OPTIONS

for the

Future of the US National Strong-Motion Program

Prepared by

The Committee for the Future of the US National Strong-Motion Program

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INTRODUCTION

The National Strong-Motion Program (NSMP) operated by the United States Geological Survey provides an important earthquake recording capability vital for Earthquake Hazard Reduction and public earthquake safety. The program provides the recordings of the main earthquake at the locations of most significance for society. It provides on-scale recordings of damaging shaking near and on man made structures. No other USGS seismic observation network or program focuses on obtaining these on-scale measurements of the main earthquake at these locations. These recordings of damaging shaking at distances less than 20 kilometers on rock and 100 kilometers on soil from the earthquake source are critical for earthquake resistant design, retrofit, and construction practice. Scarcity of strong-motion recordings and rapidly escalating costs of future earthquake disasters defines an urgent need to improve the nation's capability to obtain strong-motion recordings.

The present status of the NSMP as described by the Program Council of the Geologic Division of the USGS is

> *"The NSMP is at a watershed. Its resources have shrunk over the last few years. The project has lost several personnel in the downsizing of the Geologic Division in addition, like all other projects in the EHRP; the NSMP has experienced dwindling budgets for operating expenses. Consequently, the NSMP has been faced with meeting high expectations for products and services with declining resources. The outlook for the EHRP promises constrained personnel and financial resources for the foreseeable future. These circumstances and the tenuous current state of the NSMP call for a thorough review of the role and practices of the NSMP and the development of a plan to redefine and revitalize the NSMP mission and products in light of current realities and trends.*
>
> *The Committee on the Future of the NSMP is asked to provide two items: a vision paper and an options document. ..."*

This report constitutes the requested "Options Document". This report considers three options. Option I assumes a constant level of financial support for Operating Expenses (OE) with no additional personnel support. Option II assumes a slight increase in OE support of 150K for FY 99 and beyond. Option III considers the role that a NSMP must play if the nation's urgent need to record the main earthquake at locations of significance for society is to be met. Two parts of Option III are considered. The fist part of this option, termed Option III A considers the role that strong-motion recording in and near man-made structures must play if a near-real time hazard initiative is to be implemented in the United States. The second part of Option III, termed Option III B, considers the scope of a NSMP needed to address societies needs to record the main earthquake in locations of significance for future public earthquake safety.

FY-98 OPERATIONAL LEVEL FOR NSMP

Preliminary staffing and Operational Expense (OE) levels appropriated for FY-98 for the NSMP are summarized in Table 1. Aspects of the program considered, as core elements are those efforts associated with the maintenance and operation of the National Strong-Motion Network (NSMN) and the National Strong-Motion Data Center (NSMDC). Successful operation of these aspects of the program is vital to continued operation of the NSMP.

Total FY-98 OE appropriated for the program is $362K with an additional amount up to $100 K being appropriated separately. OE required to maintain stations for other agencies is reimbursed by the appropriate agency. OE for operation of the NSMN is appropriated at about $171K and OE for

National Strong Motion Program Staff and OE Summary

	Data Acquisition					Data Management		Data Utilization				Totals
	1a NSMN	1b Borehole & Portable Arrays	1c SM Site Charac.	1d Struc.& SSI Arrays	1e Near-real time	2a NSMDC	2b Borehole & portable Data Base	3a Gnd. Mot. Pred.	3b S. W. SM Site Char.	3c NEHRP/UB Site Factors	3d Eqk Eng. SR & SSI	
	R. Porcella	C. Dietel	J. Gibbs	M. Celebi	. Porcella	C. Stephens	G.Glassmoyer	D.Boore	H.P. Liu	R.Borcherdt	M.Celebi	
OE (k)	165	20	34	20	proposal	92	3	8	9	6	5	362
Staffing												
Acosta, A.	26.1											26.1
Anjal, C.	26.1											26.1
Baker, L.					8			3				11
Boore, D.			1					17.1	1			19.1
Borcherdt, R.		4								22.1		26.1
Celebi, M.				8							18.1	26.1
Dietel, C.		13.1										13.1
Fletcher, J.					8							8
Fogleman, K.						17.1						17.1
Foote, L.	26.1											26.1
Fumal, T.										3		3
Gibbs, J.			26.1									26.1
Glassmoyer, G.		4					8			14.1		26.1
Hamilton, J									2			2
Johnson, D.	26.1											26.1
Joyner, W.			2					16.1	1			19.1
Jungblut, W.	26.1											26.1
Liu, H-P.		1						1	15.1		1	18.1
Porcella, R.	26.1											26.1
Salsman, M.	26.1											26.1
Stephens, C.						26.1						26.1
Tam, R.						19.1						19.1
Tinsley, J.			6									6
Westerlund, R.		18.1	8									26.1
Totals	182.7	40.2	43.1	8	16	62.3	8	37.2	19.1	39.2	19.1	474.9

operation of the NSMDC is about $92K. The remainder of OE is distributed among other projects being conducted by the NSMP.

Total staffing for the NSMP is about 17 full time staff. Of this number 7 staff members are associated with maintenance of the National Strong-Motion Network (NSMN) with 2 of these positions needing immediate replacement. One staff member is directly associated with operation of the National Strong-Motion Data Center (NSMDC). Two additional members are being transferred to the NSMDC staff. Staffing for these critical aspects of the program have decreased by 6 full time positions since 1994 and about 12 positions since 1977, prior to passage of the EHR Act of 1978 and the transfer of funding responsibility to the USGS in 1981. Three additional retirements are expected within the next five years.

OPTION I -- CONSTANT LEVEL OF PROGRAM SUPPORT ($300K SIR OE)

Option Description

This option assumes that the program will continue to operate at FY-98 appropriation levels. If the program is to continue to operate at this level for the next 5 years then this scenario translates into an effective 5 percent annual decrease in total funding (salaries and operating expenses), because of the effects of inflation and escalating staff salaries. This option is considered by the external advisory committee as equivalent to **a gradual termination of USGS operational responsibility for the NSMP**.

Implications

- The FY-98 management configuration of the program is considered a positive step towards getting the NSMP back on track. It provides a small, but coherent critical mass of personnel to pursue its important role in the EHRP. It brings back together each of the important elements of the NSMP. Previous organizational arrangements with personnel interested in the program, but assigned to other sections and regions were very disruptive to the management and operation of the program. Support of the continued dedication and commitment of NSMP personnel is critical to its continued successful operation.
- FY 98 staffing and support levels for the program are at critical levels.
    1. The number of operational staff is at an all-time low with additional retirements expected.
    2. The operational budget is decreased to a bare-bone minimum.
    3. Considerable funding (>$400 K) is needed to eliminate backlog of strong-motion data that needs to be digitized.
    4. Approximately 90 % of present 900 accelerographs are analog. There is a great need to upgrade the existing hardware to digital in order to improve data retrieval rates, decrease maintenance costs, and eliminate digitization expenses.
    5. Present resources do not allow the USGS and the NSMP to meet public expectations for recording the next major earthquake.
- Maintenance of the program at these levels for the next 5 years is termed by the external advisory committee as equivalent to **a gradual termination of USGS operational responsibility for the NSMP**. (The 1978 Earthquake Hazard Reduction Act and subsequent OMB transfers of funding and personnel presently place responsibility for operation of the NSMP with the USGS.)

- If USGS support for the NSMP continues to decrease with no or only limited resources devoted to instrumentation on and near structures, then this decision needs to be clearly articulated to the EHRP community. A clear decision is needed in order that the nation's urgent need to record the next major earthquake in and near man-made structures on a variety of soil and rock conditions can be addressed by the National Earthquake Engineering Community. The present lack of these data is considered a major obstacle for Earthquake Hazard Mitigation (Procs. CASMP Workshop, Stepp, 1997). Agencies or groups of agencies with well-defined responsibility for the acquisition and dissemination of needed strong-motion measurements to the engineering community must be identified and supported with adequate personnel and funding to permit acquisition of the needed data over time-periods of several decades.

OPTION II -- SLIGHTLY INCREASED LEVEL OF SUPPORT ($300K SIR FY 98 OE; $450K FY 99 AND BEYOND)

Option Description

This option assumes that the program will continue to operate at FY-98 appropriation levels, but in FY-99 and the subsequent four years it will operate with an OE level increased to $450K. This option with its specified OE level is considered the minimal level necessary to continue USGS operation of the program provided recent retirements are replaced. If staff is not replaced, then OE must be used for service contracts. Committee consensus is that this option reduces to **gradual termination of USGS operational responsibility for the NSMP, unless staff replacements are in place** within the next 1-2 years.

Implications

- This increase in OE represents a welcome increase in funding that helps offset the annual 5 percent increase in total operating costs due to the effects of inflation and escalating staff salaries.
- This increase in OE funding level could be used for specific tasks in approximately the following proportions:
    1. Reduce analog data backlog and improve strong motion data base ($25K per year),
    2. Upgrade analog stations to digital (5 stations per year; ~ $75K),
    3. Acquisition of geotechnical and seismic information required to interpret existing strong-motion data (2 sites per year; ~ $25K).
    4. Initiate development of improved near-real time telecommunication capability for strong-motion stations (7-8 stations per year; $25K).
- Technical support staff for the NSMP has not been replaced with one exception, since the passage of the 1978 Earthquake Hazard Reduction Act and funding responsibility for the program was transferred to the USGS in 1981. As a result gradual attrition of 12 staff members through retirements has reduced technical program staff levels to a critical level. Committee consensus indicates that continued operation of the program without replacement of retirees and the addition of newly trained technical staff over the next five years is equivalent to **termination of USGS efforts** to operate the NSMP.

Recommended Actions

- USGS responsibilities and society expectations demand immediate action to improve capabilities to record the next main damaging earthquake at locations of most significance for public safety.
- NSMP staffing and funding levels **should be restored to 1981 levels** as soon as feasible.
  1. NSMP OE levels should be increased to $450K level in FY 98, if possible and subsequently increased at a rate of 10-15% per year for the next 4 years.
  2. **Replacements of recently retired staff are critical and urgently requested**. Staff replacements are the highest priority need of the NSMP. As a minimum, 7 replacements for 12 staff members in the next year or so are deemed essential. Two positions that must be urgently filled are those to replace D. Johnston and a permanent position for E. Ajal, whose 8-year temporary position expires soon. Five other positions that must be refilled are those for at least 2 technicians to replace F. Ellis, J.Nielson, F.Risavich, and R.Forshee, a network management trainee for the National Network to replace E.Etheridge and R. Maley, a database management analysis expert to replace P.Mork and A.Converse, and a recent Ph.D. in earthquake engineering focussed on instrumentation of structures and lifelines to replace E. Safak and G. Brady.
- Staff replacements are essential for continuation of the program and satisfactory progress on the following tasks.
  1. Maintenance of NSMN stations with acceptable maintenance intervals of twice a year,
  2. Upgrade of analog to digital stations.
  3. Installation and maintenance of strong-motion telecommunication effort as established for strong-motion components of TriNet.
  4. Establishment of digital strong-motion component of "Virtual Strong-Motion Database" for rapid retrieval and dissemination of data immediately following a major earthquake.
  5. Expansion of instrumentation partnerships with federal, state, and local agencies, and owners of hospitals, emergency-response centers, lifelines, and high occupancy buildings to augment USGS resources.
- Given the current level of operational support and staffing for the NSMN **we will not** be able to:
  1. Maintain the current network at necessary intervals of one year.
  2. Maintain expected progress rate on tasks 2-5 in preceding list.
  3. Respond to a moderate or major earthquake with timely generation of professional quality strong motion reports, station maps, and processed analog and digital data for proper distribution to critical users as has been done in the past.
- Allocation of OE and replacement of staff as recommended above will allow the program to be operated at a stable 1981 level with satisfactory progress on each of the well integrated tasks of the FY 1998 proposal as outlined below:

  Project Objectives: The overall objective of the **NSMP** is to significantly improve public earthquake safety through the fulfillment of national responsibility for coordination, acquisition, rapid dissemination and interpretation of strong-motion recordings of each major damaging earthquake in the United States. Ensure to the extent of available resources that each damaging earthquake is adequately recorded at locations throughout densely urbanized areas near the source, on the ground and in structures of most significance for understanding and mitigating catastrophic losses anticipated from

future earthquakes. Conduct the major components of the NSMP concerned with Data Acquisition, Data Management, and Data Utilization.

Overall Strategy, Study Design, and Planned Major Products: Conduct following components of NSMP:

1. ***Data Acquisition***
   a) *National Strong-Motion Network* – R. Porcella -- maintain and upgrade the National Strong-Motion Network (NSMN) of 850 accelerographs at 540 stations in 33 states and Puerto Rico in cooperation with Corps of Engineers, Department of Veterans Affairs, General Services Administration, U.S. Department of Energy, Hawaii State Civil Defense, and 10 other federal, state, and local agencies and universities;
   b) *Integrated Borehole Arrays and portable strong-motion arrays* – C. Dietel and R. Westerlund, R. Borcherdt -- maintain permanent arrays in San Francisco, Parkfield, Mammoth Lakes, East Bay and S. Calif. and portable wide dynamic range instrumentation for post earthquake response of WR EHZ, conduct analyses as data becomes available;
   c) *Near-Surface Lithologic and Seismic Site Characterization* – J Gibbs, W. Joyner -- Compile seismic, geotechnical and geologic borehole data for critical interpretation of existing strong-motion recordings of damaging earthquakes;
   d) *Structure and Soil-Structure Interaction (SSI) arrays* -- M. Celebi – Coordinate advise, and expand federal programs for installation of instrumentation arrays in structures in cooperation with 15 other agencies as highlighted in new 1998 program prospectus. Develop and implement special-purpose arrays for soil-structure interaction studies;
   e) *Near-real time strong-motion measurements for emergency response and warnings* – R. Porcella — Configure and implement modern telecommunications for rapid data retrieval and interpretation for damage assessments in minutes to aid in emergency response efforts to permit limited warnings in some cases.
2. ***Data Management***
   a) *National Strong-Motion Data Center* -- C. Stephens, 2 vacancies – Operate the NSMDC with major activities being: 1) digitize, process, archive and disseminate backlog of 1500 analog strong-motion records, 2) implement modern NSMDC data base for rapid data retrieval and dissemination via Internet, ftp sites, CD-Rom etc., 3) develop and implement hardware and software for rapid incorporation of near-real time strong-motion data into NSMDC data base for rapid dissemination via NSMP web site;
   b) *Borehole and Portable Array Data Management* – G. Glassmoyer – Manage the playback, archival and dissemination of large volumes of borehole array and post earthquake digital recordings, including development of WWW site for access to all past portable array strong-motion data recorded by USGS;
3. ***Data Utilization***
   a) *Strong-Motion Prediction* – D. Boore, W. Joyner – Develop equations to predict strong motion as a function of earthquake magnitude, distance, and geologic conditions;
   b) *Surface-Wave Site Characterization* – H-P. Liu – Develop and evaluate surface wave inversion techniques as a cost effective alternative to borehole characterizations of local site response in order to interpret critical strong-motion recordings of damaging earthquakes;
   c) *NEHRP/UBC Site Amplification Factors, Predictive GIS Maps of Ground Shaking, and Anelastic Wave Propagation* -- R. Borcherdt -- Empirical and theoretical studies of soil response for NEHRP and UBC site-specific, building code provisions and CA law AB-3897, Predictive GIS maps of ground shaking;
   d) *Earthquake Engineering* -- M. Celebi –

1) Structural Response and SSI research – Conduct studies of structural response and soil-structure interaction for improvements in NEHRP/UBC building codes as highlighted in 1998 program prospectus;

2) Structural Testing and post earthquake studies – Conduct, evaluate and recommend appropriate dynamic tests to infer in-situ structural response for earthquake safety evaluations and develop post earthquake loss reconnaissance capabilities.

- Biannual meetings between representatives of the EHRP Program Council and the NSMP are recommended to improve communication, review progress, evaluate strong-motion recording needs, and facilitate coordination between regional network operators and the NSMP.
- Establishment of an external advisory committee for the NSMP is a high priority. The external component of the Committee on the Future of the US NSMP is recommended as the initial advisory committee. Biannual meetings are recommended for FY 1998.

OPTION III A -- SIGNIFICANTLY INCREASED LEVEL OF SUPPORT TO PERMIT REAL-TIME DAMAGE ASSESSMENT USING STRONG-MOTION RECORDING

Real-time earthquake disaster assessment to guide emergency response actions requires strong-motion instrumentation located throughout urbanized areas most likely to be damaged by future large earthquakes. Instruments must be located on and near critical man-made facilities and in populated urban areas that have dense concentrations of structures determined to have a high likelihood of being damaged in future strong earthquakes. Such instrumentation must be capable of providing on-scale measurements of the strong ground shaking and resultant motions of structures adequate to assess the structural safety and direct emergency actions. To adequately provide the needed information, a very large increase in resources is required. Discussions at recent workshops imply that strong motion measurement must play a major role in real time hazard assessment. Points raised here are based on these discussions.

Option Description

This option provides for the exciting possibility of meeting the nation's need for on-scale measurements of earthquake motions associated with damage to man-made structures in densely urbanized areas for purposes of structural safety evaluations and guidance for emergency response and recovery actions. On-scale measurements of strong shaking near-by and on facilities such as bridges, highway overpasses, hospitals, emergency response centers, fire stations, and airports as well as near-by and in high-occupancy structures are required. To be effective a large number of instruments with near-real time parameter retrieval will need to be installed throughout densely developed urban areas that are at high risk from earthquake disasters.

Recommended Actions

To facilitate implementation of Option III A, the National Strong Motion Program in conjunction with CASMP, COSMOS, and other appropriate groups will:

- Develop a plan for implementation of the real-time disaster assessment capability in urban areas working with federal, state, and local emergency response agencies, local governments and private sector companies and organizations. Participation will include public and private sector groups responsible for critical facilities such as hospitals, fire stations, emergency response facilities, and so on; lifelines such as highways, bridges, electric utilities, telephone system, gas distribution systems, water distribution systems, and so on; private owners of

high-occupancy and commercially important industrial and business facilities; and elected officials responsible for mobilizing disaster response.

- Develop a deployment plan for strong motion instrumentation in densely urbanized areas with high risk of experiencing an earthquake disaster (Los Angeles, San Francisco, Seattle, Salt Lake City, Memphis, New York, Boston) to permit on-scale measurement of shaking levels up to 2g and rapid transmittal of strong motion time histories and damage measures for disaster assessment.
- Determine the community of users and develop and implement the capability to communicate assessments of damage to the built environment in real time and near-real time when an earthquake strikes an urbanized area.
- Develop a database of strong motion information that can be rapidly assessed by practicing earthquake engineers, local officials responsible for implementing earthquake resistant design measures, and other users concerned with earthquake loss assessment and earthquake safety.
- Provide for long-term maintenance and operation of the system for a period of several decades.

Implementation

Option III A requires a significant investment of resources and the commitment to long-term performance. Consequently, the deployment of the national system should be accomplished in stages and phases. It should be implemented in the urban areas of highest risk first, then proceed to urban areas within the high risk group that have successively lower risk. At each implementation stage instrumentation will be installed in phases starting with instrumentation of critical facilities and progressing to instrumentation of free-field sites. Following a staged and phased approach, complete implementation of real-time damage assessment capability in the seven urban areas that have the highest earthquake disaster risk will be completed over a period of fifteen years.

OPTION III B -- SIGNIFICANTLY INCREASED LEVEL OF SUPPORT TO PERMIT NATION'S ON-SCALE MEASUREMENT NEEDS OF THE MAIN EARTHQUAKE IN URBAN AREAS TO BE MET IN THE NEXT 10 YEARS

Option Description

The significance and urgency of the national need to acquire on-scale measurements of the next tragic main shock at locations in urban areas, suggests that a coordinated national effort needs to rapidly evolve. This effort can and should be conducted in concert with the new real-time hazard assessment effort. However, instrumentation placed for disaster assessment purposes will not meet all of the needs to thoroughly measure the response of various structures or soil deposits. Consequently, the overall need for strong-motion measurement is much broader in scope and must necessarily utilize a much larger set of resources.

Since the 1995 Kobe earthquake, approximately 4,000 modern strong motion instruments have been or are currently being deployed in Japan by a variety of government and private agencies. The geographical area of Japan is considerably smaller than the state California. Including installation, infrastructure, and the geotechnical analysis made at most sites, the total expenditure for these deployments is estimated to be approximately 300-400 MILLION dollars. This rapid, broad-ranging deployment was made as a response to the tragedy in Kobe, and the subsequent realization the nation seriously underestimated the urgency and importance of a long-term, broad-based national strong motion network.

Likewise, in the last several years Taiwan, approximately 1/12 the size of the state of California, has installed nearly 1,000 modern strong motion instruments to address serious concerns about damaging earthquakes. The stations are installed for purposes of earthquake engineering, but in many cases eqipped with telecommunications that permit real-time and early-warning applications.

Implications of Present Level of Effort

- Continued EHRP support of NSMP at levels recommended in Option II combined with the efforts of all other strong-motion programs, ensures that the next large and damaging earthquake in the United States **will not** be adequately recorded in whatever densely urbanized area that might be impacted.
- No urbanized area in the United States is instrumented presently so as to document ground shaking and structural performance during the main shock as needed;
    1. Extensive regional and national network "weak-motion" monitoring efforts will provide useful information at low-noise locations on rock of foreshocks and aftershocks, but little information on the main shock at locations near man-made structures at levels above damage thresholds.
    2. If the earthquake impacts California, NSMP and CSMIP instrumentation is likely to provide a number of useful on-scale recordings of the main event in urban areas. But, sparse density of ground-motion stations, scarcity of instrumentation on critical facilities and scarcity of instrumentation on important structures implies that much of the quantitative information needed to improve design and construction procedures will be missed as it was missed in the Northridge earthquake.
    3. Costs to society in terms of design of future structures to poorly documented and inadequate standards will continue to escalate. More complete justification of need for increased resources is provided in Vision Document.

Recommended Actions

- The **NSMP** should help launch a dramatically accelerated program to acquire the needed on-scale measurements of the next damaging US earthquake at locations near and on damaged man-made structures. The achievement of this objective will require an increase in resources devoted to recording strong-motion that is more than an order of magnitude greater than that currently being expended by all programs in the US.
- The **NSMP** should continue to conduct long-term partnerships, facilitate integration of efforts and interests of other national and state organizations and develop national and private resources to meet national needs. It should augment and build on the partnerships and cooperative efforts already established with the following agencies in the United States: Army Corps of Engineers, California Department of Water Resources, California Division of Mines and Geology, Department of Veterans Affairs, General Services Administration, Hawaii State Civil Defense, Kaiser, Metropolitan Water District of Southern California, Oregon Department of Transportation, Pacific Gas and Electric, University of Puerto Rico, U.S. Department of Energy, U.S. Geological Survey, Utah Geological Survey, Washington, City of Aberdeen, Washington, Tacoma Public Utilities, Washington Dept. of Natural Resources, Washington Department of Transportation, Property Owner (Code mandated), Universities, and others.
- The **NSMP** should serve as an integral and founding member of the national Consortium of Organizations for Strong-Motion Observation Systems (COSMOS) in order to help launch a dramatically accelerated earthquake measurement program for public safety.

- The NSMP should continue to integrate the efforts of both the engineering and seismology communities and work to develop improved understanding of the different cultures and user needs. It needs to integrate efforts of several committees, including: Committee for the Advancement of Strong-Motion Programs, appropriate committees of the National Academies of Science and Engineering, the Strong-Motion Committee of the Earthquake Engineering Research Institute, the Seismology Committee of the Structural Engineers Association of California, the California Strong-Motion Instrumentation Program of California Division of Mines and Geology, TriNet, the Council for the National Seismic System, and others.

APPENDIX A

QUESTIONS AND ISSUES POSED BY EHRP PROGRAM COORDINATOR (R. PAGE)

Memorandum

To: Roger Borcherdt

From: Robert Page

Subject: Future of the National Strong Motion Program

I look forward to receiving your committee report recommending a future direction for the National Strong Motion Program (NSMP) by 30 September 1997. I want to impress upon you the importance of this report. The Program Council widely perceives this part of our program to be uncertain of its goals and without a coherent plan of where the effort is headed. The Council is increasingly frustrated and impatient with the situation.

I would like your committee report to address strong-motion data acquisition and data management and dissemination issues--issues at the traditional core of the **NSMP**--and not the broader issues of data analysis and research.

Circumstances have changed since I initially requested a vision/options report in my memo of 3 October 1996 to Walter Mooney (copy appended). Namely, the Program Council has evaluated the FY-98 project proposals and made recommendations on funding, and there is a reasonable likelihood that in FY-99 we may receive a major increase in funding to upgrade seismic networks to provide real-time hazards information. Accordingly, I am no longer asking you to develop a series of three program options but rather two five-year options: one that assumes a constant level of SIR OE of about $300K per year, and one that assumes $300K of SIR OE in FY-98 and $450K per year in FY-99 and beyond. (See next paragraph for explanation of the $300K figure.) In regard to developing an option for an expanded program should the FY-99 Real-Time Hazards Warnings Initiative be successful, I ask that this be included as an integral part of the initiative implementation plan that Harley Benz is spearheading. Thus, I am not asking that you develop a separate option for this scenario.

You may expect to receive about $300K total OE in FY 98 for subtasks 1a, 1b, 1d, 2a and 2b of the Data Acquisition and Data Management tasks in your project proposal. In addition, you may expect to receive about $34K for Site Characterization (subtask 1c), but for the purposes of this exercise I choose to view this subtask as being outside the traditional core activities of the NSMP. The Council recommended no funding for subtask 1e, Near-Real-Time Strong-Motion Measurements, because it does not appear to be coordinated with associated efforts in southern and central California.)

Here are some questions to consider in developing an options document for the USGS strong motion program:

What are the most critical problems to be addressed by the program?

Where are the best locations in which to pursue these problems?

Is the current strong motion network suitably deployed to address these problems?

If not, what changes should be made?

Should recordings of strong shaking close to the fault in earthquakes larger than M 7.5 or 8.0 be a high priority of the program? If so, what is the strategy to obtain such records?

What are the priorities for documenting nonlinear soil response, soil-structure interaction, and basin effects? Should such problems be addressed within the context of current NSMP resources? If so, how and where?

What are the priorities in the context of the modest funding currently available to the program? Which of these problems can be addressed in partnership with other agencies and private entities?

What should be the balance of focus between free-field instruments and instruments in structures?

Does the USGS recover the full costs of maintaining strong-motion recorders for other Federal agencies? If not, is continued operation of these instruments in the long-term interests of the program?

What is the proper geographical balance of effort in the program in terms of impact on loss reduction?

In view of the vigor of the California Strong Motion Program, what should be the role and objectives of the USGS program in California? Should the USGS restrict its support of strong motion instruments in California to those that comprise localized arrays designed to address specific issues? Should all other USGS instruments be turned over to CSMP to operate? I understand the USGS instruments unusual building in California while the State instruments typical buildings. Does this relegate us to a role of secondary importance in terms of contributing to the reduction of losses?

What fraction of the program effort should be expended in California? In other western states? In Alaska? In eastern states?

Can the operational costs of maintaining the network be reduced?

What should be the policy with respect to instrumentation? Should analog instruments be replaced by new digital instruments? Or, should new digital instruments be used to augment (expand or densify) the existing network?

What is the long-term plan and timetable for processing old records? How many are of such significance that they should be processed?

What is the strategy for integrating the strong motion network into the National Seismic System? Interface of NSMP with other Networks (National Seismic System).

INDIVIDUAL RESPONSES TO NSMP QUESTIONS AND ISSUES

Response of R. Borcherdt

1. *What are the most critical problems to be addressed by the program?*

   On-scale measurement of the main shock on and near structures throughout stricken urban areas for purposes of improving public earthquake safety. Present resources within the program are not adequate.

2. *Where are the best locations in which to pursue these problems?*

   Densely urbanized areas within 100 km on soil and 20 km on rock of the rupture zone.

3. *Is the current strong motion network suitably deployed to address these problems?*

   Yes, but much too sparse.

4. If not, what changes should be made?

A near twenty-fold increase in resources is needed to meet societies needs to record the next main shock at locations of significance for public safety.

5. Should recordings of strong shaking close to the fault in earthquakes larger than M 7.5 or 8.0 be a high priority of the program? If so, what is the strategy to obtain such records?

Yes. Deploy instrumentation with a spatial density proportional to probability for ground motion exceedance at a specified level as derived from national seismic hazard maps (Figure 2a in Borcherdt and others, 1997; See Figure 4a here and Table 1 in Vision Document).

6. What are the priorities for documenting nonlinear soil response, soil-structure interaction, and basin effects? Should such problems be addressed within the context of current NSMP resources? If so, how and where?

Solution of these problems and other critical research problems based on strong-motion data are essential for reduction of earthquake losses. They should form a critical component of the NSMP and addressed as funding and staff resources permit.

7. What are the priorities in the context of the modest funding currently available to the program? Which of these problems can be addressed in partnership with other agencies and private entities?

Highest priorities are staffing and funding levels sufficient to permit continued operation of the network with yearly maintenance intervals, upgrade of analog instrumentation to digital , and conduct of an efficient and effective National Strong-Motion Data Center.

8. What should be the balance of focus between free-field instruments and instruments in structures?

An integrated and well balanced approach is required in order to measure ground shaking and the resultant response of man-made structures for purposes of building a safer earthquake resistant environment. A ground motion measurement program can not be effectively conducted independent of a measurement program for structures. An integrated program to measure ground motions and the resultant response of structures is essential for an effective program to meet societies needs for measurement of the next tragic earthquake throughout the stricken areas.

9. Does the USGS recover the full costs of maintaining strong-motion recorders for other Federal agencies? If not, is continued operation of these instruments in the long-term interests of the program?

Full cost is difficult to answer, but costs recovered have been the savior of the program. The conduct of these long term partnerships with some 15 different agencies is an important and necessary role of the national program. Continued long-term operation of these cooperative efforts is essential for a successful national program. It is the integration of strong-motion data acquisition efforts that provides a measurement capability whose usefulnesses to society is greater than that that could be provided by any program separately.

10. What is the proper geographical balance of effort in the program in terms of impact on loss reduction?

The proper geographical balance is as shown in Figure 1 and tabulated in Table 1 (Vision Document) as determined from exceedance rates for 0.1g and population exposure to levels exceeding 0.1g. The largest proportion of instrumentation should be located in area with the

highest population exposure to potentially damaging levels of motion. In the coterminous US the areas with the largest population exposure are the San Francisco Bay region and the Los Angeles region.

11. *In view of the vigor of the California Strong Motion Program, what should be the role and objectives of the USGS program in California?*

    The USGS earthquake measurement program in California conducted under the EHRP should provide recordings of the next main shock at locations of significance for public safety. It should continue to emphasize special structures, Federal buildings and lifelines, sophisticated borehole arrays and SSI experiments, and extensive ground motion arrays that are complementary to the State program. A major increase in instrumentation is needed to ensure that the next major chock in California is adequately recorded at the proper locations.

12. *Should the USGS restrict its support of strong motion instruments in California to those that comprise localized arrays designed to address specific issues?*

    No. The USGS has responsibilty to integrate strong-motion montoring efforts of Federal agencies and contribute to the EHRP through its earthquake monitoring efforts. No other monitoring effort in the USGS provides on-scale measurements of the main shock at noisy urban locations of significance for public safety.

13. *Should all other USGS instruments be turned over to CSMP to operate?*

    No. The state program does not have sufficient resources to to assume responsibility for the stations and can not assume responsibility for some types of stations. The urgent need to adequately record the next major earthquake requires a level of resources much greater than currently available in both programs combined.

14. *I understand the USGS instruments unusual building in California while the State instruments typical buildings. Does this relegate us to a role of secondary importance in terms of contributing to the reduction of losses?*

    No. Resources of both programs are needed.

15. *What fraction of the program effort should be expended in California? In other western states? In Alaska? In eastern states?*

    The analyses summarized in Table 1 and Figure 1 of the Vision Document suggests that approximately 72 % in California, about 3% in Alaska, and 1% in New York.

16. *Can the operational costs of maintaining the network be reduced?*

    Conversion of analog stations to digital stations could reduce maintenance visits to only those times that instrumentaion was known to be inoperable.

17. *What should be the policy with respect to instrumentation? Should analog instruments be replaced by new digital instruments? Or, should new digital instruments be used to augment (expand or densify) the existing network?*

    A combination is most appropriate. Analog stations for which a high data return is expected in areas with a high population exposure should be converted to digital first. Instrumentation plans should be developed based on detailed GIS inventories as shown in Figures 2 and 3 of the Vision document.

18. *What is the long-term plan and timetable for processing old records? How many are of such significance that they should be processed?*

In general, the strategy is to digitize all analog records with peak amplitudes sufficient to be of use in defining empirical attenuation curves, which are the basis of codes for earthquake resistant design and construction. In general, recordings with peak amplitudes greater than about 0.05-0.08g are useful for such purposes.

19. *What is the strategy for integrating the strong motion network into the National Seismic System? Interface of NSMP with other Networks (National Seismic System).*

The national seismic system as presently configured is comprised of regional and national seismic networks. These networks record "weak-motion" information at quiet locations remote from noisy urban environments via continuous telemetry primarily for the Earth Science community. The NSMP records strong-motion information from the main shock at noisy locations near man-made structures in urban environments with on-site recorders primarily for the earthquake-engineering community. These differences need to be respected in order to ensure that the earthquake measurement needs of society are met. The interface between the NSMP and the regional and national seimic networks should occur as it has in the TriNet effort. Integrety of the objectives, needs, and operational responsibilities of each program must be maintained with data from each program being shared and provided via a "Virtual" Data Center as quickly as possible.

Response of M. Çelebi

Before any discussions are made, the management and the USGS community should reach a consensus on general principles for the NSMP. A list of suggested general principles can be as follows::

- USGS-NSMP is and should be a nationally active unit within the earthquake hazards Team of USGS.
- Objective should be that we should project for instrumentation throughout the conterminous US, Alaska, Hawaii and Puerto Rico to record all events of M>5.
- USGS-NSMP should aim to make the most relevant data available in usable format within 30 days following an event.
- USGS-NSMP should reduce the backlog of analog film records that have not been digitized to zero by 1999.
- USGS-NSMP network should be upgraded to digital equipment capable of recording near real-time and/or real-time by 2002.
- USGS-NSMP complement ground stations with structural systems instrumented.
- Structural instrumentation should be achieved on an agreed, programmatic basis. Special instrumentation schemes should be fully discussed among interested parties within and outside USGS.
- USGS-NSMP should vigorously pursue instrumentation of federal buildings. A recent OFR 97-452 addresses this issue and is currently being discussed by federal agencies.
- USGS-NSMP operations unit should coordinate all USGS strong-motion deployment, maintenance, data retrieval activities. Regionalization of such activities is detrimental to in-house communication and data management that follows.
- Processing and dissemination of strong-motion data should be done by USGS-NSMP Data Center.
- USGS-NSMP should promote cooperative efforts.

- Work to more closely integrate waveform data with regional and national data centers.

Now answers to some of the questions:

What are the most critical problems to be addressed by the program?

1 First and foremost, the most critical problems to be addressed by the program are organizational.

National Activity and Coordination: USGS-NSMP is and should be a nationally active and coordinated unit within the Earthquake Hazards Program of USGS. The foundation of NSMP should be based on a nationally coordinated effort based on priorities related to enhancing public safety, scientific and engineering needs, and fiscal responsibility. Currently, there is no coordinated effort. Regional activities, although plausible in many ways, is detrimental to the establishment of a coordinated program. **Solution: An internal regional oversight committee should be formed to coordinate the activities**. USGS-NSMP operations unit should coordinate all USGS strong-motion deployment, maintenance, data retrieval activities. Regionalization of such activities is detrimental to in-house communication and data management that follows. **Today, both USGS community and those outside praises the CDMG effort. The reason why CDMG effort has the visibility that it has are two: (a) constant and dependable budget, and (b) coordination by its Sacramento center only. (e.g. there is no San Francisco County, Los Angeles County or Sonoma County – CDMG office deployment or data dissemination).**

Distinctive Objective: The main objective of the NSMP should be to obtain on-scale ground motion and structural response data throughout the conterminous US, Alaska, Hawaii and Puerto Rico from all events that are M>5. The areas that are capable of generating M>5 earthquakes are well known. Strong motion deployments should be achieved with this in mind. Currently, some of the activities are very broad based more on an individual scientists interest than the actual need. Funds that are scarce are being spent the way an individual desires rather than to meet the overall goal and objective. **Solution: (a) Establish clear guidelines on deployment activities and how funds can be spent and (b) Organize frequent and detailed action item meetings between management, NSMP and USGS scientists and engineers.**

Data Management and Dissemination: USGS-NSMP should aim to make the most relevant data available in usable format within a timely schedule (e.g. within30 days following an event). **Solution: Establish (as is being done) a dynamic data center management within the NSMP that will respond to the needs of engineering and scientific community**. *This is one reason why regional activities are detrimental because data from USGS should not be released from different locations and/or regions. They should be released by USGS-NSMP Data Center after quality processing is achieved.*

Solve the everlasting data backlog problem: USGS-NSMP should reduce the backlog of undigitized analog film records to zero by 1999. There has been positive movements towards this in the last year.

Old Equipment should be upgraded: USGS-NSMP network should be upgraded to digital equipment capable of recording near real-time and/or real-time by 2002. Two incentives are: **(a) rapid dissemination of data will enhance public safety and property, and (b) future digitization costs will be eliminated**.

2. **Second, the most critical problem is the Requisite Budget**: Without a rational budget, USGS-NSMP will always be an orphan. The budget for a viable, visible, effective and

coordinated program should be proportionate. Without going into the old stories related to NSF transfer of the Program to USGS etc, the simple question to ask is: "What is the CDMG-CSMIP Program annual budget for State of California only?." A national program should have deservedly relevant budget. Therefore, we should try to optimize the available funds by eliminating uncoordinated and unmonitored regional efforts. In addition we ought to raise external funding by cooperative efforts (e.g. TRI-NET etc). For structural instrumentation, the recent initiative prepared to instrument federally owned/leased structures is a step (detailed later).

Where are the best locations in which to pursue these problems?

Internal USGS Consensus: The USGS Earthquake Hazard Program Council, Management and NSMP should come to terms with accepting a nationally coordinated rather than regional program. The national program should be equipped with rational budget to pursue the objectives of the NSMP by concentrating efforts in (a) urban areas of all States that has the highest seismic risk (Frankel/Leyendecker maps or Seismic Areas 3 and 4 in the UBC Maps), (b) near faults that are capable of generating M>7 earthquakes. These efforts should be both for ground motion recording and structural response recording.

Is the current strong motion network suitably deployed to address these problems?

NO

If not, what changes should be made?

Should recordings of strong shaking close to the fault in earthquakeslarger than M 7.5 or 8.0 be a high priority of the program? If so, what isthe strategy to obtain such records?

Yes. It should be high priority. Deploy special purpose arrays after identifying the faults.

If funds for acquiring the hardware are available, USGS-NSMP should do this and it will provide visibility and credibility to the program.

What are the priorities for documenting nonlinear soil response, soil-structure interaction, and basin effects? Should such problems be addressed within the context of current NSMP resources? If so, how and where?

1. ***Soil-structure Interaction planning and implementation is well underway:*** Soil-structure interaction experiment has been proposed by the earthquake engineering personnel in 1987. Since then, based on recommendations of the regional funding groups, a workshop amongst nationally well know experts was held in 1992 to develop the parameters for such an experiment (USGS OFR 92-295). One of the relevant issues is the measurements below and around the periphery of the foundation of the building – thus requiring deployment on a building yet to be constructed. Currently, we are in the mode to select a project at a suitable site condition. Currently, approximately 80 % of the requisite hardware has been purchased (through funding of proposals during each of the years since 1992 and also through funding received from add-on Northridge funds).

What are the priorities in the context of the modest funding currently

available to the program? Which of these problems can be addressed in

partnership with other agencies and private entities?

Structural Instrumentation: This component of the NSMP has never had a direct budget to date. Significant part of the expenditures has been through creative financing and cooperative efforts with VA and now GSA. We are currently making efforts to broaden the cooperative

programs with an initiative to instrument federally owned/leased buildings(USGS OFR 97-452). Because instrumenting a structure is an expensive effort, an agreed upon program is necessary. **Special instrumentation schemes should be fully discussed among interested parties within and outside USGS** (as was done in the case of SSI experiment). Unfortunately, sometimes, "grab the money and do your thing" sickness has been adopted by some . We need to prevent such attempts in the future so as to optimize the scarce funds.

What should be the balance of focus between free-field instruments and instruments in structures?

Structural instrumentation in urban areas is a must. Ground motion instrumentation and structural instrumentation should be complementary. Whenever physically feasible, all instrumented structures should have associated free-field deployments.

Does the USGS recover the full costs of maintaining strong-motion recorders for other Federal agencies? If not, is continued operation of these instruments in the long-term interests of the program?

RON PORCELLA's SHOP

In view of the vigor of the California Strong Motion Program, what should be the role and objectives of the USGS program in California? Should the USGS restrict its support of strong motion instruments in California to those that comprise localized arrays designed to address specific issues?

Should all other USGS instruments be turned over to CSMP to operate? I understand the USGS instruments unusual building in California while the State instruments typical buildings. Does this relegate us to a role of secondary importance in terms of contributing to the reduction of losses?

Absolutely NO. This would be an adimission that USGS has not cared for the program and is therefore getting rid of it. Instead, let us try to cure the problems.

Can the operational costs of maintaining the network be reduced?

Ron Porcella's shop.

What should be the policy with respect to instrumentation? Should analog instruments be replaced by new digital instruments? Or, should new digital instruments be used to augment (expand or densify) the existing network?

All anolog instrument should be phased out. The sooner, the better. It is ultimately cost saving to replace all analog instruments with digital ones since it will sabve a lot of digitizing efforts and funds.

BENEFITS:

Attenuation curves

Assessment of displacements for evaluation of structural damage or collapse (Record from free-field station associated with Pacific Park Plaza Building in Emeryville was used to evaluate the amount of relative displacement between Yerba Buena Islan [rock] and east basy [soft soil[).

Seismic Code base shear coefficients have been revised as a result of data retrieved from earthquakes since 1933. With more data retrieved in subsequent years, the larger peak accelerations experienced resulted in increased design base shear coefficients.

Site Coefficients in UBC were introduced in 1976 and revised later due to the site amplifications observed during earthquakes.

Empirical "building period formulas" have been incorporated into the building codes and revisions have followed as a result of analyses of structural response data acquired from instrumented buildings.

In the 1991 UBC revision, the requirement for the restraints of flexible diaphragms were increased by 50 % because of the excessive deformations observed from recorded responses of instrumented buildings with diaphragms.

Several studies of records from instrumented structures identify the significance of (a) drift assessment and change of stiffness, (b) significance of SSI and (c) deficiencies in development of site specific design response spectra, (e) deficiencies in identifying resonating site frequencies.

Response of W. Joyner

1. What are the most critical problems to be addressed by the program?

In order of priority they are:

a. Defining the ground motion at distances of 0-5 km from an earthquake of moment magnitude greater than 7.0 for various site conditions.

b. Determining the relationship between ground motion and damage for various structural systems.

c. Determining the nature and amount of nonlinear soil response from ground motion measurements, to avoid reliance on questionable inferences from laboratory measurements.

d. Obtain measurements of strong ground motion in regions of moderate to low seismicity where few measurements now exist, such as eastern North America.

2. What are the best locations to pursue these problems?

For (a) the best locations are within 5 km of faults with a significant probability of a moment magnitude 7.0 or greater earthquake in the next 50 years. A list of such faults could readily be obtained for a specified probability level from the fault data used by Art Frankel in making the National Ground Motion Maps. The list would include such faults as the Imperial, San Jacinto, Elsinore(?), San Andreas, Garlock(?), Hayward, Rogers Creek-Healdsburg, and Maacama(?). The best locations for problem (b) are those with both a high density of structures and a high probability of significant levels of ground motion. Roger Borcherdt has made maps showing the best locations based on population data combined with probabilistic ground-motion data from the National Maps. The best locations for (c) are sites with a variety of material types within areas of high probability for significant ground motion. These locations can be found from a superposition of geologic maps and probabilistic ground-motion maps. The best locations for (d) are sites within the regions of interest with relatively high probabilities of significant ground motion. Such locations can be found from probabilistic ground-motion maps.

3. Is the current strong-motion network suitably deployed to address these problems? If not, what changes should be made?

The current network has changed very little in the last 20 years, a simple consequence of the fact that the Program has been starved for funding and manpower and that it is almost as expensive to move a station as to install a new one. Under the circumstances the current network addresses the problems remarkably well. Changes are needed, however. The highest priority is to examine the existing network within 5 km of faults likely to produce magnitude 7+ earthquakes, and, in cooperation with the California Strong Motion Instrumentation Program, add stations where necessary to assure a sufficient number of records from sites representing a variety of site conditions. The second priority is to add stations for determining the relationship between ground motion and building damage. Along with these priorities it is necessary to move forward to replace existing analog instruments with digital ones to help reduce the operational costs of the network.

4. Should recordings of strong shaking close to the fault in earthquakes larger than m 7.5 or 8.0 be a high priority of the program? If so, what is the strategy to obtain such records?

Absolutely, they should be the highest priority. The strategy is outlined in the answers to questions 2 and 3.

5. What are the priorities for documenting nonlinear soil response, soil-structure interaction, and basin effects? Should such problems be addressed within the context of current NSMP

resources? If so, how and where?

The priorities among the three items are, in my view, in the order listed. Within current NSMP resources nonlinear soil response is addressed by the existing network, as long as resouces are available after earthquakes to document site conditions at sites where strong-motion records have been obtained. A soil-structure-interaction experiment has already been planned and is being implemented. Much can be done on basin effects using existing records and future records from stations now existing.

6. What are the priorities in the context of the modest funding currently available to the program? Which of these problems can be addressed in partnership with other agencies?

In my view, the top priorities in the context of current funding are the same as in the context of greater funding. They are listed in the answer to question 1. Items (a) through (c) should be pursued in close cooperation with the California Strong Motion Instrumentation Program. Items (b) and (d) can be pursued in cooperation with FEMA and other Federal agencies through the instrumentation of Federal buildings and other facilities, and item (b) might be pursued in cooperation with private building owners.

7. What should be the balance of focus between free-field instruments and instruments in structures?

In my view, both are needed to provide the basis for the earthquake-resistant design of structures. For the Geological Survey the first priority should be free-field ground motion.

8. Does the USGS recover the full costs of maintaining strong-motion recorders for other Federal agencies? If not, is continued operation of these instruments in the long-term interests of the program?

I will let Ron Porcella answer the first question. If the answer is no, then perhaps we should renegotiate our maintenance agreements. Discontinuing our cooperative arrangements with other agencies, however, is a step we should not take without careful consideration. If the

USGS won't assist other Federal agencies with their earth-science-related problems, it forfeits some of its reason for existence. Some of the instruments in cooperative programs, furthermore, contribute to priorities (b) and (d) in the answer to question 1.

9. What is the proper geographical balance of effort in the program in terms of impact on loss reduction?

The strategies described in the answers to questions 2 and 3 will automatically determine the geographical balance. Unavoidably it will mean a heavy emphasis on California. The place to measure strong ground motion is where it occurs.

10. In view of the vigor of the California Strong Motion Program, what should be the role and objectives of the USGS program in California? Should the USGS restrict its support of strong motion instruments in California to those that comprise localized arrays designed to address specific issues? Should all other USGS instruments be turned over to CSMP to operate? I understand the USGS instruments unusual buildings in California while the State instruments typical buildings. Does this relegate us to a role of secondary importance in terms of contributing to the reduction of losses?

Close cooperation between the NSMP and CSMIP is very important to the attaining the objectives of both agencies. A beginning of such cooperation is taking place with the TRINET and "TRINET NORTH" projects. In my view, the USGS should be content to let CSMIP play the primary role in California. Without regret, actually. There is more to be done than the resources of both programs can manage. Any station that CSMIP installs frees the USGS to devote an instrument to a different problem. If, however, the USGS believes that the CSMIP instrumentation is not adequate to solve an important problem, it should be free to augment that instrumentation. I do not believe that CSMIP could (or would if it could) take over maintenance of all the USGS instruments in California. The USGS is in a better position to use instrumentation of Federal buildings as a strategy for increasing the number of instruments that could help with the problem of relating ground motion to building damage. I believe that the agreement that CSMIP instruments typical buildings and the USGS instruments unusual buildings is a very sensible arrangement, with the advantage to the USGS that our results are of more interest to our prime constituency, the structural engineers. A couple more comments off the record concerning the USGS program in California. Without instruments in California the people responsible for USGS strong-motion instruments in the rest of the country would go for years without obtaining any strong-motion records. I doubt their effectiveness under those circumstances. What are the political consequences when a major earthquake occurs and CSMIP collects hundreds of strong-motion records and the USGS collects none? By its poor support of the strong-motion program the USGS has already forfeited much of the good will it had in the structural engineering community. Lets not give up what remains.

11. What fraction of the program effort should be expended in California? In other western states? In Alaska? In eastern states?

The strategies described in the answers to questions 2 and 3 will provide the answer for the western states (see the answer to question 9). The result will be a significant fraction for

California and perhaps Alaska, though the higher costs of operations in Alaska must be figured in. The eastern states require some special consideration because of their large population and the very limited data that have been recorded there. Since it is clear that ground motion is different in the East, some effort there is essential, but, because of the much lower earthquake probability, the fraction of the total effort there must be limited.

12. Can the operational costs of maintaining the network be reduced?

Ron Porcella should really answer this question, but I should say that my answers to other questions are based on the assumption that replacing analog instruments by modern digital instruments with dial-up will reduce costs.

13. What should be the priority with respect to instrumentation? Should analogue instruments be replaced by new digital instruments? Or, should new digital instruments be used to augment (expand or densify) the existing network?

Both (see the answer to question 3). The highest priority should be to augment the existing networks as needed within 5 km of faults likely to produce magnitude 7+ earthquakes. After that funding for new instrumentation should be divided between new sites chosen for determining the relationship between ground motion and building damage and upgrading sites now occupied by analog instruments

14. What is the long-term plan and timetable for processing old records?

We need to distinguish between digitizing and processing. Digitizing is by far the greater problem. Because of the huge backlog and the shortage of manpower inhouse it will be necessary to contract for digitizing much of the backlog. We now have a digital database listing all records and specifying which are digitized and which are processed. We will prioritize the list and digitize as many as available funding permits. As soon as the quality of the digitized records has been assured they will be put on our website uncorrected and will be available to anyone by ftp. As soon as possible the processed records will also be posted on the website. Chris Stephens should answer the question about timescale.

15. How many are of such significance that they should be processed?

Chris Stephens has the data base and I will let him give the definitive answer. There are hundreds of records that should be digitized and processed. The exact number is highly sensitive to the cutoff criteria, which are necessarily a bit arbitrary. The key is to digitize and process according to a reasonable priority scheme.

16. What is the strategy for integrating the strong motion network into the National Seismic System?

Data from the strong-motion network will be freely available to anyone and network personnel are prepared to cooperate with others in the maintenance of instruments and the collection of data. Stations in the regional networks or the National Network, however, are not, in general, located at sites likely to produce significant strong-motion data.

Response of A. Frankel

Some answers to some of Page's questions concerning USGS strong-motion instrumentation program (not in any order) - Art Frankel

I think the highest priority is to replace all the analog instuments with digital recorders. The central mission of this program should be to have strong-motion data available on the Internet as soon as possible after a significant event. This necessitates having digital instruments.

Critical problems: 1) Better understanding and description of site effects, including: nonlinearity, correlation with geologic unit and Vs, spatial variability, and basin effects. The goal here is to better predict site effects in urban areas for future large earthquakes.

2) Better understanding and description of source excitation of strong-ground motion for large earthquakes (M> 7). 3) Better description of ground motion as function of magnitude and distance for Central and Eastern U.S. earthquakes (M>5.0).

I think there needs to be an emphasis on densifying our strong-motion network in high-risk urban areas such as Los Angeles region, San Francisco-San Jose-Oakland, Seattle, Portland, Salt Lake City, and Reno. Such urban sites should also have weak-motion sensors and be linked into traditional high-gain seismic networks. They should span a variety of site conditions and distances from major faults.

Also more strong-motion instruments should be put in areas of the CEUS with relatively high hazard, such as New Madrid, Charleston, eastern Tennessee, and the northeast. These would be situated near the expected sources, not necessarily in urban areas.

In California, I think the USGS should concentrate on dense deployments in high-risk urban areas. Also, if we have weak-motion sensors in addition to FBA's, we can provide ground motion info realtime for moderate-sized events, which can improve our public visibility between the occurrence of large events, educate the public on seismic hazards, and provide important scientific information on site response and basin effects. We should also concentrate on deploying free-field instruments around instrumented structures, to look at soil-structure interaction and building reponse/damage.

Response of R. Porcella

1. Most critical NSMP problems to be addressed?

a. The number 1 problem to be addressed is the NSMP's lack of national recognition among both the engineering and seismological communities, a situation brought about by many years of invisibility-- primarily due to neglect and a lack of financial support by the USGS Earthquake Program. The NSMP and strong-motion networks in general, possess little credibility in the eyes of the seismological community. The main reason, in my opinion, is because of an ignorance of and lack of appreciation for legitimate, inescapable differences in both the immediate objectives and long-term requirements for successful operation of weak- versus strong-motion recording. Fundamental differences include instrumentation parameters, recording site conditions, installation and housing logistics, data usefulness and rate of return, and record processing and dissemination obligations. Nothing of substance will change unless the Geological Survey makes a substantial effort to address these fundamental differences, and then DEAL WITH THEM in an unbiased manner consistent with the explicit, long-standing goals and responsibilities of the NEHRP.

b. Many regional networks have already begun to purchase FBA's, which they will deploy as "strong-motion instrumentation" for early warning and response; but these sensors will, I believe, after the next major earthquake, have contributed **little or nothing** to urban hazard mitigation. The USGS must act quickly if it is to redirect this uncoordinated, inefficient, and ultimately costly and divisive regionalization of seismic recording efforts in this country. Although I think these networks must necessarily continue to operate with a high level of autonomy, I would point out that there does exist significant opportunity for cooperation. For example, there are a number of "quiet" NSMP (and CSMIP) stations instrumented with real-time digital accelerographs that might be (and, in a several cases are already being) utilized by regional seismic networks in California. During the next 5 years at least 100 additional NSMP real-time strong-motion stations could be made available to regional seismic networks throughout the U.S. (at the current funding level).

c. TriNet has effectively demonstrated that there is ample opportunity for cooperation between several diverse networks operating in southern California. The TriNet project recognizes the equally important roles that weak- and strong-motion networks play in their efforts to bring about meaningful reduction of earthquake hazard in the southern California region. Many problems related to these differences have already been solved; TriNet should be used as a model for all regional and national network upgrade efforts supported by USGS.

Once these highly divisive issues have been resolved, we can move on to solving the logistical problems of operating ONE NATIONAL STRONG-MOTION PROGRAM. Strong, sound leadership, both at the Agency and Program levels, is key. The USGS must provide the Program with a national mandate, with clear and precise goals; the Program must assemble reasonable short-term objectives for acquiring the data needed to solve the multitude of earthquake engineering and strong-ground motion problems facing an extensive and diverse community of strong-motion researchers. Only a NATIONAL program will assure a geographically vigorous effort in the acquisition of strong ground motion data for use by scientists and engineers working in all seismic regions of the U.S. Once these political and logistical issues have been put to rest, we can move on to the really interesting issues of how to address problems such as monitoring the response of engineered structures, characterizing strong ground motion in the urban environment; documenting site response, measuring soil-structure interaction, etc., etc.

2. The best locations to pursue these problems?

Specialized arrays along and normal to faults already instrumented; such arrays desperately need to be upgraded and enhanced, particularly outside California. We need more ground sites in major eastern U.S. cities.

3. Is current Network suitably deployed/ any changes?

Overall, the Network is reasonably well placed, considering its size (850 recorders at 550 sites in 33 states and the Caribbean). The truly ideal network-- needed to solve most of the above-mentioned (ques. 1) problems-- does not appear to be economically feasible in the current economic environment. I recommend, for now, smaller, yet more comprehensive specialized arrays that can help solve a wide variety of current engineering and strong-ground motion issues; these arrays should be located in all seismic regions of the country. Obviously, the arrays must be weighted toward the more seismically (not politically) active regions; but we cannot miss an opportunity to acquire meaningful data from ANY large U.S. earthquake

4. Should close-in recordings of large earthquakes be high priority/ strategy?

Close in recordings have always been an NSMP high priority; strategy has been to establish the specialized arrays mentioned above.

5. Discuss priority for documenting soil response, soil-structure interaction, basin effects/ within NSMP/ how/ where?

Of the three, I believe soil-structure interaction should be the highest NSMP priority, as it was nearly 20 years ago when Fritz Matthiesen hired Noel Bycroft to specifically address that problem. Because Noel was never replaced, one can only assume this problem is now a low USGS priority. My second priority would be documenting non-linear soil response, though I believe data from the current network can equally be used to investigate all three problems. A few more specialized arrays to augment data for studies of soil-structure interaction and soil response is doable and would

be appropriate work for NSMP. Some permanent stations might be established/relocated to optimize basin-effects arrays in cooperation with the regional seismic networks.

6. Can these be addressed in partnership with other agencies?

Top two priorities in (5) and all structure/foundation-related problems might be accomplished in concert with current reimbursable agencies , including the VA, Corps of Engineers, and Metro. Water District of southern California. New agreements with GSA, NASA (see Celebi comments), and others might be tailored to better meet NSMP needs than has been achieved in the past.

7. What is balance between ground sites and structure instrumentation?

There is no formula. New engineering and ground motion problems seem to arise after each subsequent damaging event; thus, the urgency is highly variable, and therein lies the priorities. My gut observation is that, over the past 25 years, the ground motion vs. structural efforts (in terms of dollars and people-power spent), are probably running at about 60-40.

8. Does USGS recover full costs from the reimbursable program?

The numbers are highly classified! Reimbursable income, however, amounts to more than double the Network's total annual OE. And although the network OE barely covers the total network maintenance costs, the cost to maintain the reimbursable portion of the network is only about one fourth of the USGS portion (no. of stations). And, I would like to point out, the current digital-upgrade effort involving exclusively USGS-owned instrumentation is being funded entirely with reimbursable income (very highly classified!).

Economics aside, the USGS cannot expect to play a key leadership role in promoting earthquake hazard mitigation efforts without a willingness-- no, an eagerness-- to fully cooperate and consult with others, particularly those agencies at all levels of government, academic institutions, and various private consulting companies and organizations worldwide that are currently putting forth serious effort to help solve seismic-engineering-related problems. USGS dollars alone will not make us a leader in the worlds of science and engineering.

9. What is proper geographical balance in terms of impact on loss reduction?

Anywhere we can reasonably expect to obtain strong-motion data in the next 30-50 years is fair game. There are no political boundaries within the U.S., only seismic boundaries. While urban sites are politically correct and are obviously needed for most engineering studies, relevant strong ground motion data can often be collected in various geologic regimes, irregardless of population centers; site conditions and frequency of strong shaking are key.

10. In view of the CSMIP program, what role should NSMP have in Calif/ Localized arrays/ Specific issues/ Turn over all other USGS instruments?

The NSMP role in California has been a supplementary one to CSMIP since the late 70's. NSMP cannot hope to be a National player, or for that matter even survive, without maintaining a significant role in California; we know this and CSMIP knows it. This is why NSMP has long worked with CSMIP to coordinate operation of both ground motion and structure response instrumentation. We long-ago realized that the combined resources of all strong-motion operators in California could never approach that which is needed to truly characterize strong-shaking in this geographically diverse, highly seismic, and most-populated state. There are plenty of ground sites and buildings for everyone; cooperation has been key, communication remains a must. Since the late 70's, new NSMP projects in California have generally involved specific problems related to

strong ground motion, site response, soil-structure interaction, or structural response, including base isolation.

11. Does instrumenting atypical structures in Calif. relegate NSMP to a secondary role in terms of its urban loss reduction efforts?

See Mehmet's response. My feeling is that atypical structures are also occupied by people; the damage to atypical structures, and there are many out there, can be just as spectacular and devastating as to typical structures. Both types must be instrumented if we are to provide engineers with design/performance data.

12. What fraction of NSMP efforts should be expended in Calif/ western states/ east/ Alaska/etc? Can operational costs be reduced?

See (2) - (3) above. It is somewhat important that the NSMP mirror the regional networks efforts--they largely mirror seismic activity levels. More importantly, NSMP must allocate its funds and effort on the basis of national need. However, the NSMP must make every effort to work cooperatively with the local seismic network when installing/operating realtime instrumentation within any given region. Five-year plans for specific regions (current funding level), have been developed and are available at the NSMP web site.

13. Should digital instrumentation replace analog/ supplement analog?

The current plan is to replace analog stations in the most seismically active regions with new digital stations; analog instruments are then refurbished (outside contractor), and relocated to new sites in lower seismicity regions with little or no strong-motion instrumentation. A more poignant question would be "how long can we keep this upgrade effort going without acquiring additional help?"

14. Long-term plan for processing records/ how many should be processed?

Defer to Chris, others. But-- a quality strong-motion program should be measured by the quality of strong-motion recordings, not by merely the quantity of seismic data...

15. What is the strategy for integrating NSMP into the NSS?

NSMP must be integrated into the NSS with the same considerations given to NSN, the regional nets, or any others: while each entity must have some control over its territories/functions/data, the good of the NSS is paramount. The current attitude of CNSS is disheartening. All past prejudice must be overcome; the success of the NSMP is as critical to the success of the USGS earthquake program as is any other element, and more so than many. I believe it is imperative that the NSMP have a full seat on the CNSS. The NSMP, and thus the USGS, absolutely must take the reigns of leadership in order to achieve the trust of the engineering community and the respect of the seismological community in those matters related to studies of earthquake engineering and strong ground motion. It is crucial that the USGS be recognized as the national leader of earthquake hazard mitigation efforts in the United States; it must, in concert with the CNSS, assure continuous communication and coordination between the NSMP and both the National Seismic Network and all USGS-supported regional seismic networks across this country.

Again, LEADERSHIP is KEY.

APPENDIX B

"NSMP WORKING GROUP" RECOMMENDATIONS FOR THE NATIONAL STRONG MOTION PROGRAM

Members – B. Bolt, **Chair**, *C.B. Crouse,* **Reporter**, *N. Abrahamson, C. Rojahn, D. O'Connell, P. Somerville.*

USGS Liaison Members – R. Borcherdt, M. Celebi, A. McGarr, W. Mooney, J. Mori.

1. **Enhance the capability for the collection, processing and dissemination of strong-motion accelerogram data from significant earthquakes.**
   - The USGS should strive toward a goal of disseminating strong motion data within months (in the case of analog records) or days (in the case of digital telemetered records) after a major earthquake.
   - Because approximately 90% of the USGS accelerograph network consists of analog instruments, the USGS should establish an aggressive schedule for replacing these instruments with digital accelerographs with remote (telemetry) access capability. Priority for this replacement should be given to urban areas in California where the likelihood of a moderate to large earthquake is relatively high. The analog instruments should be redeployed to other areas if feasible.
   - The USGS should acquire proper hardware to process analog accelerograms and not rely on outside vendors for this task.
2. **Increase instrumentation in regions of moderate to high seismicity outside California so that strong motions from all magnitude 6 or greater earthquakes will be recorded.**
   - The USGS should give priority to urban areas in implementing this recommendation.
   - An executive order requiring all new federal buildings to be instrumented with a minimum number of accelerographs (e.g. 3) should be pursued. This order might apply to those areas where the ground-motion hazard, as mapped by the USGS, exceeds a specified threshold. Cooperative arrangements with other U.S. government agencies should be sought to assist in carrying out the order.
3. **Convert old analog data to digital or electronic format.**
   - The USGS has compiled useful data on seismic hazards throughout the U.S. during the NEHRP program. Examples of these data include maps of liquefaction and landslide hazards in urban areas. Also, written observations of damage and felt reports, collected by the USGS through surveys following major earthquakes, may be useful in calibrating loss estimation algorithms. These analog data should be converted to electronic format.
4. **Establish an Advisory Board to assist the USGS in the planning and implementation of the NSMP.**
   - Model the concept after the State of California strong motion instrumentation program (CSMIP) which has several panels of experts that advise the CSMIP.