recently.

SCEC organized a monthly meeting on February 24, 1994, 6 weeks after the earthquake to exchange notes among researchers working on the earthquake. It covered seismology, geodesy and geology, and the earthquake was put in the perspective of the master model being developed in the Phase-II report. More than 200 people attended the meeting, and intensive communication took place among them during the pizza hour which followed the meeting.

My personal feeling is that SCEC has been effective in coordinating responses to these earthquakes. The problem is that the name of SCEC does not show up on TV screens when the national attention is focused on the earthquake disaster.

With this memo, I request your response to the following questions.

(1) What did SCEC do in coordinating scientific and media response to the Northridge earthquake?

(2) How can SCEC best complement the existing efforts of the Caltech media center?

Southern California Earthquake Center

Senior Research Investigators (1994)

Principal Investigator and Science Director:	**Keiiti Aki** Department of Earth Sciences University of Southern California Los Angeles, California 90089
Executive Director:	**Thomas L. Henyey** Department of Earth Sciences University of Southern California Los Angeles, California 90089

Principal Institutions	**Scientists**
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Massachusetts Institute of Technology Department of Earth, Atmospheric, and Planetary Sciences Cambridge, Massachusetts 02139	Brad Hager Tom Herring Robert King

Harvey Mudd College Claremont, California	Greg Lyzenga
University of Nevada Department of Geological Sciences Reno, Nevada 89557	John Anderson Raj Siddharthan Feng Su Steven Wesnousky Yue-hua Zeng
University of Oregon Department of Geological Sciences Eugene, Oregon 97403	Gene Humphreys
Oregon State University Department of Geosciences Corvallis, Oregon 97331	Robert Yeats
Princeton University Department of Geological and Geophysical Sciences Princeton, New Jersey 08544	John Suppe
San Diego State University Department of Geological Sciences San Diego, California 92182	Steven Day Harold Magistrale Thomas Rockwell
Woods Hole Oceanographic Institute Department of Geology and Geophysics Woods Hole, Massachusetts 02543	Jian Lin

Industry Participants	**Scientists**
ACTA, Inc. Torrance, California	Mark Legg
Davis and Namson Ventura, California	Thom Davis Jay Namson
Leighton and Associates Diamond Bar, California	Eldon Gath
Lindvall, Richter, Benuska, Associates, Inc. Pasadena, California	Scott Lindvall
S-Cubed, Inc. La Jolla, California	Keith McLaughlin
Vortex Rock Consultants Diamond Bar, California	Mehrdad Mahdyiar
Woodward-Clyde Associates Santa Ana, California	Lisa Grant

Southern California Earthquake Center

1994-1995 Post-doctoral Fellows and Visitors Program

Visitor	Institution (Host)	Research Project
Y. John Chen (Oregon State)	UCSD (Minster)	Finite Element Modeling of Three-Dimensional Interaction/Coupling between Blind Thrust and Strike-Slip Faults in the Los Angeles Basin
Edward H. Field (Post-doctoral Fellow) Ph.D., Columbia	USC (Aki)	Toward a Better Understanding of Earthquake Site Response in Terms of Hazard Assessment
Stefan Nielson (Post-doctoral Fellow) Ph.D., Paris	UCLA (Knopoff)	Simulation of Dynamic Rupture
Kim B. Olsen (Post-doctoral Fellow) Ph.D., Utah	UCSB (Archuleta)	M8+ Earthquake in Southern California?
Guang Yu (Post-doctoral Fellow) Ph.D., Nevada-Reno	San Diego State (Day)	Prediction of Strong Ground Motion
J. Douglas Yule (Post-doctoral Fellow) Ph.D., Caltech	Caltech (Sieh)	Neotectonic and Paleoseismic Investigation of the San Andreas Fault System in the Vicinity of San Gorgonio Pass
Jiakang Xie (St. Louis University)	USC (Aki)	Fault Zone Structure Study by Slowness Power Spectrum Analysis of the 1992 Joshua Tree Aftershock Data

SCEC RESEARCH TASKS

Task 1: **Construct Maps of Probabilistic Seismic Hazard of Southern California**

Task 1A: Construct a data base for characterizing earthquake sources in southern California.

Task 1B: Construct a library of Green's functions for characterizing propagation-path effects in southern California.

Task 1C: Construct a data base of meso-scale site amplification factors at various frequencies and basement accelerations for southern California.

Task 1D: Develop the methodology for probabilistic seismic hazard analysis.

Task 2: **Develop Plausible Earthquake Scenarios Emphasizing the Los Angeles Basin**

Task 3: **Study Fundamental Relationships Among Fault Structures, Dynamics, and the Earthquake Recurrence Process**

Task 3A: Detailed study of the 3-D fault zone structure for selected fault segments.

Task 3B: Development of the "physical master model".

Task 3C: Study of the regional stress field in southern California.

Task 4: **Develop and Test Intermediate-term Earthquake Prediction Methodology**

Task 5: **Support the Development of Real-time Earthquake Information**

Task 6: **Response to Future Earthquakes**

•SCEC 1994 Discipline Task Matrix for Science and Northridge Response

	Group A	B	C	D	E	F	G	Sub-Total
Task 1	158	14	134	28	28			362
Task 2	43	215	108	24	45		32	467
Task 3	173	11	223	447	54	138	83	1,129
Task 4	55					10	36	101
Task 5	3			7	14	57		81
Task 6	35	80	22		132	446		715
Sub-Total	467	320	487	506	273	651	151	2,855

1994 SCEC Funding

NSF Regular Program	$2.850M
USGS Regular Program	$1.200M
Caltrans Program	$0.750M
FEMA Regular Program	$0.130M
USGS Northridge Supplement	$0.150M
NSF Northridge Supplement	$0.400M
USGS Data Center Supplement	$0.100M
Total Funds Available:	$5.580M

Funds Budgeted:

Regular Research Plan	$4.045M
Northridge Post-Earthquake Studies	$0.525M
Data Center Enhancement	$0.190M
Subtotal	$4.760M
FEMA Program	$0.130M
Caltrans Program	$0.690M
Total Program	$5.580M

1991-94 SCEC BUDGETS (in K$)

Infrastructure

	1991	1992	1993	1994
Management:	240	225	223	240
Workshops/Meetings:	45	90	60	100
Visitors Program:	290	150	110	175
Data Center				
Maintenance and Catalog Update:	150	200	181	225
Equipment:	147	0		
Strong Motion Data Base:	0	30	35	60
Broad Band Center:				
Equipment:	215	120	125	80
Maintenance:	67	80	77	90
GPS Data Analysis:	335	320	310	355
Monumentation:	140	90	0	0
GIS:	80	70	105	85
Earthquake Geology GIS:			95	90
Education and Outreach:	30	100	90	300
Facilities: Pinon Flat:	0	20	20	50
TERRAscope:	0	60	60	55
Subtotal Infrastructure:	1,739	1,555	1,490	1,905
Landers Post-Earthquake Studies			289	
Northridge Post-Earthquake Studies				715

Science

	1991	1992	1993	1994
A - Master Model	150	223	299	432
B - Ground Motion Prediction	200	167	163	240
C - Earthquake Geology	200	399	281	465
D - Subsurface Imaging and Tectonics	275	170	82	506
E - Crustal Deformation	160	117	136	141
F - Seismicity and Source Processes	145	150	145	205
G - Physics of Earthquakes	200	154	95	151
H - Engineering Applications				
Subtotal Science:	1,330	1,380	1,201	2,140
Total Obligated Per Year:	3,069	2,935	2,980	4,760
NSF Funding Available:	1,400	1,620	1,780	3,250
USGS Funding Available:	1,850	1,134	1,200	1,450
Caltrans Funding:				60
Total NSF/USGS Funding Available:	3,250	2,754	2,980	4,760

Note: SCEC received an additional $80K from NSF in FY92 to study the Joshua Tree earthquake; $68K from NSF in FY92 to support field expenses for study of the Landers-Big Bear earthquakes sequence; $11.5K in FY92 from the USGS to assist in the preparation of the Phase I report; $46K from the USGS in FY93 to assist in preparation of the Phase II report; and $75K from NSF in FY93 for the LARSE experiment.

1995-1998 Proposed SCEC Budgets (in K$)

Infrastructure

	1995	1996	1997	1998
Management:	265	280	300	320
Workshops/Meetings:	110	120	120	130
Visitors Program:	300	330	300	300
Data Center Support:	220	240	260	280
Data Center Equipment:	0	0	0	0
Strong Motion Data Base and Empirical Green's Function Library:	80	85	90	90
Broad Band Recorders:				
Equipment:	135	120	100	70
Support:	100	110	120	130
GPS Acquisition:				
Data Analysis Support:	220	230	240	250
Permanent GPS Stations:	200	200	160	160
Borehole Strainmeters	135	10	10	10
GIS:	110	115	120	135
Earthquake Geology GIS	105	110	110	110
Education and Outreach:	320	340	360	380
Facilities:				
Pinon Flat:	25	30	30	30
TERRAscope:	65	70	70	75
Subtotal Infrastructure:	2,390	2,390	2,390	2,470

Science

		1995	1996	1997	1998
Group A	Master Model	390	430	490	550
Group B	Ground Motion Prediction	260	310	350	370
Group C	Earthquake Geology	390	400	400	400
Group D	Subsurface Imaging and Tectonics	210	240	280	300
Group E	Crustal Deformation	200	210	220	230
Group F	Seismicity and Source Processes	240	280	320	330
Group G	Physics of Earthquakes	170	190	200	200
Subtotal Science		1,860	2,060	2,260	2,380
Total Budget		4,250	4,450	4,650	4,850
NSF Funding		3,050	3,250	3,450	3,650
USGS Funding		1,200	1,200	1,200	1,200
Total NSF/USGS Funding		2,980	4,050	4,250	4,450

Projects Funded by SCEC in 1994

PI	Research Group	Title
Abercrombie (USC)	F	Fine Scale Analysis of Earthquake Sources, Fault Zones and Crustal Structure Using the Deep Seismic Recordings at Cajon Pass
Agnew (UCSD)	E	Investigation of Blind Thrust Faults in the Los Angeles Basin
Agnew (UCSD)	W	Geodesy Workshop
Agnew (UCSD)	E	Pinon Flat Observatory - Continuous Monitoring of Crustal Deformation
Aki (USC)	Northridge Response	SCEC Field and Travel Expenses for Northridge Post-Earthquake Studies
Aki (USC)	A	Modeling of Tectonic Stress for 2-D Block Structures
Aki (USC)	I	1994 SCEC Meetings and Workshops
Aki (USC)	I	1994 GIS Operations at USC/UCR
Aki (USC)	I	1994 Post-Doctoral and Visitors Program
Aki/Henyey (USC)	I	1994 SCEC Management Operations
Aki/Henyey/Abdouch/ Johnson (USC)	E&O	Education and Knowledge Transfer Workplan
Aki, Li, Chin, Abercrombie (USC)	Northridge Response	SCEC/USC Northridge Post-Earthquake Response
Aki/Hisada (USC)	B	Simulation of Long-Period Strong Ground Motion for 3-D Models of the Los Angeles Basin
Anderson/Siddharthan (UNR)	B, H	Seismological Perspective on Theoretical Non-linear Effects on Strong Ground Motions in Saturated Media
Anderson/Zeng (UNR)	B	Simulation of Ground Motion in the Los Angeles Basin: Simplified Approaches
Anderson/Zeng/Su (UNR)	B, H	High Frequency Ground Motion Prediction by Regression and Simulation
Archuleta (UCSB)	I	Portable Broadband Instrumentation
Archuleta (UCSB)/ Pizzi (Bishop Garcia Diego H.S.)	E&O	Seismology Curriculum Using CUBE for Santa Barbara County Schools

Archuleta/Tumarkin (UCSB)	I	SCEC Strong-Motion Database SMDB and Empirical Green's Function Library EGFL
Archuleta/Tumarkin (UCSB)	B	Maps of Gross Site Amplification Factors for the LA Basin
Archuleta/Steidl (UCSB)	B	Weak Motion Site Effects in the Los Angeles Basin
Archuleta/Lindley/Martin/ Nicholson/Steidl/Tumarkin, Tumarkina (UCSB)	Northridge Response	SCEC/UCSB Northridge Post-Earthquake Studies
Ben-Zion/Rice (Harvard)	A, G	Recurrent Earthquakes Along Complex Fault Systems and Basis for Evaluating Seismic Risk and Precursors
Bock (UCSD)	I	Support for Permanent GPS Geodetic Array
Bock (UCSD)	E&O	IGPP Participation in SCEC Outreach Program
Bock (UCSD)	Northridge Response	SCEC/UCSD Northridge GPS Studies
Bock (UCSD)	Northridge Response	New Stations for the PGGA Array
Clayton (Caltech)	I	SCEC Data Center Operations
Clayton (Caltech)	I	Enhanced Data Center Facilities
Clayton (Caltech)	D	Analysis of Data from the LARSE
Clayton (Caltech)/Henyey (USC)/Davis (UCLA)/ Okaya (USC)	D	Marine Component of the Los Angeles Regional Seismic Experiment (LARSE)
Cornell (Stanford)	A, H	Southern California Probabilistic Hazard Assessment
Davis (UCLA)	D	Participation in LARSE
Davis (UCLA)	Northridge Response	SCEC/UCLA Study: Focused Aftershock Seismic Array of Enhanced Damage Zones in Los Angeles
Davis/Namson (Davis and Namson)	Northridge Response	Structural Geological Models for Northridge Area
Day (SDSU)	Northridge Response	SCEC/SDSU Northridge Post-Earthquake Studies
Day (SDSU)/Harris (USGS)	G, B	3D Dynamic Modelling of Earthquakes Encountering Fault Bends and Non-Parallel Fault Strands

Day (SDSU)/McLaughlin (S-Cubed)	B	Three-Dimensional Simulation of Long Period Ground Motion in L.A. Basin
Dolan (USC)	C	Paleoseismic Analysis of the Hollywood and Santa Monica Faults, Northern Los Angeles Basin
Donnellan (JPL)/Lyzenga (Harvey Mudd)	Northridge Response	GPS Measurements of Postseismic Deformation following the 1994 Northridge Earthquake
Gath (Leighton)	C	Tectonic Geomorphology of the Southeastern Los Angeles Basin: A Quantitative Analysis of the Relationships Between Transpressional Tectonics, Fluvial Evolution, and Marine Eustatics
Grant (Woodward-Clyde)	C	Paleoseismic Investigation of the Newport-Inglewood Fault Zone Southern California
Hager/Herring/King (MIT)	E	Improvement and Application of GPS Geodesy to Models of Fault Slip and Post-Seismic Deformation in Southern California
Hauksson (Caltech)	F	Precise Locations and Mechanisms of Aftershocks and Stress State of the 1992 M6.1 Joshua Tree, M_W7.3 Landers, and M6.2 Big Bear Earthquakes
Hauksson (Caltech)	E&O	Landers Video for SCEC Outreach
Hauksson/Clayton (Caltech)	Northridge Response	SCEC/Caltech Recording and Archiving of Northridge Earthquake Sequence
Hauksson/Kanamori (Caltech)	F	Towards, Real-time, Routine Broadband Seismology
Hauksson/Scott (Caltech)	F	Application and Interpretation of 3-D Southern California Velocity Models
Helmberger (Caltech)	F	Rapid Source Retrieval (Renewal)
Henyey (USC)/Clayton (Caltech)/Davis (UCLA)/ Okaya (USC)	D	Los Angeles Regional Seismic Experiment (LARSE)
Henyey/Okaya (USC)	A	Development of a Subsurface Geophysical Data Base for Southern California
Henyey/Okaya (USC)	D	Los Angeles Region Seismic Experiment: Crustal Structure Derived from Vertical Incidence Imaging
Hornafius/Sorlien (UCSB)	A	Offshore Ventura Basin: Three-D Unfolding and post-Miocene Strain

Humphreys (Oregon)	D	Kinematic Modeling of the Southern California Region: A First Step Towards Dynamic Modeling
Jackson (UCLA)	A	Earthquake Hazard Estimation
Jackson (UCLA)	E	Crustal Deformation Modeling
Jackson (UCLA)	Northridge Response	SCEC/UCLA Geodesy Group Northridge Earthquake Response Activities
Jackson/Kagan/Shen (UCLA)	A	Stress Modeling
Jackson/Salyards (UCLA)	I	GPS Infrastructure
Jin/Aki (USC)	F	Scaling Law of Aftershock Spectra of Joshua Tree-Landers-Big Bear Earthquakes
Kanamori/Hauksson (Caltech)	I	Enhancement of TERRAscope
Knopoff (UCLA)	G	Investigation of Low Frictional Sliding due to Crack-Opening (Schallamach) Wave Phenomena
Knopoff (UCLA)	G	Simulations of Stochastic Rupture Source Effects
Knopoff (UCLA)	G	Seismicity on a Model of the Southern California Fault Network
Legg (ACTA)	A	Compile Updated Fault Maps of the Southern California Continental Borderland (Offshore Region) for the Master Model
Li/Aki (USC)	D	Study of the 3-D Structure and Healing of the Fault Zone Ruptured in the Landers Earthquake of 1992 Using Seismic Trapped Waves
Lin (WHOI)/King (Institut de Physique du Globe)	A, E	Investigation of 3D Coulomb Stress Changes Caused by Blind-Thrust Earthquakes in the Los Angeles Basin
Lindvall (Lindvall Richter Benuska Associates)	C	Paleoseismology of the Western Sierra Madre Fault Zone
Luyendyk/Archuleta (UCSB)	W	A Workshop on Detachment Faults in the Transverse Ranges and the Southern California Borderland
Magistrale (SDSU)	B	Integrated Los Angeles Basin Velocity Model
Mahdyiar (Vortex Rock)	A	Probabilistic Seismic Hazard Analysis of Southern California

McGill (CSU,San Bernardino)	C	Paleoseismology of the San Andreas Fault in San Bernardino and Publication of Landers Research
Minster (UCSD)	A	Contributions to the Southern California Master Model: Intermediate-term Earthquake Prediction Algorithms\
Nicholson (UCSB)	F	3-D Analysis of Seismicity, Focal Mechanisms and Stress Using the 1992 Landers-Big Bear-Joshua Tree Earthquake Sequences, Southern California
Nicholson (UCSB)	E	Seismic Behavior and Fault Geometry of Blind Thrust Faults
Okaya/Henyey (USC)	D	Structural Geometries of the Los Angeles Basin: Application of Industry Seismic Reflection Profiles
Park (UCR)	I	GIS Center Activities
Rice/Ben-Zion (Harvard)	G	Elastodynamics of Rupture Propagation and Arrest in Relation to Generating and Sustaining Complexity of Seismic Response
Rockwell (SDSU)	C	Completion of Paleoseismic Studies in the Landers Earthquake Region
Rockwell (SDSU)	C	Paleoseismic Studies in the Los Angeles Area
Rojahn (ATC)	Northridge Response	A Statistically Rigorous Damage Survey of the Northridge Earthquake
Rubin (Central Washington Univ.)	C	Paleoseismic Studies Along the Southern Flank of the Central Transverse Ranges: Slip Rates and Recurrence Interval on the Sierra Madre Segment [max. magnitude]
Rubin (Central Washington Univ.)/Sieh (Caltech)	C	Long Recurrence Interval for the Emerson Fault: Implications for Slip Rates and Probabilistic Seismic Hazard Calculations
Sammis (USC)	G	Precursory Seismicity Patterns and Fault Structure
Seeber/Armbruster (Lamont-Doherty)	A, F	Fault Kinematics, Stress and Stress Changes from Focal Mechanisms in Southern California
Shaw (Lamont-Doherty)	G	Dynamic Models of Earthquake Faults
Sieh (Caltech)	C	Surficial Ruptures of the Landers Earthquake
Sieh/Dolan (Caltech)	C	Neotectonic and Seismic Hazards of the Northern Los Angeles Basin

Sieh/Lilje (Caltech)	I	Computational Support for Paleoseismic and Neotectonic Studies
Stock (Caltech)	D	Compilation of New and Existing Stress Observations for Southern California
Suppe/Mueller (Princeton)	C	Paleoseismic Studies of Active Blind Thrusts in the Los Angeles Basin
Suppe/Price (Princeton)	A	Arc/Info Based Mapping of Active Blind Thrusts in Southern California
Sykes/Buck/Menke (Lamont-Doherty)	A	Development of a Physical Master Model of Evolution of Stresses in Southern California
Templeton (CSU, Fullerton)	D	Refining High-Resolution Seismic Reflection Imaging as a Tool for Paleoseismic Studies
Teng (USC)	B	Long-Period Strong Motions in Los Angeles Basin Using 3-D Surface-Wave Gaussian Beam Method
Vernon (UCSD)	Northridge Response	SCEC/UCSD Northridge Post-Earthquake Response
Vernon (UCSD)	Northridge Response	SCEC/USGS Portable Instrument Data Organization for the 17 January 1994 M6.7 Northridge Earthquake Sequence
Vernon (UCSD)/Day/ Magistrale (SDSU)	D	Peninsular Ranges Piggy-Back of the Nicholson-Legg Offshore Experiment
Ward (UCSC)	A	Synthetic Seismicity Models of the San Andreas Fault
Ward (UCSC)	A	A Multidisciplinary Approach to Earthquake Hazard in Southern California
Ward/Valensise (UCSC)	C, E	Dislocation Models of the San Clemente Island Marine Terraces
Wesnousky (UNR)	A	Construction of Seismic Hazard Maps
Yeats/Huftile (OSU)	C	Interaction Between Blind Thrusting and Strike Slip Between the Whittier Fault and the LA Fold-Thrust Belt
Yeats/Kimerling (OSU)	C	Quaternary and Tertiary Structures of the Northern Los Angeles Fold-Thrust Belt: Producing Digital Data in GIS Format
Zhao/Kanamori (Caltech)	D	Seismic Imaging of Structural Heterogeneities Along the Major Fault Zones in Southern California

SCEC EDUCATION ACTIVITY SUMMARY FEBRUARY-SEPTEMBER, 1994

FEBRUARY

Feb. 24-26 Participated (with four other Southern Californians) in a three-day *Tremor Troop* elementary education workshop, Portland, OR, in preparation for a CAPSE (Center for the Advancement of Precollege Science Education) training workshop in April.

Helped organize and lead a series of CAPSE-related meetings and presentations (Feb.-June).

Conducted a three-hour earthquake education class for 30 elementary teachers in the Centralia School District (Orange County)

MARCH

Completed remodeling of SCEC E&O office, completed set up and became fully functional.

March 25 Presented status report and plans for education to SCEC Advisory Council.

March 30-April 2 Organized and staffed SCEC exhibit, in conjunction with the Coalition for Earth Science Education, at the National Science Teachers Association Annual Conference, Anaheim. Handed out SCEC materials, discussed educational opportunities and services and promoted *Seismic Sleuths* workshop. Engaged about 1,000 science teachers and conference participants.

APRIL

April 4-7 Awarded partial support to 18 graduate students to attend Seismological Society of America Annual Meeting, Pasadena.

April 21-22 Organized and hosted two-day field trip and *Tremor Troop* orientation for CAPSE Cadre (teacher group) leaders.

Completed three-color SCEC brochure.

April 27 Conducted a one-hour workshop for earthquake disaster response teams, Los Angeles Conservation Corps.

April 27 SCEC education grant awardees notified. Two education-related project grants awarded: CUBE pilot program for high schools to Robert Pizzi and Landers earthquake video to Egill Hauksson.

MAY

May 6-7 Arranged earthquake symposium at the Annual Meeting of the Southern California Academy of Sciences, Irvine.

Awarded undergraduate summer internships to 13 students. (Targeted quota: 10)

JUNE

Advanced preparations for CAPSE Earth Science Institute, including

- field trip permitting;
- sponsorship of two CAPSE Cadre leaders;
- ordering supplies and equipment for personal and group educational and field trip supply kits;
- construction of hands-on earthquake education equipment;
- development and field testing of educational activity sheets for field trip sites;
- set up of field trip and SCEC headquarters tour/activity schedule; and
- preparation of opening day presentation.

June 13-17 SCEC Assistant Director for Education participated in the first national educational leadership institute for the release of *Seismic Sleuths* earthquake education materials, National Emergency Training Center, Emmitsburg, MD.

JULY

July 11-13 Opened CAPSE Summer Earth Science Institute for 150 elementary teachers. (See attachment)

Outfitted SCEC-sponsored CAPSE tours and field trips.

Completed SCEC Palos Verdes Field Trip Guide. (Mike Forrest)

July 18-21 Conducted four-day technical orientation for SCEC undergraduate summer interns.

Arranged and supported a conference presentation by a Los Angeles school teacher to discuss school reaction to the Northridge Earthquake. This Natural Disasters Conference to be held in October at the Center for the Earth Sciences in New Jersey.

AUGUST

August 1-3 Conducted three day *Seismic Sleuths* workshop for 20 participants including

* middle and high school teachers;
* science education specialists from three museums;
* Red Cross educators;
* OES staff; and
* LA Conservation Corps.

SEPTEMBER

Initiated development of SCEC Education/Knowledge Transfer Resource Center.

Performed preliminary tasks toward the development of a SCEC Education Utilization Council.

Conducted a policy-level meeting on the possible expansion of the CUBE pilot school program and the development of user guidelines for the expansion of CUBE in schools in future years.

Began preparation of Groundwater Festival game board for premier at Cerritos College on October 22.

Received notification of a $30,695 grant from the Federal Emergency Management Agency (FEMA) to carry out a project related to *Seismic Sleuths* education materials.

Developed a plan for SCEC to sponsor high school students who will be working on earth science-related research projects, November, 1994-May, 1995 as part of the Southern California Academy of Sciences Jr. Academy Research Training Program.

Participated in SCEC Annual Meeting

1994 ACTIVITY SUMMARY
KNOWLEDGE TRANSFER PROGRAM

FEBRUARY

Initiate knowledge transfer program.

Initiate series of telephone and in-person interviews with SCEC scientists, OES staff members, and others involved in past SCEC E&O efforts. (February – August)

MARCH

Set up SCEC E&O office, USC.

Finalize SCEC logo.

Design First Vulnerability Workshop, to be conducted with members of Los Angeles Northridge Damage Task Force (originally scheduled for June 1994; postponed to late Fall 1994).

March 25: Present status report and plans for knowledge transfer to SCEC Advisory Council.

APRIL

April 7: SCEC sponsored joint SSA/EERI symposium, Pasadena, CA.

April 7 – 9: Attend EERI Annual Meeting, Pasadena, CA.

Complete SCEC brochure - 10,000 copies printed. 5,000 copies sent to USGS for distribution following nationally televised special on earthquakes, May 21, 1994.

MAY

May 17 – 19: Attend Seismic Safety Commission's workshop on draft State Research Plan, San Diego, CA.

May 27: SCEC E&O meeting with OES Region earthquake program staff. Outline joint activities such as Northridge conference, Phase II release, and education workshops.

JUNE

Conduct series of telephone and in-person interviews with staff members involved in knowledge transfer at other earthquake-related research centers or organizations, including:

- o Earthquake Engineering Research Institute (EERI);
- o National Center for Earthquake Engineering Research (NCEER);
- o Earthquake Engineering Research Center (EERC);
- o Applied Technology Council (ATC);
- o Central U.S. Earthquake Consortium (CUSEC); and,
- o University of Memphis' Center for Earthquake Research (CERI). (June – September)

JULY

Complete review of revised draft Phase II report and developed plan for publication and release. Three versions are planned for December/January release--the complete technical version to be published in the BSSA, an abridged technical version published by CDMG/USGS, and a non-technical version possibly published as a newspaper insert. (June 1994 – January 1995)

July 17-19: Attend Natural Hazards Workshop, Boulder, CO. Presentation on panel entitled "Progress in Research and Outreach."

AUGUST

August 5: SCEC Board of Directors approves proposal to prepare a Research Utilization Plan. Initiate process by forming a Research Utilization Council comprised of 11 utilization experts to serve for a short-term period guiding this effort. The council will have about 4 meetings over the next 6 months. At the first meeting, October 6, councilmembers will meet with SCEC steering committee members to review SCEC's strategic science plan and identify priority user groups for the Center's research. At the second meeting, November 16, the council will conduct a detailed needs assessment with representatives of the priority user groups. The final meetings will take place in 1995 to review the draft Research Utilization Plan resulting from this effort. (August 1994 – March 1995)

Construct SCEC bulletin board for Internet. (August – December)

SEPTEMBER

Create annual listing of E&O activities of SCEC scientists. (September – December)

September 23 – 24: SCEC Annual Meeting and Advisory Council Meeting. Present status report and develop 1995 knowledge transfer program proposal.

OCTOBER

October 6: Research Utilization Council Meeting 1, Davidson Conference Center, USC.

October 20: SCEC exhibit at California Chapter Meeting of the American Planning Association, San Diego, CA. (tentative)

NOVEMBER

November 16: Research Utilization Council Meeting 2, Davidson Conference Center, USC.

Vulnerability workshop with Los Angeles' Northridge Damage Task Force. (tentative)

ADDITIONAL PLANS

Phase II reports published and released, non-technical version to appear in "One Year After Northridge" newspaper insert prepared by USGS. (December 1994 – January 1995)

Phase II Workshop, possibly in conjunction with a "One Year After Northridge" conference sponsored by OES. (January 1995)

Research Utilization Council Meetings 3 & 4. (January – March 1995)

Insurance Industry Workshop. (tentatively February 1995)

Media Workshop. (tentative)

Western States Seismic Policy Council's 1995 Los Angeles Area Workshop, June 19 – 20, 1995. (tentative)

Suggestions for
SCEC KNOWLEDGE TRANSFER PROGRAM

Name (optional): ______________________________

SCEC Working Group: ______________

1. Who are potential users for your working group's products/Center products? ____________

2. How can SCEC best reach these user groups (i.e. professional organizations, periodicals, annual conferences)? If you can, please describe how these organizations serve, or communicate with, their members (i.e. monthly newletters, computer bulletins, regional chapters, chapter meetings).

3. How can the knowledge transfer program better serve you in communicating your working group's research/Center research? ______________________________

4. Do you have any suggested activities/ideas for the knowledge transfer program? __________

5. In writing a job description for the Assistant Director for Knowledge Transfer, what qualifications (i.e. academic training, experience) would you suggest? ______________

Please return to: Laurie Johnson, Assistant Director for Knowledge Transfer,
c/o SCEC, University of Southern California, Los Angeles, CA 90089-0740.
Ph. (213)740-3459, FAX (213)740-0011, e-mail johnson@coda.usc.edu

Seismic Hazards in Southern California: Probable Earthquakes, 1994-2024

WORKING GROUP ON SOUTHERN CALIFORNIA EARTHQUAKE PROBABILITIES

Convened by the
Southern California Earthquake Center

Principal Authors

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WORKING GROUP ON SOUTHERN CALIFORNIA EARTHQUAKE PROBABILITIES

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James Dieterich	U.S. Geological Survey
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David Schwartz	U.S. Geological Survey
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PREFACE

This study is the second part of a continuing series of reports on earthquake hazards in southern California prompted by the 1992 *m*=7.3 Landers earthquake. It is intended to update and expand upon a previous report entitled "Probabilities of Large Earthquakes Occurring in California on the San Andreas Fault," prepared in 1988 by the Working Group on California Earthquake Probabilities (WGCEP 88). The first report (available from the California Department of Conservation, Division of Mines and Geology) entitled "Future seismic Hazards in southern California: Phase I, Implications of the 1992 Landers Earthquake Sequence" dealt primarily with short-term hazards through 1993 posed by the Landers earthquake and its aftershocks.

This report is timely for several reasons: 1) there is new information regarding earthquake histories for the faults considered by WGCEP 88, including the San Andreas; 2) there is a need to address the seismic hazard more broadly throughout southern California than was done by WGCEP 88, 3) we have an improved understanding of "blind" faults that do not break the surface, as well as other lesser faults that are individually not as hazardous, but pose a significant aggregated danger because they are so numerous; 4) new geodetic data on strain rates in the crust are rapidly becoming available; and 5) improvements have been made in the seismological methods for studying recent earthquakes and in the statistical methods for dealing with their uncertainties. Following the 1989 Loma Prieta Earthquake, a similar reassessment was made regarding the chances for large earthquakes in northern California in a report entitled "Probabilities of Large Earthquakes in the San Francisco Bay Region, California" (USGS Circular 1053, 1990), prepared by the WGCEP90.

The Southern California Earthquake Center has coordinated preparation of the post-Landers series of reports at the request of the National Earthquake Prediction Evaluation Council (NEPEC) and the California Earthquake Prediction Evaluation Council (CEPEC). An *ad-hoc* Working Group on Southern California Earthquake Probabilities was established to oversee the generation of this and the earlier report. For this study, NEPEC and CEPEC asked the working group to: 1) include a regional perspective on the current tectonic environment, 2) review the methodology of the 1988 and 1990 reports and emphasize any differences from the current report, 3) consider new models for earthquake recurrence, 4) review newly available data for inclusion in updated probabilistic analyses, and 5) include some examples of strong ground motion predictions using existing models and attenuation relationships.

NEPEC was established in 1979 pursuant to the National Earthquake Hazards Reduction Act of 1977 to advise the Director of the United States Geological Survey (USGS) concerning any formal predictions or other information pertinent to the potential for the occurrence of a significant earthquake. CEPEC was established in 1976 under existing administrative authority as the successor to an advisory group formed in 1974. CEPEC advises the Director of the California Office of Emergency Services (OES) on the validity of predictions of earthquakes capable of causing damage in California, including the reliability of the data and scientific validity of the technique used to arrive at a specific prediction. SCEC was established in 1991 under the National Science Foundation's Science and Technology Center Program and the U.S. Geological Survey's component of the National Earthquake Hazards Reduction Program.

Preliminary versions of this report have been presented to the community of earthquake scientists and engineers at various meetings including a NEPEC meeting in June, 1993, a joint NEPEC-CEPEC meeting in August, 1993, a symposium during the Fall 1993 AGU meeting, and several SCEC workshops addressing various aspects of the study. The report has been reviewed jointly by both NEPEC and CEPEC in order to assess the extent of scientific consensus regarding the analytical approach and conclusions.

JOINT COMMENTARY OF THE NATIONAL EARTHQUAKE PREDICTION EVALUATION COUNCIL AND THE CALIFORNIA EARTHQUAKE PREDICTION EVALUATION COUNCIL

This joint statement of the two earthquake predictions evaluation councils addresses the suitability of the conclusions presented in this report for application to public policy and compares them with the existing earth science understandings upon which current policies are based. It also presents some of the caveats to the conclusions that should be considered when they are applied to public policy.

The scientific conclusions that drive public policy applications must derive from a broad consensus within the earth science community, based on the conviction that objective, internally consistent analyses were accomplished using appropriate existing data sets and methodologies. This critique by the two councils further extends the report's peer review process. An advanced draft of the report was circulated to the membership of both councils for review. This resulting commentary compares the reports conclusions regarding damaging earthquake potential to the results of earlier studies that have been relied upon for the development of public policy.

BACKGROUND

The 1988 Working Group report presented long-term 30-year probabilities for the occurrence of $m \geq 7$ earthquakes on segments of the San Andreas fault and $m \geq 6.5$ on the San Jacinto fault. After the June, 1992 Landers/Big Bear earthquakes, an earlier (November 1992) report in this series re-examined $m \geq 7$ earthquake probabilities in southern California in the 1 to 5-year time frame, specifically considering any implications for increased hazard following the 1992 events. The present report is directed towards reappraising the 30-year probabilities of $m \geq 7$ earthquakes in southern California using new data and revised and expanded methodologies.

COMPARISONS OF CONCLUSIONS

- **Comparison of San Andreas/San Jacinto Independent Segment Probabilities with Earlier Studies**

The probability estimates of the largest earthquakes (characteristic) to be expected on individual southern San Andreas/San Jacinto fault segments range from about 10 percent to 40 percent in the 1988 report compared with about 6 percent to 43 percent (with uncertainties between 6 percent and 18 percent) in this report (Table 4.2). Although methods and data sets differ somewhat, the present authors do not consider the differences between their 1994 probability estimates for individual segments of the San Andreas/San Jacinto fault system and the 1988 conclusions to be significant. Single segment probabilities in the 1994 report are presented between 1 percent and 24 percent (with 3 percent to 15 percent uncertainties) for two additional segments of the San Jacinto fault and for portions of the Whittier/Elsinore faults (Table 4.2) that were not considered in the 1988 report.

- **Policy Implications**

This report provides the needed assessment of the southern San Andreas and San Jacinto segments using important data acquired since the 1988 report, and refinements in analysis methods. It is the first comprehensive evaluation of these fault segments since 1988. The results are reassuring. The priorities currently given to earthquake preparedness that are based upon the 1988 estimates are not likely to change significantly in response to the 1994 conclusions, except perhaps for some fine tuning at the local scale. These conclusions may help private sector entities who wish to refine the geographic focus of the application of their earthquake preparedness activities.

- **Comparisons of the Independent Segment Probabilities with the 1994 Cascade Model**

In addition to the independent segment probability estimates, the authors of this report have developed a "cascade" model that endeavors to take into account the interactive rupture of multiple segments during individual earthquakes (Table 4.3). Multiple-segment earthquake estimates reduce the number and increase the average size of ruptures to be expected during the next 30-year time frame compared to the independent-segment events. The present report estimates that, if segments are independent, there is an aggregate 65 percent probability that at least one characteristic earthquake will occur on one of the four southern San Andreas segments in the next 30 years. This compares with a 53 percent probability estimate that a multiple-segment earthquake will occur at least once according to the cascade model during the same period.

- **Policy Implications**

Both the independent-segment and cascade model analyses estimate that there is a significant likelihood of large damaging events. The presently operative rationales for earthquake preparedness in the areas adjacent to the San Andreas, San Jacinto and Whittier/Elsinore faults do not seem to be significantly modified by the cascade model conclusions.

- **Southern California Earthquake Regional m≥7 Probability Estimates**

From a more regional perspective, this report addresses the entire portion of the State south of latitude 36° with a "preferred" model that proportions the seismic moment budget for all of southern California among 65 source zones using geologic (including paleoseismic), geodetic and earthquake catalog data. This holistic analytical approach is based upon the comprehensive concept of the SCEC master model. Rules are established regarding the partitioning of the seismic moment among the 65 zones that are categorized into A, B and C types, depending upon the amount of geologic data that is available to be combined with geodetic and earthquake catalog sources. The preferred model predicts a rate of 0.07 events/year to 0.085 events/year for $m \geq 7$ earthquakes in southern California. This corresponds to a 30-year probability of 88 percent to 92 percent. This value, of course, exceeds the 1988 southern California estimate of about 50 to 60 percent that only considered the aggregated San Andreas/San Jacinto probabilities in southern California. While the present estimate raises the probability somewhat, it expands the area in which the $m \geq 7$ event occurrence is considered during the time frame.

- **Policy Implications**

The regional $m \geq 7$ probability estimates of this report underscore the need for continuing the priorities of the earthquake preparedness efforts already in progress in urban areas, and they further justify the need for earthquake preparedness activities elsewhere in the more rural areas of southern California which were not considered in the 1988 report.

- **The Use of the Regional Preferred Model in Probabilistic Seismic Hazard Analysis for Public Policy**

An important attribute of the preferred model is its regional characterization of the 65 sources using a standardized set of rules for partitioning seismic moment rate. The manner of establishing the boundaries and the partitioning of the seismic moment are inevitably somewhat arbitrary. The greatest confidence for valid delineation of the characterization of the seismic sources using these procedures might have resulted from a close correspondence between the predicted seismic rate for large events such as $m \geq 7$ and the historically observed rate. Although it is not emphasized in this report, there is a disparity between the observed moment release represented by seismic activity since 1850 and the larger moment accumulation budget during that period, calculated from the currently observed rate of plate movement. The long term nature of this disparity is difficult to quantify. An important qualification to the results of the preferred model results from the observed rate of $m \geq 7$ earthquakes since 1850 (0.035 events/year), and is only about half the calculated preferred model rate (0.08 events/year). As the authors point out, there are changes that can be made in the approach such as adjusting the cascade analysis to lower the rate of $m \geq 7$ events to be closer to the observed value. By making some of these changes, an alternative model (Table 5.3) comes closer (0.065 events/year compared to 0.035 events/year observed), but still leaves a significant gap. As the authors point out, an unknown, but significant portion of the cumulative plate motion budget in southern California can be taken up by anelastic deformation and not entirely released by earthquakes. Additionally, given the limited temporal extent of the earthquake catalog, we cannot rule out the possibility that future very large earthquakes will more closely balance the observed and calculated moment release rates.

The comparison of the calculated and observed seismic rates of $m \geq 7$ does not provide an intrinsic, definitive test of the validity of the model. In the absence of such a test, another approach should be used to evaluate the suitability of the preferred model to public policy applications. To be used in public policy, a seismic hazard model should not yield maps with patterns of ground motion that are severely affected by the choice of seismic zone characteristics that are relatively unconstrained by data. Sensitivity of seismic hazard analyses to variations in the selection of seismic source boundaries and parameter values are needed to determine uncertainties.

Another limitation of the preferred model is the present lack of consensus among investigators regarding how to characterize some types of seismic sources. As a consequence, it was not possible to precisely characterize blind thrust sources in the modeling.

  - **Policy Implications**

    At present, the circumstances outlined above require that caveats be applied to the ways in which spatially focused detailed conclusions of this report are used in public policy. The appropriateness of the rules and the assumptions used in defining and partitioning seismic moment among the source zones should be further examined to see how variations in the least constrained parameters affect the overall patterns of ground motion.

<u>CONTINUING INVESTIGATIONS ARE RECOMMENDED TO EMPHASIZE THE FOLLOWING ISSUES:</u>

- **Blind thrust configurations and slip rates and how they should be incorporated in the preferred model methodology.**
- **The intrinsic variability in characteristic earthquake recurrence**

rates and its significance in probability analyses.

- **Further acquisition and appraisal of geologic evidence that significantly modifies earlier paleoseismic interpretations such as that concerning the Carrizo segment of the San Andrea fault.**
- **The assumptions used in the distribution of seismicity and the sensitivity of the seismic rate and hazard maps to reasonable variations in these assumptions.**
- **The geographic characterization of Type C seismic source zones and the sensitivity of predicted seismic rate and seismic hazard maps to variations in their definition.**

In the meantime, from a public policy point of view, the maps derived from the preferred model can be used to characterize regional variations in seismic hazard in southern California. Like any other single model, the preferred model should be used with professional caution and with appropriate sensitivity studies when applied as input to site-specific geotechnical estimates for earthquake resistant design of individual structures.

NOTWITHSTANDING INEVITABLE UNCERTAINTIES, THIS REPORT IS A SIGNIFICANT ADVANCEMENT IN THE CHARACTERIZATION OF SOUTHERN CALIFORNIA SEISMIC SOURCES USING REGIONAL GEOLOGIC, GEODETIC AND EARTHQUAKE CATALOG OBSERVATIONS. THE EARTH SCIENCES AND THE CITIZENS OF CALIFORNIA ARE IN DEBT TO SCEC AND ITS INVESTIGATORS FOR THIS EFFORT. THIS LINE OF INVESTIGATION IS PROMISING AND ITS CONTINUATION SHOULD BE ENCOURAGED.

Tom McEvilly, Chair
National Earthquake Prediction
Evaluation Council

Jim Davis, Chair
California Earthquake Prediction
Evaluation Council

I. EXECUTIVE SUMMARY

This report has two primary purposes: 1) to update the data and review the methodology for estimating probabilities of large earthquakes on the southern San Andreas and San Jacinto faults estimated in 1988 by the Working Group on California Earthquake Probabilities, and 2) to extend the analysis to consider potentially damaging earthquakes throughout southern California.

We examined the earth science data relevant to earthquakes in southern California, and identified three types of seismotectonic zones according to available data. Type A zones contain faults for which paleoseismological data suffice to estimate conditional probabilities of earthquake occurrence by the 1988 Working Group method. Type B zones contain well-known active faults for which the available data are not sufficient for conditional probability analysis. Type C zones are not dominated by any one fault, but may contain diverse and/or hidden faults. We identified 16 Type A, 25 Type B, and 24 Type C zones (Figure 5.1).

For Type A zones we estimated the slip rate and expected recurrence time of "characteristic" earthquakes, together with their uncertainties from the dates and amounts of displacement in past earthquakes. These are listed in Table 4.1. Probabilities for the occurrence of large earthquakes in each of these zones are given in Table 4.2. Fault length, slip rate, and other important parameters are listed for all zones in Table 5.2.

The methods developed by the 1988 Working Group for conditional probability analysis are applicable to Type A zones. We reviewed this methodology and employed it with some revisions. New high-quality paleoseismic data, and advances in modeling fault interactions suggest that the periodicity of earthquake occurrence is not as strong as assumed in 1988. Consequently we revised downward the probabilities for some zones, such as the Coachella Valley segment of the San Andreas, for which the elapsed time since the last event exceeds the expected recurrence time. Likewise, we revise upward the probabilities for a few zones where the elapsed time is less than the recurrence time.

A fundamental assumption made by the 1988 Working Group is that fault segments fail independently. However, recent detailed paleoseismological studies reveal that contiguous segments frequently rupture simultaneously. Thus, we developed a "cascade" model which allows for failure over multiple segments (Table 4.3). The effect of allowing for segment interaction is to reduce the estimated net rate of earthquake occurrences.

We describe the seismic potential of each zone by a population of randomly distributed earthquakes, plus a set of characteristic earthquakes on a specific fault. The distributed earthquakes are assumed to be uniform in time, equally probable anywhere within the zone, and characterized by a truncated form of the Gutenberg-Richter magnitude distribution. Thus for each zone, the seismic hazard is defined in terms of three parameters (Table 5.2): the "a-value" of the magnitude distribution, the limiting magnitude of the distribution, and the frequency of characteristic earthquakes. The "b-value" of the magnitude distribution is assumed to be 1 for all zones, and the limiting magnitude of distributed earthquakes is set equal to the magnitude of characteristic earthquakes.

For all zones, the limiting magnitudes are determined from the lengths of surface fault traces, with adjustments in a few cases to account for buried faults. For Type A zones, characteristic earthquake rates are described by the cascade model. For Type B zones, the rate of characteristic earthquakes is chosen to assure that the predicted seismic moment rate matches that inferred from geodetic and geologic observations. We assume there are no characteristic earthquakes in the Type C zones except as the limiting magnitude.

The "a-value" is determined from observed seismicity, in combination with other information. In Type A zones, this seismicity is determined from a smoothed version of a special earthquake catalog, with the characteristic earthquakes removed. For Type B zones, seismicity is determined from a smoothed version of the entire catalog of earthquakes above magnitude 6 from 1850 to 1994. For Type C zones, seismicity is determined by combining catalog data as above and geodetic strain rates.

The seismic hazard parameters in Tables 4.3 and 5.2 constitute a master model for earthquakes throughout southern California. The model agrees well with observed slip rates on faults and strain rates in the crust, and is consistent with the frequency distribution of earthquake magnitudes since 1850. For example, the Northridge earthquake of January 17, 1994 occurred in Zone 54, a Type B zone characterized by a relatively high moment rate. Although the causative fault had not been known prior to the event, the magnitude and style of the earthquake were consistent with the model. The model predicts a probability of 86-91% that a $m \geq 7$ earthquake will occur within southern California before 2024.

The master model can be used to calculate the probability of strong shaking anywhere in southern California. For example, we adopt a peak horizontal acceleration of 0.2 g or higher as a criterion for strong shaking. The probability of experiencing such strong shaking in the next 30 years is significant throughout southern California, but exceeds 80% only in the Parkfield area. It exceeds 60% in the Ventura and San Bernardino areas, and a relatively high probability (50-60%) zone includes much of the Transverse Ranges fold and thrust belt between Santa Barbara and San Bernardino. The master model also can be used for hazard analyses at specific sites. For example, we find that at all levels of motion, seismic hazards at San Bernardino City Hall are due to the large faults systems near the city, while at the Los Angeles City Hall, relative contributions from distant large faults and nearby small faults depend on the level of shaking and the frequency content of the ground motion.

The apparent seismicity rate predicted by the master model is considerably higher than the rate observed in southern California since 1850. This important finding can be explained in one or more of the following ways: 1) the magnitude of the largest possible earthquake may be larger than that of the largest historic earthquake in southern California -- namely the 1857 Fort Tejon earthquake, 2) a significant part of the strain accumulating in southern California may be released aseismically (without earthquakes), and/or 3) during the past 150 years, the rates of $m \geq 6$ and $m \geq 7$ earthquakes may be anomalously lower than the long-term rates. Although at present, we cannot reach a consensus on these issues, the explanation preferred by the majority (the "preferred model") is based on accepting possibility (3) above. The "alternate model" is based on the acceptance of possibility (1). Although certainly plausible, possibility (2) was excluded in this report only for the sake of erring on the conservative side in our hazard estimates.

PHASE-III REPORT

Chapter I. Seismic source characterization for southern California. This is a summary of Phase-II report and possible update. [Dave Jackson]

Chapter II. Review of empirical attenuation relations for southern California, with comparisons of strong motion predictions by various formulas with the observations made during recent earthquakes in southern California since the Whittier-Narrows earthquake of 1987. [John Anderson, James Chin, Mehrdad Mahdyiar, Norm Abrahamson]

Chapter III. Site characterization; mapping of amplification factor and/or site classification. [Mladen Vucetic, James Chin, Steve Park, Norm Abrahamson]

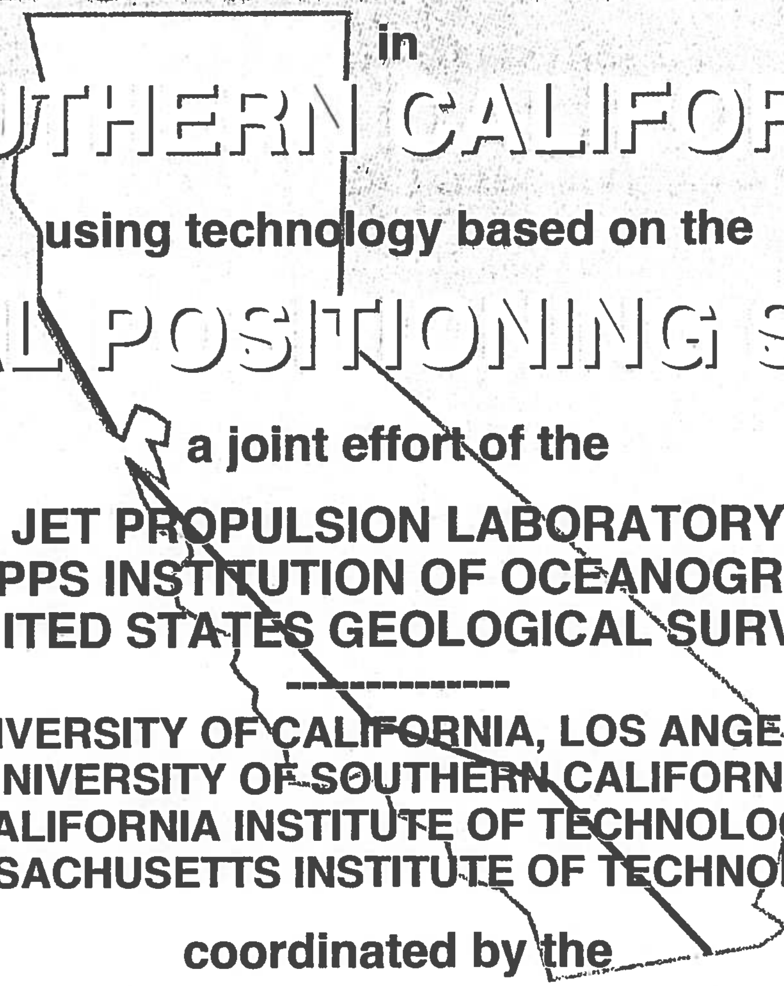
(a) Whole of southern California area (5x5 km)
(b) Los Angeles Basin, San Fernando Valley, San Gabriel Valley and San Bernardino areas (finer meshes).

Chapter IV. PSHA mapping for the whole of southern California. [Allin Cornell, Norm Abrahamson, Mehrdad Mahdyiar]

Chapter V. PSHA mapping for the Los Angeles Basin, San Fernando Valley, San Gabriel Valley, and San Bernardino areas. [Allin Cornell, Norm Abrahamson, Mehrdad Mahdyiar]

Chapter VI. Scenarios (time history) for selected earthquakes and sites in southern California. [Steve Day, John Anderson, Norm Abrahamson, James Chin, Jim Mori, Tom Heaton, Dave Wald and Guang Yu]

Chapter VII. Conclusions.



a proposal to establish a

DENSE GEODETIC NETWORK

in

SOUTHERN CALIFORNIA

using technology based on the

GLOBAL POSITIONING SYSTEM

a joint effort of the

JET PROPULSION LABORATORY
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNITED STATES GEOLOGICAL SURVEY

UNIVERSITY OF CALIFORNIA, LOS ANGELES
UNIVERSITY OF SOUTHERN CALIFORNIA
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

coordinated by the

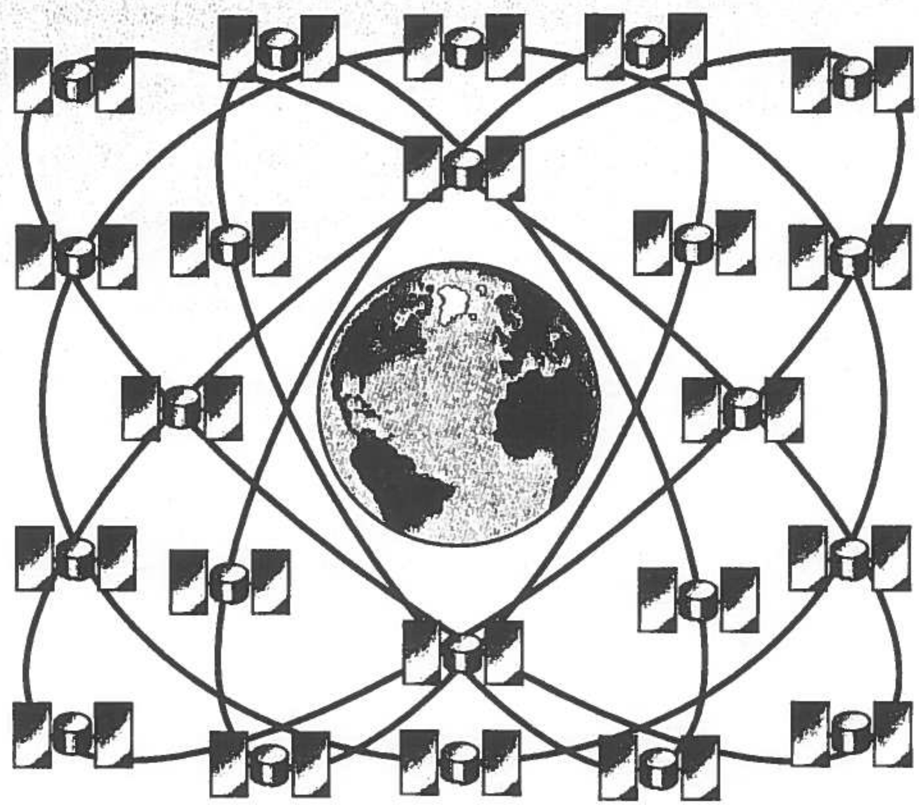
SOUTHERN CALIFORNIA EARTHQUAKE CENTER

GLOBAL POSITIONING SYSTEM

Constellation of 24 satellites

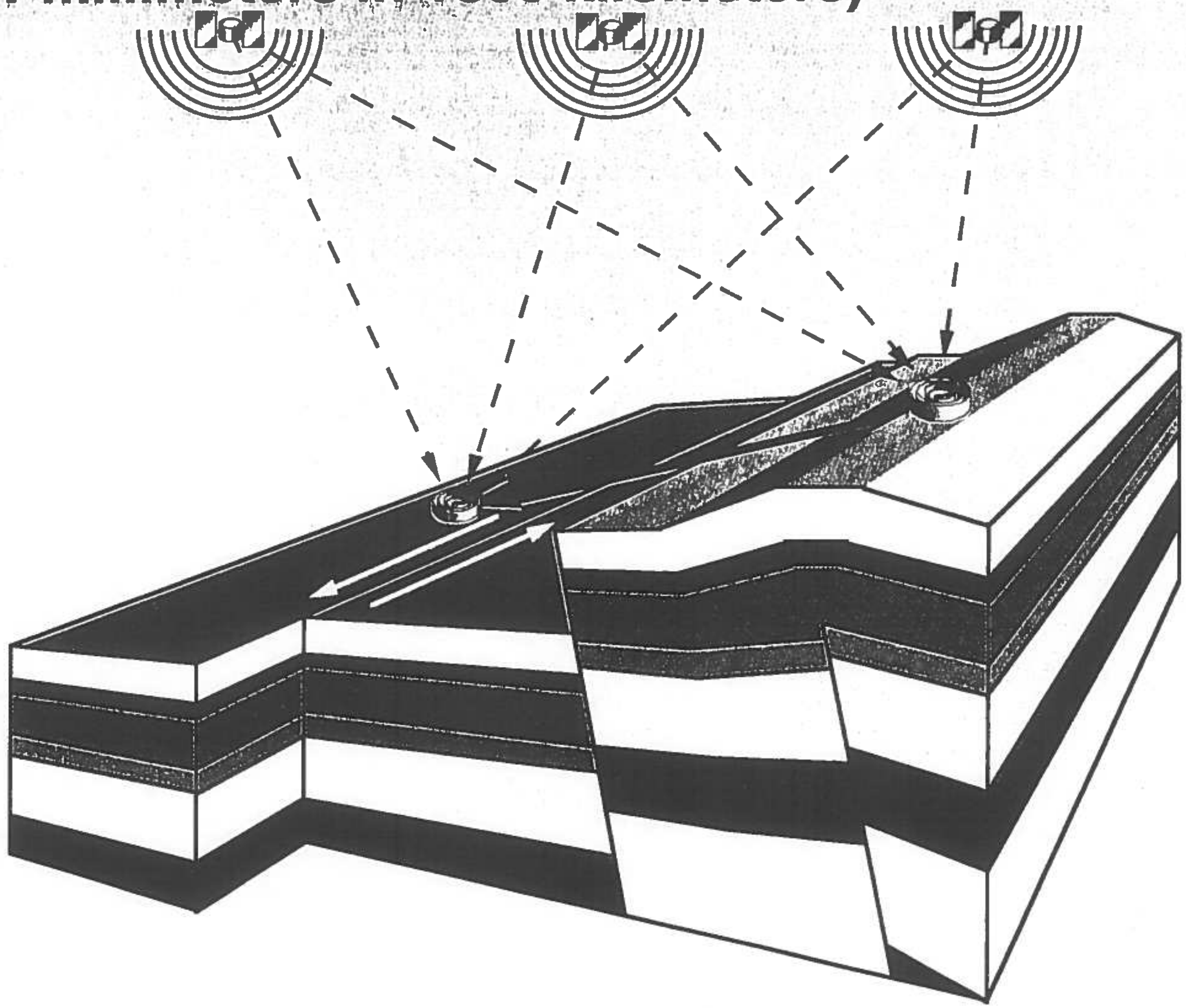
Microwave signals emitted by satellites enable position determination

- **at any point**
- **at any time**
- **in any weather**
- **to an accuracy of a few millimeters**

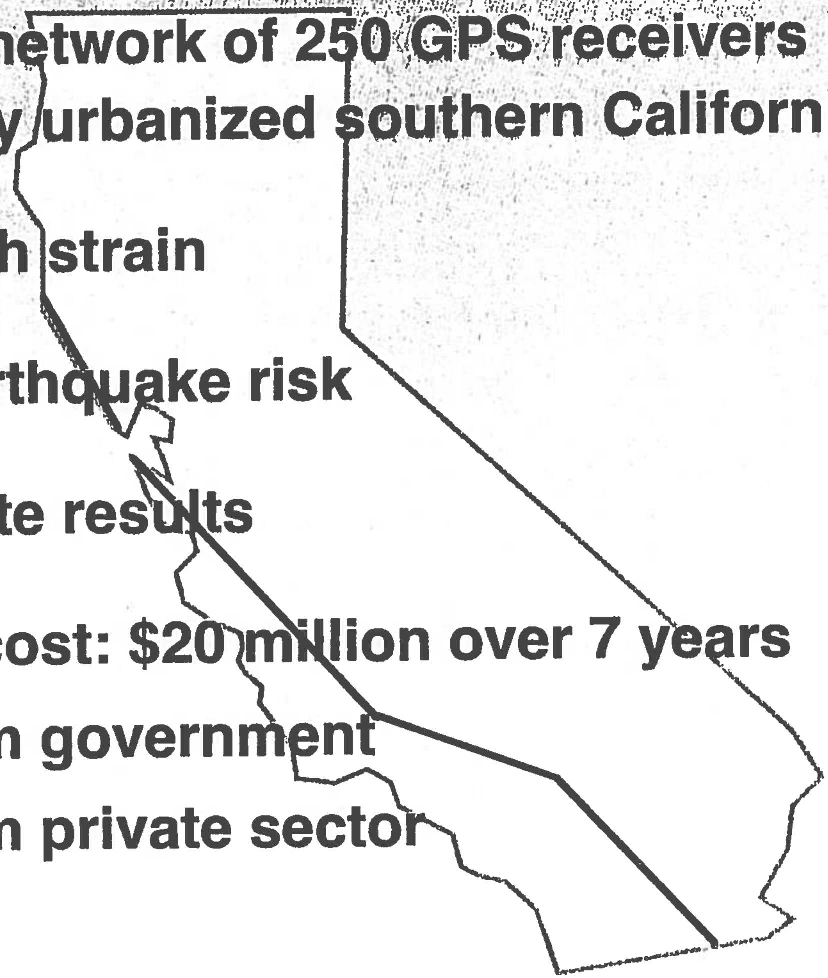


GPS BASELINE DETERMINATION

Baselines determined to a part per billion
(a few millimeters in 1000 kilometers)



PROPOSAL



Establish a network of 250 GPS receivers in earthquake-prone, highly urbanized southern California.

Monitor earth strain

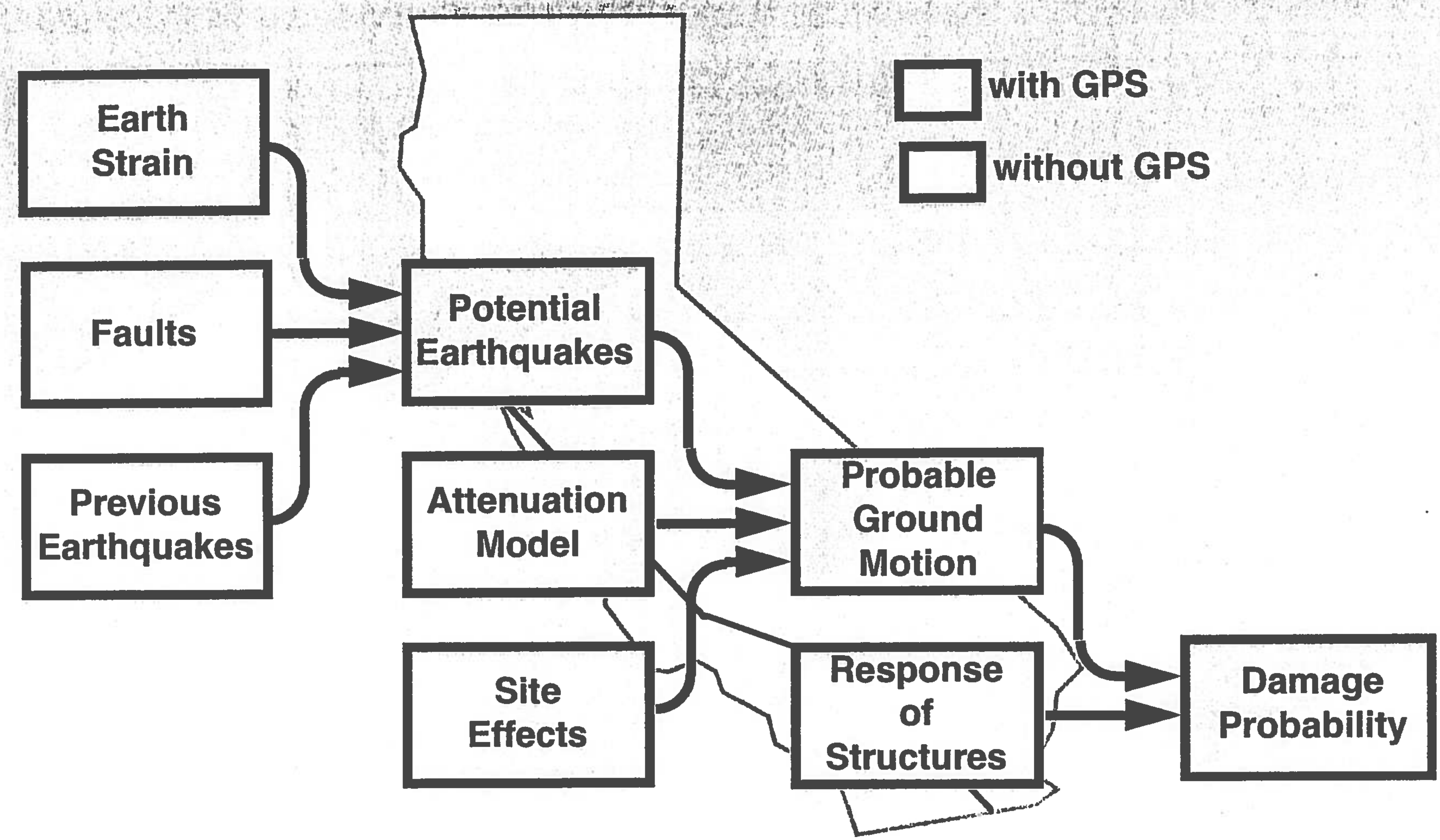
Estimate earthquake risk

Communicate results

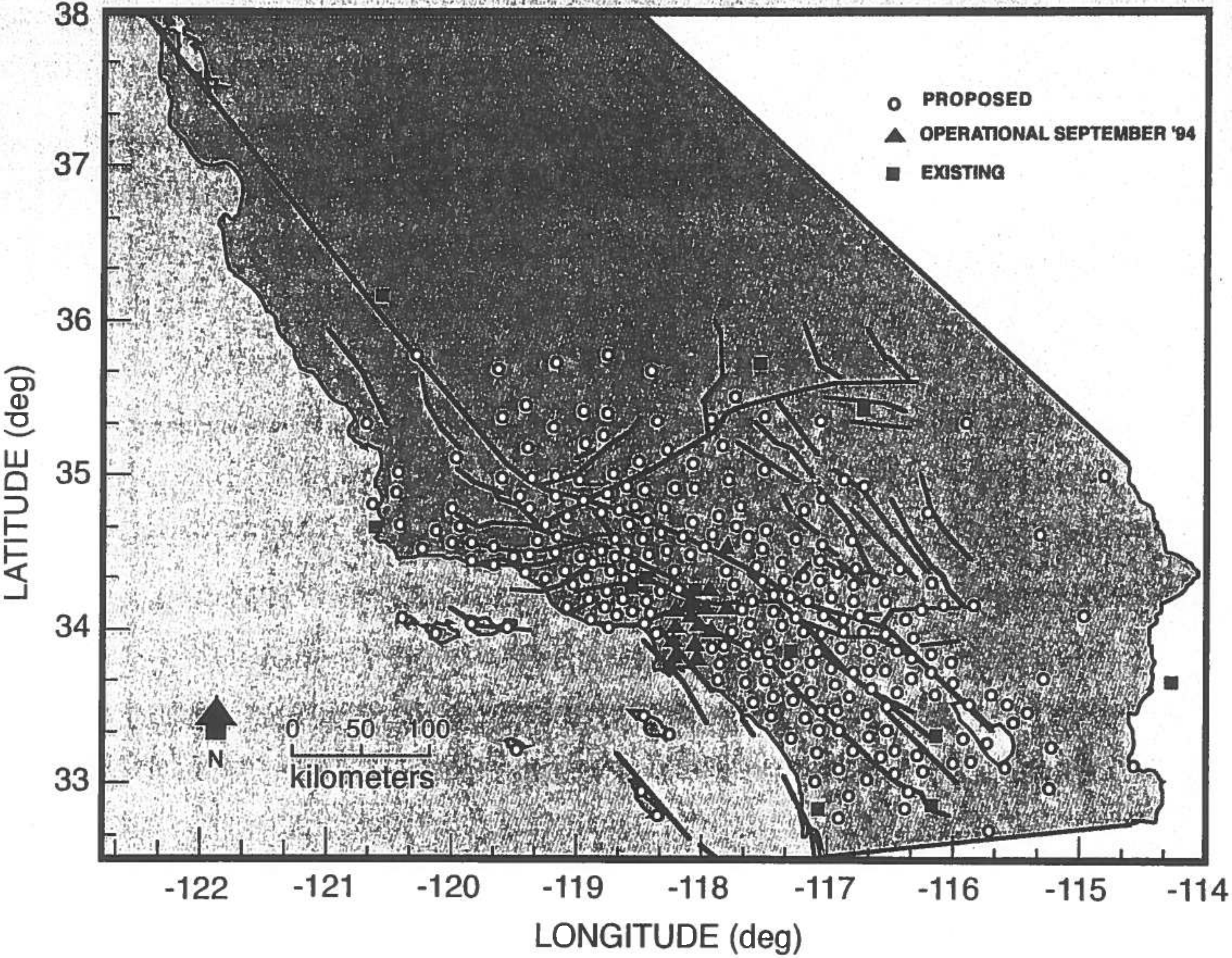
Estimated cost: $20 million over 7 years

- 75% from government
- 25% from private sector

EARTHQUAKE RISK ESTIMATION

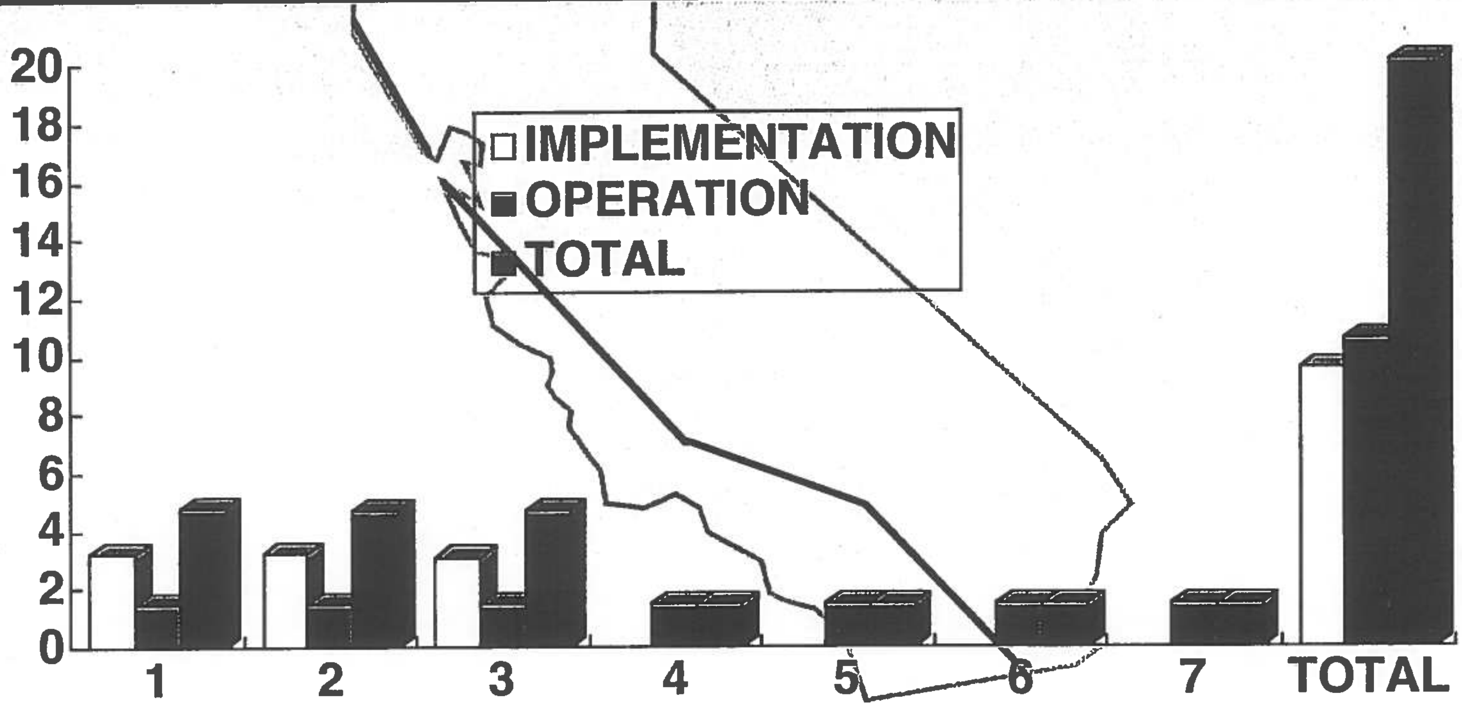


SOUTHERN CALIFORNIA DENSE GPS GEODETIC ARRAY

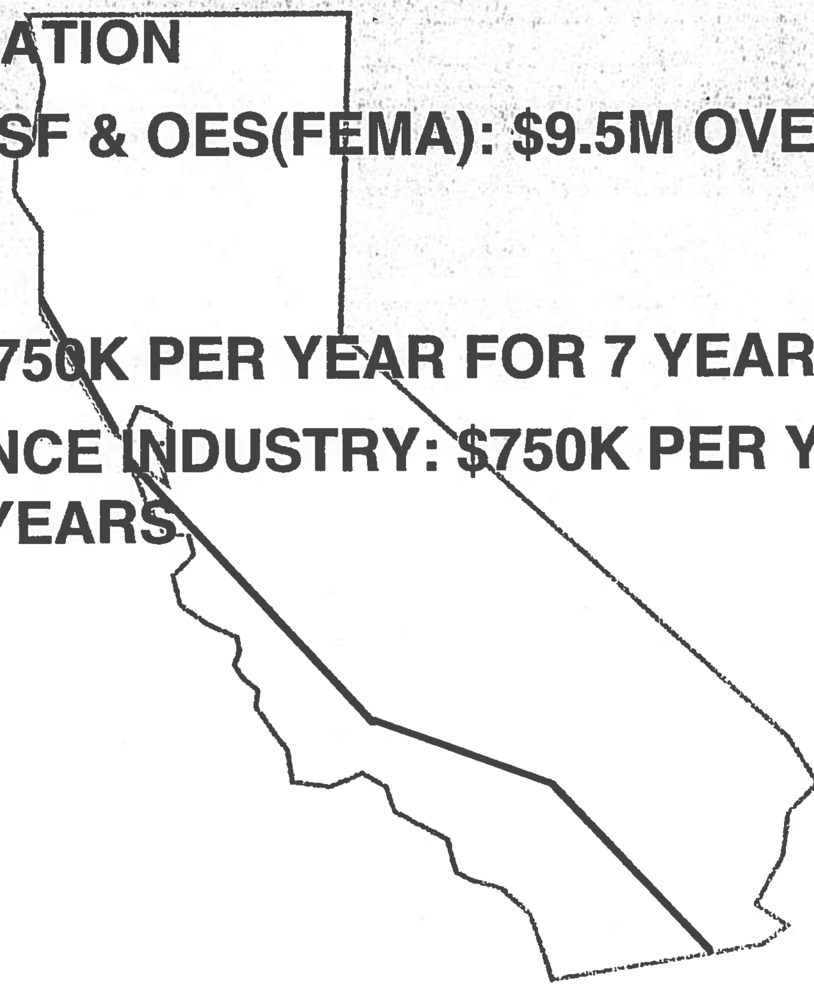


COST ESTIMATE ($M)

YEAR	1	2	3	4	5	6	7	TOTAL
IMPLEMENTATION	3.2	3.2	3.1					9.5
OPERATION	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5
TOTAL	4.7	4.7	4.6	1.5	1.5	1.5	1.5	20.0



FUNDING PROPOSAL



IMPLEMENTATION

- **NASA, NSF & OES(FEMA): $9.5M OVER 3 YEARS**

OPERATION

- **USGS: $750K PER YEAR FOR 7 YEARS**
- **INSURANCE INDUSTRY: $750K PER YEAR FOR 7 YEARS**

EARTHQUAKE HAZARD MITIGATION:
AN APPLICATION OF THE GLOBAL POSITIONING SYSTEM (GPS)

A Joint Effort Coordinated By The Southern California Earthquake Center

Background

The Southern California Earthquake Center is coordinating an effort by scientists at the Jet Propulsion Laboratory, the U.S. Geological Survey, and various academic institutions to establish a dense 250 station, continuously recording GPS geodetic array in southern California for measuring crustal deformation associated with the numerous faults that affect the major metropolitan areas. This array makes use of new, high precision satellite technology, and will complement the existing southern California seismic network.

Estimates of the time to the next earthquake on any active fault segment are based on the fault's historic record of earthquakes, long term slip rate, and displacements during previous earthquakes. For only a very small number of faults are these factors known with any degree of confidence. Since the patterns of crustal deformation in space and time govern when and where earthquakes will occur, the proposed GPS network will have major implications for earthquake hazard assessment and mitigation in southern California, allowing scientists to determine the earthquake potential of faults in the region.

In addition to the traditional funding sources (NSF, USGS, and NASA), the project will be pursuing funds from other state and federal sources, as well as the private sector. The projected cost for initial implementation is approximately $10M, with annual operating costs of $1.5–2.0M. A first-order strain-rate data set can be acquired in 5–7 years at which time a re-evaluation of the overall program and its future objectives can be made.

The Global Positioning System

The Global Positioning System (GPS) is a satellite technology developed by the Department of Defense for navigation. During the last decade improved instrumentation and increased accuracy in satellite orbital parameters have led to significant advances in applying GPS to high precision geodesy (surveying). With the appropriate analyses, absolute positions of points on the earth can now be determined to 1 centimeter, and relative positions of sites can be determined to a few millimeters for baselines thousands of kilometers long.

Over time, the positions of points on the earth move due to drift of the tectonic plates and from deformation of the earth during earthquake cycles in seismically-prone areas such as southern California. GPS has been successfully applied to measuring this motion of the earth's plates with a precision of 2 to 3 millimeters per year. GPS technology represents a breakthrough in geophysics because the slow, aseismic (quiet) component of earth motions can be measured absolutely and quickly at any point on the globe. These aseismic motions occur during the normal earthquake cycle, and are also part of the equilibration process following a major event.

There are currently more than a dozen GPS receivers operating continuously in southern California. GPS measurements also have been collected at several hundred points throughout California on a spot basis (perhaps once or twice a year) using portable receivers. These intermittent measurements will require more than 10 years to accurately calculate the subtleties in the strain field and assess earthquake hazard. This is because of geologic complexities and intrinsic errors in intermittent measurements. Continuous GPS measurements, on the other hand, allow for vastly improved resolution in time, since in effect, many measurements are made every day. Not only is the amount of time required to accurately determine the deformation field greatly reduced, but also crucial data can be collected following large earthquakes in order to rapidly assess the horizontal and vertical deformation fields, and the nature of the earthquake source.

Following the Northridge earthquake, NASA, the U.S. Geological Survey, and the National Science Foundation committed funds to install 22 new continuous GPS stations in the metropolitan Los Angeles area. The network will be operational by autumn of 1994, but the number of new receivers still falls far short of what is needed to fully characterize the earthquake hazard of the earthquake-prone region between San Bernardino and Santa Barbara, and along the San Andreas and San Jacinto faults.

Earthquake Hazard Assessment and Mitigation

Earthquake hazard assessments depend on a knowledge of the potential earthquake sources, the probability of occurrence of earthquakes of a given magnitude, and the expected levels of ground shaking. While the later is primarily derived from seismic studies, estimates of potential sources and their magnitudes are based on geological and geodetic studies of faults and their slip rates. GPS specifically addresses the source problem since earthquake potential is a direct manifestation of crustal deformation. Thus, earthquake hazards and their probabilities can be better estimated when geodetic observations are combined with the more traditional geologic and seismological measurements. Better estimates of earthquake hazards, in turn, lead to improved mitigation strategies. The geodetic data are particularly important for identifying active buried faults that do not reach the ground surface, which are common in the Los Angeles metropolitan region. The 250 station network of continuously operating GPS stations would greatly improve the quality and resolution of the next generation of earthquake hazard maps for the southern California metropolitan region.

Identify areas of greatest seismic potential

Regions of high seismicity, such as plate boundaries, deform rapidly as strain accumulates. The distribution of the strain measured with GPS provides constraints on models that are used to evaluate the earthquake potential of locked fault segments. Perhaps the greatest asset of geodetic methods are their ability to infer the existence and earthquake potential of possible blind thrust faults by sensing motion attributable to these types of structures. An improved definition of earthquake potential has important implications for activities such as earthquake preparedness (e.g., by developing better earthquake scenarios), retrofit prioritization, and seismic code development.

For example, GPS measurements indicate that the Los Angeles area between the Palos Verdes Peninsula and Pasadena is shortening at a rate of 5 to 8 millimeters per year. Several faults, including the Palos Verdes, Newport-Inglewood, Compton-Los Alamitos

Santa Monica-Hollywood-Raymond Hill, and Sierra Madre faults, lie within this region. At present we don't know how the 5 to 8 millimeters per year is distributed across these faults. GPS measurements will enable us to determine the distribution of strain and thus which faults pose the greatest hazard. Geodetic data, in combination with other subsurface geologic information, also can be used to estimate upper-bound magnitudes of potential earthquakes on these faults.

The Southern California Earthquake Center (SCEC), in its "Phase II" report currently under review by the California and National Earthquake Prediction Evaluation Councils (CEPEC and NEPEC), is pioneering the use of GPS-derived crustal deformation data in seismotectonic zonation and probabilistic earthquake hazard analysis. The earthquake potential of 65 seismotectonic zones in southern California is being derived from a combination of historical seismicity, paleoseismicity (evidence of past earthquakes) and GPS strain rates. The historical seismicity only gives a picture of what has happened over the last 150–200 years of recorded history in southern California, while the paleoseismicity is confined to the major surficial faults. GPS data nicely fill the gaps in these other two data sets, and is particularly useful for assessing earthquake potential in areas without historical seismicity, but with known active faults. A dense GPS network installed and operated over the next 5 years in southern California can be used to assess the relative earthquake potential throughout the region during the next 20–30 years — essentially the time from the San Fernando earthquake to the subsequent Northridge event.

Elucidate earthquake processes

GPS geodetic methods can help elucidate the entire earthquake processes because they sense the quiet deformation due to strain accumulation prior to earthquakes, the episodic motions due to sudden strain release during earthquakes, and the post-earthquake equilibration (including major aftershocks). This can be compared to seismic networks which only tell us about the earthquake itself, and thus can't be used to study patterns of deformation that lead up to earthquakes or how strain is redistributed after the event. Continuous GPS methods enable us to evaluate how changes in the strain (or stress) field after major earthquakes may affect neighboring faults — for example, whether the earthquake has brought them closer to failure.

Between 1987 and 1993, GPS measurements collected in the western area of Los Angeles County and Ventura County showed that the Santa Clara River Valley was the most rapidly deforming part of the region. The style of deformation suggested that thrust type earthquakes should occur there, and that the earthquake hazard was high. The 1994 Northridge earthquake was consistent in size and style with what was suggested by these GPS data and the regional geology. Thus the method's value was demonstrated and it should be applied across southern California.

Equally significant studies have explored the redistribution of stress (which is proportional to strain) following major earthquakes such as the Landers and Northridge earthquakes, and in particular, the relationship of subsequent earthquake ruptures to redistributed stress from earlier events. In many cases, earthquakes appear to nucleate in regions where the stress toward failure from an earlier event (or combination of events) has increased along faults with favorable orientations. Continuous GPS measurements can be used to map the stress redistribution following a major earthquake and identify faults which have been loaded by the event and pose an increased risk. Such faults can be given special attention, especially during major aftershock sequences in which a magnitude 7 or larger mainshock, for example, would almost certainly include one or more $M \approx 6$ events.

Earthquake Damage Assessment

A continuously operating dense GPS geodetic array in metropolitan regions of southern California will have important post-earthquake applications for assisting response and recovery.

Reveal earthquake mechanism and likely aftershock patterns

The earth's crust permanently deforms in response to large earthquakes. The deformation can be measured with GPS and can be used to reveal the earthquake mechanism — namely the fault on which the earthquake occurred (including its orientation) and sense of displacement on the fault. From this information, the resulting stress redistribution and likely pattern of aftershocks can be inferred, since aftershocks typically occur at the edges of the rupture and, as noted earlier, in regions where the stresses have increased as a result of the primary rupture .

The Northridge earthquake occurred on a blind thrust fault that ramps up to the north. The GPS sites near Northridge moved in accordance with this type of fault. Sites south of and over the rupture plane moved upward and towards the north. In contrast, sites to the north moved down and to the south. Although there was no ground rupture due to the earthquake, the surface of the earth moved in a manner consistent with the faulting mechanism. These results were determined in days to weeks following the earthquake. With a continuous GPS network we can measure the ground motions from the earthquake, and identify the fault that ruptured and probable locations of damaging aftershocks in real time with an automated system. This should lessen confusion in the future in identifying the causal fault for the media, emergency personnel, public officials, and post-earthquake scientific and engineering studies.

Measurement of permanent ground or structure displacements

In large earthquakes the permanent ground displacements can be significant. For example, Oat Mountain to the north of Northridge rose 15 inches as a result of the Northridge earthquake. The 250 station continuous GPS network would provide nearly immediate measurements of such deformation so that agencies responsible for maintaining and repairing these facilities would obtain critical information much more rapidly than is currently possible — that is, within a matter of hours, rather than several days to weeks. Immediate knowledge of these ground displacements is important for assessing damage to infrastructure after earthquakes. This is particularly true of water distribution and sewage systems which not only rely on gravity gradients for proper operation, but can be severely damaged as a result of shifting ground. For example, after the 1971 Sylmar earthquake, vertical ground displacements of up to 2.5 meters occurred over a distance of less than 10 kilometers, greatly damaging the water supply and sewage lines. In the Northridge earthquake, the vertical displacements at Jensen filtration plant were large enough (even though they were less than one foot) to affect the pond capacity and water flow rates of some of the crucial parts of that facility. Real-time GPS measurements of permanent strain can go hand-in-hand with real-time strong ground motion recordings of the seismic wavefield and knowledge of the built infrastructure to assess the likely extent and distribution of damages following a major earthquake.

Finally, the 250 station continuous GPS network would provide a basis for agencies to monitor important structures. GPS stations placed on and near dams, bridges and buildings would allow off-site detection of probable damage to the structures. Los Angeles County proposes to initiate continuous GPS monitoring of Pacoima Dam, a concrete arch dam that was damaged in both the 1971 and 1994 earthquakes. We are collaborating with the County in a pilot continuous GPS monitoring study of Pacoima Dam.

Products of a Dense GPS Network

Continuous GPS measurements would provide a variety of products for a seismically-prone region. Three-dimensional maps of strain accumulation will enable us to more effectively evaluate future regional earthquake hazard and probabilities, as well as develop earthquake scenarios for specific faults. This in turn will permit prioritization of earthquake mitigation activities, including emergency preparedness and retrofit strategies. Continuous GPS measurements will also allow for more rapid regional damage assessment following large earthquakes. Not only will the earthquake mechanism be defined more rapidly, but also permanent displacements will be determined and can be evaluated in light of their overall effect on the cultural fabric of the region.

Costs and Management

Total implementation costs of a 250 station network are estimated to be $10M. Plans are to install the network over a 2-3 year period and operate it for an additional 5 years. Operational costs, which include data processing and maintenance of the network, are estimated to be $1.5–2M per year. The effectiveness of the network will be evaluated during the sixth year of the seven-year project.

SCEC will coordinate the operations of the proposed GPS network in southern California through a SCEC GPS Coordinating Board. This board will be comprised of those individuals currently conducting GPS work in southern California plus well established scientists in geodetics from other parts of the country. Principal members from southern California will come from the Jet Propulsion Laboratory, Scripps Institution of Oceanography, UCLA, and the U.S. Geological Survey. Coordination by this board should maximize the returns from GPS networks in southern California.

To the extent possible under programmatic and granting guidelines, this initiative has been encouraged by NASA, the National Science Foundation, and the U.S. Geological Survey. Participation by the State of California will go a long way in making the network a reality, and should greatly help in extending it to central and northern California.