EARTHQUAKE

HEARINGS

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY

OF THE

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EARTHQUAKE

TUESDAY, JUNE 22, 1976

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
Washington, D.C.

The subcommittee met, pursuant to notice, at 9 a.m., in room 2318, Rayburn House Office Building, Hon. James W. Symington (chairman of the subcommittee) presiding.

Mr. SYMINGTON. Good morning, everybody. I am happy to have you here bright and early.

Today the subcommittee begins 3 days of hearings into earthquakes. The purpose of the Subcommittee on Science, Research and Technology in holding these hearings is to gather information to help determine what legislation might be desirable in the area of earthquake hazard reduction. We are going to hear that phrase "earthquake hazard reduction" frequently in the next few days, so let me explain: "earthquake hazard reduction," means reducing by any available methods the harm done by earthquakes. The methods under consideration for earthquake hazard reduction cover a broad range, including, for example, constructing earthquake-resistant buildings, preparing earthquake emergency plans, and preventing major earthquakes from occurring at all.

Before I call the first witness this morning I would like to describe some of the events which have led to these hearings and to pose the questions we believe to be important to investigate.

In the past 12 years the United States has suffered two major earthquakes—in Alaska during 1964 and in San Fernando, Calif. during 1971. Each of these caused about half a billion dollars damage. The United States may expect to be subjected to equally intense earthquakes in the future. Even now there is in California what geologists call an uplift—a vast area of land raised 25 centimeters or so above its normal elevation—which many believe to be the precursor of a severe earthquake. Indeed, based on the evidence of the uplift and other factors, an earthquake has been predicted in California by a seismologist at the California Institute of Technology. The science of earthquake prediction has not yet progressed far beyond an art, and there are scientific disputes over the meaning and validity of evidence thought by some to indicate a future earthquake. In the present instance, a council of experts evaluated evidence for an earthquake in the California uplift area and reported "The council did not conclude that the probability of an earthquake in the area in question is significantly higher than the average for similar geologic areas of California." This subcommittee has no intention to judge that particular

dispute, but the situation is richly illustrative of the current state of earthquake prediction. Not only are there elements of technical dispute in that situation; there are also social elements of interest.

The comparative experience of foreign counties shows the critical importance of the social element. We might contrast events in China and Italy. The Chinese, it is reported, embarked on a major effort in earthquake prediction and preparedness following a destructive earthquake in 1966. By 1975 the Chinese system had developed to the point where an earthquake warning led to the evacuation of over a million people to the outdoors, and the probable saving of tens of thousands of lives when a destructive earthquake occurred as predicted. In Italy, according to the Washington Post, an Italian seismologist, Raffaele Benandi, published an article in 1975 predicting a major quake in Northern Italy. There was no program to evaluate the prediction or to take action if it had been evaluated, and there was no significant reaction to the prediction in the press or other media. On Thursday, May 6, Northern Italy was hit unprepared by a major quake and hundreds were killed. Now, I suspect that the Chinese are more accustomed to being regimented than the Italians, and this may explain part of the difference. It seems likely to me, however, that the difference in Government policy was critical.

Our purpose is to determine what Government policy should be in the United States. The Senate has already passed S. 1174, entitled the "Earthquake Hazard Reduction Act." That is Senator Alan Cranston's bill, as amended. Several bills have been introduced in the House of Representatives toward the same end. My colleagues John Burton, Alphonzo Bell, and Charles Mosher are responsible for the introduction of those bills. The executive branch has not ignored the area either. There are continuing efforts against earthquakes in several agencies and a recent initiative to plan for earthquake research in the near future has been spearheaded by Guy Stever acting as the President's science adviser.

We plan to address five rather broad questions during these hearings. These are:

1. What is being done now by Federal and State agencies to assure general earthquake preparedness, to predict or modify earthquakes, to protect lives and property if a prediction is made, to render post-earthquake assistance, or to take other actions for earthquake hazard reduction?

2. What is the current state of earthquake prediction and modification, and what is the likely future development of these areas? What are the costs of development likely to be?

3. What can be done to reduce the damage done by earthquakes, and what are the costs of taking these actions? This question is meant to be broadly construed, and under it we hope to investigate such areas as building design, planning, insurance, evacuation, and so forth.

4. How can the earthquake hazard reduction efforts of various parties be coordinated?

5. How well do the pending bills, S. 1174, H.R. 13722, and H.R. 13845 meet the Nation's needs in earthquake hazard reduction? We hope to identify the virtues and deficiencies of each bill.

The subcommittee has assembled a group of witnesses of high competence to address these questions. In the next 3 days we shall hear

from two Senators and Congressman John Burton, from representatives of four Federal agencies with the President's science advisor as the first of those representatives, from the academic leaders in earthquake research and research of human behavior related to earthquakes, and from representatives of State agencies.

Several of the witnesses have been to China and Russia to study their earthquake prediction efforts. The chairman of the National Academy of Sciences Panel on Earthquake Prediction will appear, as will the Cal Tech seismologist who predicts an earthquake in California.

I expect to hear much fascinating testimony this week and I look forward to it.

Speaking of uplift in California, I always thought that referred to the work done by my colleague, George Brown. I would like to recognize him at this point.

Mr. BROWN. Thank you, Mr. Chairman.

I do not have a prepared statement. However, I do wish to point out the great importance to California of this legislation. I am sure the witnesses from California will testify to the same point. California has long been noted as a State subject to frequent and generally severe earthquakes. And there is great concern about being able to alleviate this situation in some fashion or another. It is no coincidence that our distinguished Senator has offered legislation to enhance the capability of our Nation to deal with this problem and another distinguished California Member of the House has offered comparable legislation in the House to accomplish this goal. I would like to indicate my own very great appreciation to you as the chairman of this subcommittee for the promptness with which you have shown your concern for this problem by scheduling hearings on the subject.

I know your own deep concern with all programs aimed at increasing the scientific knowledge of this country to meet the problems which face us. It has obviously become true within just the past few years that we have now an emerging field of scientific knowledge that has the capability of doing a great deal of good for the people of this country. It has applications in ways which will save lives and property. It is appropriate that you, as chairman of this subcommittee, concerned with the health of the Nation's science and technology, would take the initiative in holding these hearings and I want to compliment you for that.

Mr. SYMINGTON. Thank you very much, Mr. Brown.

Mr. Mosher?

Mr. MOSHER. Mr. Chairman, I think I will say only that this obviously is an extremely important subject. I think perhaps it is a crucially important subject at this time. These hearings are, therefore, important and timely and are undoubtedly past due. I salute you for organizing this effort and I anticipate participating actively.

Mr. Chairman, you speak of Mr. Brown as being a symbol of uplift in California. Of course, on our side we have a similar symbol of uplift, Mr. Goldwater.

Mr. SYMINGTON. I am quite aware of that and I would like to recognize him.

Mr. BROWN. If the gentleman would yield, may I point out that both the political and the physical uplift occur in Mr. Goldwater's history, if I am not mistaken.

Mr. SYMINGTON. It is true and we would be happy to recognize our friend, Mr. Goldwater, at this time for any comments he wishes to make.

Mr. GOLDWATER. Thank you, Mr. Chairman.

I recall back in 1971 waking up with most of my constituents in Los Angeles at around 6:30 in the morning due to the earthquake that was centered in my congressional district. As I later on in the day looked down upon the once three-story building that was called the veterans hospital out near Sylmar that entrapped some 30 men, I wondered at that point why we had not progressed further in handling natural disasters. Previous to that, I had a forest fire that raged from one end of my district to the Pacific coast, some 60 miles, burning out literally millions of acres and killing untold life and destroying a lot of property.

I also wondered why we had not really been more serious about our concern for natural disasters, obviously one of the most devasting of which is the earthquake. I think it is far past time that members of the Government begin addressing themselves seriously to the whole area of earthquake.

There is a recent breakthrough, I understand, in enabling us to better understand earthquakes and even perhaps to predict earthquakes. I think that is good and we probably should pursue this faster and more extensively. Not knowing what is going to happen oftentimes can spell disaster. On the other hand, knowing what is going to happen, as I think we have proved here, how to handle masses of populations with regard to these predictions, with regard to evacuation and shelter, et cetera, is a very serious question because not only do we get into the area of prediction of the future but we also get into the whole question of relief once the event occurs. How do we handle that? It doesn't matter whether it is an earthquake or a fire or a tornado or hurricane, how do we best handle the disaster which is before us?

I feel that we have not gone very far in this whole area of addressing ourselves to how we adequately provide relief to specific areas.

Lastly, the thing that comes to my mind is how we can best provide for future protection. I can only rely upon my experience dealing with the Federal Government in the earthquake of 1971 and I watched the—I think it was then called Office of Emergency Preparedness of the White House—move into the area of the San Fernando Valley and how inadequate the machinery was to really do what was needed.

I have to say for what was available and what the experience was that they did a good job. But they, in my opinion, were not equipped to handle a disaster. The whole question which arose in my mind is: Why aren't the people who are in this business doing this, the insurance industry, for instance, with their adjustors who are trained professionals in moving in and assessing damage and assigning value?

But instead we had bankers, accountants, contractors, people out of jobs who are assigned the responsibility of evaluating the results of the disaster. So I said to myself: Why is the insurance industry not more involved in the whole area of coverage of natural disasters? We provide coverage for fires that destroy our houses. We cannot get a loan from a bank unless we have fire coverage, an insurance policy covering fire and theft. Yet we have nothing to cover earthquake or other natural disasters. There is earthquake coverage that you can get and there also is water, but why don't we have a comprehensive natural disaster

program. These are a lot of questions that I have had in my mind, and I think it is timely that these hearings have been provided for. And certainly in the forefront of this has been my colleague, Al Bell, and Senator Cranston on the other side and John Burton from up in northern California, as well as Charles Mosher, who have all introduced pieces of legislation drawing our attention to the whole question of disaster.

I thank the chairman for providing this forum and opportunity.

Mr. MOSHER. May I make a comment?

Mr. SYMINGTON. Yes.

Mr. MOSHER. Lest anyone tend to think that the only concern about earthquakes is in California—I am sure no one here would make that mistake—we have over here a map prepared by my staff—in fact, prepared by a congressional fellow in my staff—and each one of those red circles, as I understand it, locates a very substantial earthquake that has occurred. This means that every State is vulnerable. We need to keep in mind that this is a matter of national concern and not just California concern. If I am not mistaken, historically probably the major recorded earthquake in this country occurred in Missouri and, therefore, I am sure the chairman is concerned.

Mr. SYMINGTON. That is quite true and I see that one of the red dots is probably on top of my house there. Unlike lightning, earthquakes apparently can strike the same place twice, and so we are very conscious of it. Unfortunately, it has increased the cost of some housing projects.

I thank also the gentleman from California, Mr. Goldwater, for his remarks.

Our first witness today is one of the authors of a bill which is before us. We welcome him, our good friend, Hon. John Burton, Congressman from California. We are happy to have you with us today.

[A brief biographical sketch of Mr. John L. Burton and Mr. Burton's written testimony follow:]

John L. Burton, Congressman from California, Fifth Congressional District, "The Golden Gate District," San Francisco, Marin, and southern Sonoma Counties, Democrat; younger brother of Congressman Philip Burton (D., San Francisco); the only brother team serving in the Congress; raised and educated in San Francisco public schools; B.A., San Francisco State, 1954; LL.B., University of San Francisco Law School, 1960; U.S. Army, 1954–56; dues-paying member of Bartenders Union, Local 41; member of the California State Assembly, 1965–74; chairman of the Assembly Rules Committee, 1971–74; sponsor of California Constitutional Amendment for open legislative meetings; led the first successful veto override in California in 28 years to maintain hospitals for mentally ill and mentally retarded; recipient of California Society for Autistic Children Award; author of legislation providing the highest level of benefits for aged, blind, and disabled of any State in the Nation; cochairman of the California Democratic Delegation to the National Convention, 1972; chairman of the California Democratic Party, 1973–74; active in the peace movement; dedicated to achieving social and economic justice for all peoples; elected to the 93d Congress in a special election on June 4, 1974; reelected to the 94th Congress in November 1974; married to the former Sharon Bain; one daughter, Kimiko; member of Committees on Government Operations, House Administration, and the Select Committee on Aging.

STATEMENT OF CONGRESSMAN JOHN L. BURTON

Mr. Chairman, I would like to thank you and members of the subcommittee for the opportunity to appear and testify before you this morning on earthquake

legislation, especially H.R. 4892, the Earthquake Disaster Mitigation Act which I introduced on March 13, 1975.

On May 24, 1976, the Senate passed S. 1174, the Earthquake Hazard Reduction Act, sponsored by Senator Alan Cranston. Senator Cranston has been an advocate of earthquake research for quite a while, and I am pleased that the Congress is taking positive action in this important area. H.R. 4892 and S. 1174 are similar in many respects, and I look forward to the House taking positive action as well.

I am particularly aware of what an earthquake can do, inasmuch as I represent a portion of San Francisco which suffered through the famous 1906 earthquake. As a member of the California State Assembly, I played a part in the passage of various earthquake measures, including a Seismic Safety Act.

H.R. 4892, and an identical bill, H.R. 13453, would provide for a $50 million-a-year, 10-year nationwide research and engineering program to develop operational methods for predicting earthquakes, an early warning system to reduce casualties and property loss, and improved construction practices and land use in areas of seismic risk. Scientists would also investigate ways of controlling, or moderating the effects of, earthquakes themselves.

There is a growing recognition that earthquakes are not just a California problem. Studies show that 39 states, with nearly 35 percent of the population of the United States, have been identified as lying in zones subject to moderate to major damage, and all 50 states are subject to some earthquake hazards.

Substantial progress has already been made in earthquake prediction especially in China, Japan, and the Soviet Union, but development has lagged in the United States primarily because of insufficient investment of funds.

H.R. 4892 would provide nearly five times more money than the federal government is currently putting into earthquake research and earthquake resident engineering.

The measure gives joint responsibility to the U.S. Geological Survey and the National Science Foundation, with the U.S.G.S. having primary responsibility for research and implementation. The N.S.F. would concentrate on engineering, planning, and social science.

To paraphrase an old saying, the only things in life that are certain are death, taxes, and earthquakes. No one denies that the United States will suffer future damaging earthquakes. Our task should be to take effective action now to mitigate the destructive potential of these earthquakes.

This Subcommittee will also be considering an earthquake bill authored by my colleague from Ohio, Congressman Charles Mosher. Congressman Mosher shares my concern in this important matter, and his measure, H.R. 13845, approaches the problem in a different way.

The basic difference between the Cranston-Burton and the Mosher bills is one of technique and priority. Both H.R. 4892 and S. 1174 seek to attack the earthquake problem with a combination of engineering, research, and funding. The Mosher measure seeks a solution through the use of various management organizations and techniques.

I respectfully suggest that the magnitude of the dangers posed by earthquakes, together with the degree of death and destruction that they have inflicted in the United States, calls for action that moves beyond the concepts advocated in H.R. 13845.

I believe that it would be a wise use of funds, and a prudent move on the part of Congress, if an earthquake research program as proposed in H.R. 4892 were approved and implemented.

STATEMENT OF HON. JOHN BURTON, REPRESENTATIVE FROM THE STATE OF CALIFORNIA

Mr. BURTON. Thank you very much, Mr. Chairman, and members of the committee.

Mr. Chairman, I would like to thank you and members of the subcommittee for the opportunity to appear and testify before you this morning on earthquake legislation especially H.R. 4892. The bill that introduced was the companion bill to Senator Cranston's measure. His bill as it passed the Senate had some changes in it that would have changed the funding authorization from 10 years to 3 years with the

first year providing no funds, the second year $50 million, and the third year $60 million of authorized funding. And the bill also provided authority to have the President direct the program with special emphasis on involving and coordinating with the National Science Foundation, and the U.S. Geological Survey and would assure coordination with other Federal agencies.

There is another bill before this committee by the distinguished gentleman, Mr. Mosher, who is ranking on the subcommittee, that goes basically to a structuring in management organization and techniques of some of the present availabilities of the national agencies which should be involved in such programs as mitigation of earthquake disasters. The basic difference is that we feel it is also important at this time to make a commitment of investment of funds to provide engineering and research to show the best type of structures that may be built in certain areas that are proximate to earthquake faults. In our State of California I think it was in 1932, there was an act passed called the Field Act that stated that all public buildings had to meet a seismic safety test. And until the earthquake of 1971 that was rather ignored but after the earthquake, 1970 and 1971, it started to be implemented and panic went throughout the various public localities where schools had to be closed and public buildings had to be closed, torn down, and rebuilt because they did not coincide with the standards of the so-called Field Act within our State.

California certainly isn't the only State affected by earthquakes but because they seem to come more frequently than they do in other areas, we did move to establish a joint committee on seismic safety in the State. There is seismic safety legislation in the State that unfortunately doesn't go far enough. It almost just points out the problems and says what should be done but doesn't provide the implementation.

I feel that the bill I have introduced, which has been coauthored by Mr. Goldwater and others, does go a step beyond Mr. Mosher's. It does come to the realization that there should be an investment of funds in the area of research, in the area of finding the right type of technology and engineering that could prevent great damage. As I am sure the committee knows and as was stated in the Senate's report on Senator Cranston's bill, the People's Republic of China, through their early warning system or evacuation system and other types of programs they have in an area where there was a very substantial earthquake have managed to evacuate the people and save approximately 10,000 lives. I can remember back in 1957, I believe, in San Francisco, when I was attending school sitting on the ledge of the Student Union Hall which was all glass—in effect where the cafeteria was the glass was back to the first row here and all I heard was a rumble and I turned around and saw this wall of glass come. It must have been this far from my face and just snapped back. And had that entire glass wall broken, there would have been several of the students injured.

I don't know of any statute which could have prevented that from happening except possibly had there been an early warning system and had there been a program that when earthquakes are predicted that certain areas should be evacuated for safety. That type of occurrence, had it reached its magnitude, would not have had an adverse effect at least on this individual.

I would commend the chairman greatly for moving expeditiously into this area, because it is one that seems rather esoteric. It is the type of thing people don't talk about until it happens. But I think it is our duty, as Members of Congress, to try to be a little bit ahead of disasters.

I think again that Mr. Mosher's measure has merit to it. It is a step in a meaningful direction but again I feel that time is of the essence and certainly we should be willing to go beyond that to make an investment of funding to provide really ways of dealing with the subject matter. We all agree that the problem is there and we all know the type of calamity that can happen. I would think a mere administrative arrangement would solve some of the problems once the earthquake happened such as the problems that were faced down in Mr. Goldwater's district, problems that have been faced in other areas after an earthquake hit, and the lack of coordination of programs. But I believe we should go beyond that and be able with great accuracy to predict potential earthquakes, to have recommended engineering structuring that in certain fault areas should be the norm in construction and, lastly, to provide some type of meaningful evacuation from areas where an earthquake is likely to hit in the very near future.

The highway system initially was developed after World War II as a means of evacuating people out of the areas in case of a military disaster. One of the problems that has been found when you have an earthquake, is that some of these highways and freeways go right down with the rest of the buildings since they are not structurally able to withstand seismic shock. So I would commend to you the provisions of the legislation that I have introduced along with Mr. Goldwater and others. I would say that I believe the provisions of this legislation and the provisions of Mr. Mosher's bill are not incompatible. I believe there is definitely an area where the concerns are the same but the approaches to the solution are somewhat different and they can be married to provide the type of legislation that not only could merit the support of this subcommittee but I believe also enjoy final support by the administration.

And I thank you.

Mr. SYMINGTON. I want to thank you very much, Mr. Burton, for bringing this bill before us. It is a benchmark initiative. I thank you very much for your testimony in support of the bill and also, of course, in analyzing the problem.

Are there any questions by the panel?

Mr. GOLDWATER. I wonder if you have any thoughts on this: I believe in your legislation you provide the National Science Foundation as the lead agency and I am wondering why you did it that way instead of, say, having NASA or the U.S. Geological Survey or someone else?

Mr. BURTON. It was felt by those who did the basic research on this problem based on the Senate hearings that the National Science Foundation should well be the place to implement the basic research, that USGS would develop the prediction system and monitoring, et cetera, but it was felt, notwithstanding the Bauman amendment, that the National Science Foundation would be the area where this type of basic research could be implemented. I assume that is because of the way they operate, that they lay grants out to the various institu-

tions of higher learning, et cetera and that way it would be within their normal function that they could draw on the expertise through their grant system of various colleges and universities throughout the Nation, whereas I do not know that the USGS has that type of present situation.

But that is what comes to my mind.

Mr. SYMINGTON. Thank you, Mr. Goldwater.

Mr. BURTON. Thank you very much, Mr. Chairman, and members of the committee.

Mr. SYMINGTON. We now are privileged to hear from the distinguished senior Senator, Senator Alan Cranston, who is here this morning to testify on the bill he has submitted. We are grateful to you, Senator, for spending this time with us today and we look forward to hearing your testimony.

[A brief biographical sketch of Mr. Alan Cranston follows:]

Alan Cranston, Senator from California, Democrat, of Los Angeles; born in Palo Alto, Calif., on June 19, 1914, son of William and Carol Cranston; reared in Los Altos, Calif.; attended Mt. View Union High School in Los Altos, Pomona College and University of Mexico; graduated from Stanford University, 1936; International News Service, covering England, Germany, Italy, and Ethiopia, 1937–38; returned to the United States and continued writing, 1939; chief, foreign language division, Office of War Information, 1940–44; enlisted in the U.S. Army, 1944, and served until the conclusion of World War II; national president, United World Federalists, seeking to strengthen the United Nations, 1949–52; wrote Killing of Peace, rated by the New York Times as 1 of 10 best books published in 1945; founded and served as the first president of the California Democratic Council, 1953–57; elected first Democratic controller of California in 72 years, 1958; reelected in 1962; wife, Geneva; two sons, Rob and Kim; his business career has been in land investment and home construction; elected to the United States Senate November 5, 1968, reelected November 5, 1974; member: Banking, Housing, and Urban Affairs, Labor and Public Welfare Committee, Veterans' Affairs Committee, Budget Committee, Select Committee on Nutrition and Human Needs.

STATEMENT OF HON. ALAN CRANSTON, SENATOR FROM THE STATE OF CALIFORNIA

Senator CRANSTON. Thank you very much. I am very very grateful to you for arranging this hearing and I am also grateful to Congressman John Burton for his effective work on the House side on the companion measure which he introduced to S–1174.

I appreciate the promptness of this hearing on this measure and your attention to the other proposals under consideration to establish an accelerated and coordinated Federal program to reduce the many hazards associated with earthquakes.

I do not intend to make a lengthy statement today. You will have an opportunity to hear from the experts over the course of your 3 days of hearings on the earthquake problem. But I do want to touch upon a few points which need emphasis.

First, the threat of future destructive earthquakes is a national problem. Certainly, the Pacific Coast States—principally Alaska and California—are especially vulnerable to earthquakes and related disasters. Yet nearly every State in the Nation faces some degree of risk from future earthquakes, and some 70 million people live in the 39 States that are wholly or partly in areas facing a risk of moderate to major damage from future earthquakes. Earthquakes have occurred

in our history all over the United States, with major earthquakes in Charleston, S.C. (1886), New Madrid, Mo. (1811–1812), Cape Ann, Mass. (1775), Seattle, Wash. (1949) and Hebgen Lake, Mont. (1959), and the terrible "Good Friday" earthquake in Alaska (1964).

Second, we must remember that despite a considerable seismic history, the United States has been extraordinarily lucky. Less than 1,200 people have lost their lives in U.S. earthquakes. Compare this to the more than 20,000 Guatemalans who died earlier this year in a major earthquake and its aftershocks. Throughout history somewhere in the neighborhood of 74 million people have died in earthquakes. And in just the second quarter of the 20th century, more than 350,000 people worldwide have lost their lives in earthquakes and related disasters.

Third, the United States today faces the greatest potential danger from earthquakes that we have ever faced. It is only in the last decade or so that our population has become concentrated in major cities and along our coastal regions, and major construction has occurred on land-fill and other unstable soils. Thus, it is only very recently that the potential for great earthquake destruction in this country has existed. Indeed, if the San Andreas Fault were to give us an encore of the 1906 San Francisco earthquake, the deaths could number in the tens of thousands and the property damage could excess $20 billion. On top of this, we must consider the incalculable losses resulting from the loss of economic and social functioning. Such an earthquake would have enormous repercussions on our national economy and our national psyche.

In the past few months, many of us have grown concerned about the existence of the so-called "Palmdale bulge"—a substantial land uplift straddling some 100 miles along the southern section of the San Andreas Fault just north of Los Angeles.

If this uplift is a signal that a major earthquake will occur in the near future—as some experts believe—then the legislation before this committee becomes all the more urgent. Estimates of the potential damage in the Los Angeles areas go as high as $25 billion in destroyed property and as many as 12,000 lives lost. Such a catastrophe would certainly have national economic repercussions.

Even if the uplift does not culminate in a destructive earthquake in the near future, it is still in the public interest to establish a well-funded earthquake program so that we can be better prepared for the earthquakes that are inevitable in our future. We know that major destructive earthquakes have struck the United States before—and not just in California—and it is therefore logical to assume they will occur again. A major earthquake could strike tomorrow, next year, or 30 years from now. It is irresponsible, in the face of new advances in the sciences of earthquakes and engineering not to take preventive action now.

The time remaining in this second session of the 94th Congress is preciously short. I am therefore appealing to this committee to make every effort to complete work on a final legislative proposal before we adjourn in October.

In closing, I would like to comment briefly on the differences in approach embodied by the bills offered by Congressman John Burton and myself and the bill offered by the distinguished ranking minority member of this committee, Congressman Charles Mosher. I believe the

problem envisioned by S. 1174 and H.R. 4892 is superior in two respects: (1) it established a national commitment to solving the earthquake problem, and (2) it spells out a specific set of goals and objectives backed up by an adequate level of funding. Mr. Mosher's proposal, on the other hand, is probably superior to mine in the area of coordinating a Federal earthquake program that spans a large number of existing Federal agency responsibilities. The issue of Federal coordination certainly needs this committee's attention. I, therefore, recommend that this committee consider how best to meld together the program spelled out by S. 1174 and the coordination addressed by H.R. 13845.

The issue, to be sure, is not whose bill is finally passed, but rather the establishment of a well-funded and effective Federal earthquake program. I am convinced, based on my 4 years of work on earthquake legislation, that the $50 million a year level of funding authorized by S. 1174 can be effectively spent and is urgently needed.

I deeply appreciate this opportunity to participate with the House toward the goal of enacting legislation to establish a Federal earthquake hazards reduction program.

Thank you.

I do most strongly urge action before this Congress completes its work.

Mr. SYMINGTON. Thank you very much, Senator Cranson, for your fine statement which will be very helpful to us. And I commend you very much on your initiative. Are there questions for Senator Cranston?

Mr. MOSHER. Mr. Chairman, I would just like to say how much I appreciate his positive comments concerning the legislation I have introduced. I would like to repeat one sentence in his testimony because I think it is crucial. The Senator says it is irresponsible in the face of new advances in the sciences with regard to earthquake engineering not to take preventive action now. I think that needs to be reemphasized throughout these hearings and I expect it will be. I assume, Senator, that that type of action you would agree should be comprehensive action which might be a wedding of the two pieces of legislation I have introduced.

Senator CRANSTON. That is exactly what I mean and I am greatly encouraged by the fact that you singled out that particular section of my remarks.

Mr. SYMINGTON. Thank you, Mr. Mosher, and thank you very much Senator Cranston.

Senator CRANSTON. Thank you.

Mr. GOLDWATER. Mr. Symington, I have some questions.

Mr. SYMINGTON. I beg your pardon.

Mr. GOLDWATER. Senator Cranston is my good friend and a colleague in this effort. He certainly has provided leadership and all of California should be thankful. There are a few questions I have concerning the legislation. In the legislation passed in the Senate there is a provision, I believe, concerning the development and application of local building codes. Is it your intention that the Federal Government should be dictating to the local government on this aspect?

Senator CRANSTON. Absolutely not. The only purpose there is to give assistance in research that can lead to locally made decisions on codes

that would be beneficial in terms of reducing the dangers of earthquake.

Mr. GOLDWATER. The thrust of your legislation is primarily in the area of prediction research and development in this area. Do you feel that we ought to be also going into the area of looking at the mechanisms for providing relief? Third, there is a question which I raised in my opening remarks, concerning getting the Federal Government out of the business of disaster relief and getting the private sector—specifically, I was thinking of the insurance industry, which is far more qualified at least to provide coverage—looking into it instead of having these disaster programs which seem to be a band-aid kind of approach after the fact. If these programs cannot develop with the private sector, maybe a quasi-public/private insurance kind of coverage utilizing the private sector, who are professionals in the area of moving in and making adjustments and analyzing disasters or damage or what have you, could be developed. Do you feel that this is an appropriate kind of legislation for examining that?

Senator CRANSTON. I think the matter of insurance is certainly one that merits study and action, but it is a very complicated matter that I think might well be kept separate from this particular piece of legislation. This legislation does not address it. I think we might get bogged down on all of the difficult details of how you might make an insurance program work effectively. The focus in this legislation is more on preventing disasters from occurring than on dealing with the consequences once they have occurred.

Mr. GOLDWATER. I would like to thank you for coming over and sharing your expertise on this matter.

Senator CRANSTON. Thank you very much.

Mr. SYMINGTON. At this time we welcome to the witness table the distinguished Director of the National Science Foundation and the Science Adviser to the President, Dr. Stever, accompanied by Dr. Charles Thiel with the Foundation. We are grateful to have you here today, Dr. Stever, knowing that you have given much thought to this problem, as well as the others that you face.

We look forward to hearing your testimony.

[Brief biographical sketches of Dr. H. Guyford Stever and Dr. Charles Thiel follow:]

DR. H. GUYFORD STEVER

Dr. H. Guyford Stever assumed the post of Director of the National Science Foundation on February 1, 1972, following his nomination by the President to a six-year term and his unanimous confirmation by the Senate.

In addition to his duties as Director of the Foundation, Dr. Stever has been named Science Adviser and Chairman of the Federal Council for Science and Technology by the President.

He is also the U.S. Chairman of the U.S.–U.S.S.R. Joint Commission on Scientific and Technical Cooperation; Chairman of the Board of Governors of the U.S.–Israel Bi-national Science Foundation; and Chairman of the Energy R. & D. Advisory Council.

Dr. Stever is a member of the National Science Board and Chairman of the Board's Executive Committee. He is also a member of the Energy Resources Council; President's Committee on the National Medal of Science; National Council on Educational Research; National Cancer Advisory Board; National Cancer Institute; U.S.–Japan Committee on Scientific Cooperation; Federal Council on the Arts and the Humanities; the Senior Executives Council of The Conference Board; and the Joint U.S.-Saudi Arabia Commission on Economic Cooperation.

Prior to his appointment to head NSF, Dr. Stever has served as President of Carnegie-Mellon University (and one of its predecessors, Carnegie Institute of Technology) since February 1965. His presidency was marked by significant change and growth in the university.

Before his appointment to the Presidency of CMU, Dr. Stever served on the faculty of the Massachusetts Institute of Technology for more than 20 years. He held positions which included Head of the Departments of Mechanical Engineering, Naval Architecture, and Marine Engineering (1961–1965); Professor of Aeronautical Engineering (1956–1965); and Associate Dean of Engineering (1956–1959). He was Science Liaison Officer at the London Mission of the Office of Scientific Research and Development from 1942 to 1945.

During the time he was at MIT, Dr. Stever achieved prominence as an educator and in his service to the Federal Government. He was Chief Scientist of the U.S. Air Force from 1955 to 1956 and was a member of the Advisory Panel to the House of Representatives Committee on Science and Astronautics from 1959 until 1972. He was a member of the President's Commission on the Patent System from 1965 to 1967 and Chairman of the Commission's Ad Hoc Science Panel. Dr. Stever also has headed many other aeronautical and scientific advisory committees at the Federal level.

Professionally, Dr. Stever has specialized in aeronautical, missile, and spacecraft engineering, design, and performance, particularly aerodynamics; radiation physics; scientific and engineering education; university administration; and science policy, with principal contributions in the fields of high speed flows of compressible fluids and control and guidance of flight vehicles. He is best known for his work on condensation phenomena in high speed flows and the growth of the boundary layer behind a shockwave. He has pioneered in missile guidance, and increased our understanding of the stability and control of transonic aircraft.

As an internationally-known expert on aeronautical engineering and space technology, Dr. Stever has often been honored for his work in both fields and for his service to the Government. He is a member of the National Academy of Sciences, National Academy of Engineering (Chairman, Aeronautical and Space Engineering Board, 1967–1969), Institute of Aeronautical Sciences (Vice-President, 1958–1959; President, 1960–1962), American Physical Society, American Institute of Aeronautics and Astronautics (Fellow), American Academy of Arts and Sciences, Royal Aeronautical Association, American Association for the Advancement of Science, Phi Beta Kappa, and other organizations.

Dr. Stever received his A.B. from Colgate University in 1938 and his Ph.D. in physics from California Institute of Technology in 1941. He has received 14 honorary degrees and other honors, including the President's Certificate of Merit, 1948; Exceptional Civilian Service Award, U.S. Air Force, 1956; Scott Gold Medal, American Ordnance Association, 1960; Distinguished Public Service Medal, Department of Defense, 1968; he was named Pittsburgh's "Man of the Year" by the Junior Chamber of Commerce in 1966; and was appointed an Honorary Councilor of the Superior Council for Scientific Research of Spain in 1975.

He is the author of more than 45 published articles, papers, or chapters on scientific, technical, educational, and science policy matters.

Dr. Stever is married to the former Louise Risley Floyd. They have two daughters, Sarah Newell and Margarette Risley, and two sons, Horton Guyford, Jr. and Roy Risley.

CHARLES C. THIEL, Jr.

Dr. Charles C. Thiel is Acting Director and Deputy Director, Division of Advanced Environmental Research and Technology, Directorate for Research Applications, National Science Foundation. He was born in 1940 in Chicago, Illinois, and received his education at a number of schools throughout the country, prior to receiving a Ph.D., in Engineering Sciences from Purdue University. Prior to joining the Foundation's staff, he was a research engineer for the General Technology Corporation and a member of the Purdue University faculty. Within the National Science Foundation, Dr. Thiel was program manager for Earthquake Engineering prior to assuming management responsibilities within the division. Dr. Thiel organized and chairs the Interagency Discussion Group on Disaster Mitigation. Internationally, he is a member of the Joint Committee of the US/USSR Agreement on Housing and Other Construction and serves as Chairman of the Construction in Seismic areas group. He also is Task Group Chairman for

Engineering Seismology of the US/USSR Agreement on Cooperation in the Field of Environmental Protection. Dr. Thiel serves on several professional committees, is a member of several professional societies, has served on organizing committees for national meetings, and has published in his areas of specialty.

STATEMENT OF DR. H. GUYFORD STEVER, SCIENCE ADVISER TO THE PRESIDENT AND DIRECTOR, NATIONAL SCIENCE FOUNDATION, ACCOMPANIED BY DR. CHARLES THIEL

Dr. STEVER. Thank you very much, Mr. Chairman and members of the subcommittee.

I am pleased to have this opportunity to discuss with you the Federal activities for reducing the hazards of earthquakes and their relation to the several bills—all dealing with earthquake hazard reduction—now pending before the subcommittee.

In the opinion of most Americans, I would say, earthquake hazards in the United States are limited to the Pacific coast, especially to California. When we talk of earthquakes, we talk of San Francisco in 1906, Long Beach in 1933, Alaska in 1964, and San Fernando in 1971.

But major earthquakes are by no means unknown to the rest of the country. Earthquakes occurred in the St. Lawrence River region on several occasions from 1650 to 1928, in the vicinity of Boston in 1755, in the Central Mississippi Valley at New Madrid, Mo., in 1811 and 1812, in Charleston, S.C., in 1886, and at Hebgen Lake, Mont., in 1959.

What's more, earthquakes affect human beings and their activities over widely spread areas. The San Francisco quake was felt over a 400,000-square-mile area; the quakes at Charleston, New Madrid, and along the St. Lawrence were felt over an area of 2 million square miles. And in 1973, earthquakes were felt in 34 States.

This last figure may be a better index of the extent of earthquake hazard in the United States. A recent study suggests that all or portions of 39 States lie in regions of major and moderate risk—with a combined population in 1970 of more than 70 million persons.

Fortunately, a damaging earthquake at a given site is a relatively rare event in this country. And perhaps that is why the average annual loss from earthquakes is relatively low. During the past century, it has amounted to about $30 million per year.

Still, historical data can be misleading. The development of dense populations in seismically hazardous regions, for example, is a relatively recent phenomenon in the United States. If such development continues, an NSF funded project estimates the average loss for the rest of this century resulting from earthquakes could exceed $1 billion per year.

Mr. Chairman, it is a very interesting experience to fly down the San Andreas Fault in California and discover new communities, dams, and new freeways—just amazing construction. Right across that fault runs one of the finest scientific instruments in the world, the linear accelerator at Stanford University. So we have built where there is great danger.

A recurrence of earthquakes at specific sites, of course, is estimated to result in much greater damage and loss. Another catostrophic San Francisco earthquake, for example, could, in the worst possible case, cause losses in the tens of billions of dollars. Clearly, earthquakes now pose an increasingly costly threat to the local and national community.

As you know, two items of the past year have brought renewed attention to the threat of earthquakes. In China, a major earthquake of magnitude 7.3 destroyed the town of Haicheng and damaged industrial plants. In the Los Angeles area, Geological Survey scientists reported an uplift of the earth's crust along a section of the San Andreas fault, a section said to have been "quiet" for the past 40 years. This uplift is not equivalent to an earthquake prediction, since such uplifts are not always followed by a major earthquake.

The two items are unrelated and unconnected, yet both draw increased attention to this subject. Chinese scientists actually predicted the Haicheng quake, the population was removed from hazardous buildings, and few were killed even though 1 million live in the area. In the opinion of one California scientist, seismic velocity anomalies along the San Andreas uplift near Palmdale indicate an earthquake of magnitude 5.5 to 6.5 within the next year.

Early last winter, these items and recent earthquakes in other parts of the world were brought to the attention of the President by several means. The Presidential science advisory committees known as the Baker-Ramo Committees, then examining new opportunities in science, determined that the area of earthquake hazard reduction might be an area where increased research could be especially beneficial. Discussion of this subject among officials of the executive branch led to a recommendation on my part and others, approved by the President, that a program to monitor the Palmdale uplife and evaluate the resulting data be undertaken. This has resulted in the reprograming of $2.6 million in research funds for the Geological Survey, of which $2.1 million is to monitor the scientific implications of the uplift and $0.5 million is to increase their earthquake prediction research program. Whether this uplift is a premonitor of an earthquake is as yet unclear. The research to be undertaken by the Geological Survey is intended to help determine whether this is indeed the case.

The growing prospects for earthquake prediction, based in part of the still tentative experience of the Chinese, Japanese, and the Soviets, suggest that in coming decades we may have a capability to predict earthquakes in the United States. The achievement of prediction will, in part, be limited by the capability and capacity of our scientists to observe and interpret premonitory effects. It should be noted, however, that unless local communities have made changes in their land use and building codes to reduce earthquake vulnerability over long periods, the capability to predict an earthquake would not result in as much reduction in property damage and life loss as otherwise would be possible.

All impacts of an earthquake ultimately revolve around property damage. Damaged or collapsing structures are the source of most life loss and injury during an earthquake. While the Federal Government has been funding most earthquake prediction and hazard mitigation research, the principal responsibility for using this knowledge through the reduction of building damage during an earthquake rests with State and local governments and private individuals. Thus, the actual limitation of the impact of earthquake prediction lies in non-Federal hands.

As noted above, the reprograming of funds from the NSF and the USGS to undertake a $2.6 million research activity will help us under-

stand the Palmdale uplift as a possible premonitory effort of a major southern California earthquake. In addition, NSF and USGS are jointly preparing a plan to outline the research which would be necessary to provide the technological base for making predictions, changing building codes, and restructuring land use. An advisory group on earthquake prediction and hazard mitigation has been established and held its first meeting on June 14. Based upon a draft plan to be presented to this group and their deliberations, a revised plan will be prepared for submission by the Science Adviser to the President. This plan will form the basis for consideration by the affected agencies in preparation of their fiscal year 1978 and subsequent budget proposals in these areas.

At this point, Mr. Chairman, let me discuss the three bills pending before the subcommittee. The first, the Earthquake Hazard Reduction Act, S. 1174, as introduced by Senator Cranston and passed by the Senate, provides for the establishment of a program in research on earthquake hazard mitigation. The Earthquake Reduction and Preparedness Act of 1975, H.R. 13722, introduced by Mr. Bell, would establish a Federal research program on prediction and control and provide for earthquake prediction preparedness. The National Earthquake Hazards Reduction Conference Act, H.R. 13845, introduced by Mr. Mosher, provides for the establishment of a National Earthquake Hazards Reduction Conference.

I might point out that the NSF and the USGS have the authority to pursue research on earthquakes and indeed are doing so. They have received authorization and appropriation in the areas covered by S. 1174. Thus, the Cranston bill would direct Federal agencies to undertake numerous activities for which they already have the authority.

As I have noted, an advisory group in earthquake prediction and hazard mitigation is preparing a plan for research which will identify types of actions needed to reduce earthquake impacts. Under the Federal Disaster Assistance Act of 1974, Public Law 93–288, the Federal Disaster Assistance Administration of HUD is delegated responsibility for the warning of impending natural disasters, including earthquakes. HUD redelegated its authority concerning earthquake warning to Interior; specifically, the director of the USGS has been delegated responsibility for the issuance of earthquake predictions. Thus, it would appear that the proposals of the Bell bill are being accomplished through current executive action.

There has been considerable experience within the executive on the operation of large Federal committees to achieve specific purposes. The establishment of a 29-member conference which includes 22 Federal officials may be unwieldy. The objectives set out for this conference are probably most readily accomplished with a smaller, more focused group. If additional coordination is necessary, the question must be asked: Can it be accomplished under the broad authority in the Federal Disaster Assistance Act of 1974, or is more legislation needed to achieve effective coordination? There are already several formal and informal mechanisms that provide some degree of coordination.

Dr. McKelvey will describe an organization which the Geological Survey has established for this purpose. Further, an interagency discussion group on disaster mitigation, hosted by the RANN program of

NSF, meets monthly to discuss not only earthquakes, but other sorts of disaster agents. By the way, it is a completely informal group. On the other hand, it publishes a newsletter. That newsletter on disasters has gone through 11 editions. While it is not at all clear that yet another coordinating body should be established, the executive branch is reviewing this question.

If another sort of coordinating body should be established, there may be adequate legislative authority to do so under the Federal Disaster Assistance Act and the legislation which recently created the Office of Science and Technology Policy.

Summing up, let me say, the administration agrees with the broad objectives of these three bills, two of which are: Reduction of property loss and personal injuries from earthquakes is a desirable and potential achievable goal; many private, local, State, and Federal decisions need to be coordinated in order to help achieve that broad goal.

Then there are two which are implicit in the bill: The Federal role is limited to conducting research and attempting to develop the technological base to enable reliable warnings to be issued in the future; and budget resources to support the Federal role in this program area will need to be fully justified in terms of program priorities and investment timing.

We believe existing authorities are adequate, but should our current effort in developing a program plan reveal some deficiency which would require additional authority, the administration would make the legislative proposal it believes appropriate. Accordingly, we recommend that the committee defer action on these three bills.

Mr. Chairman, in saying that, I do not want at all to say that action on earthquakes is unimportant. What I am pointing out is that the authority to do the job is there. What we really have to do is to find out how much money is needed and from which parts of the society it is needed to do the job.

Mr. SYMINGTON. May I interrupt at that point?

Dr. STEVER. Yes.

Mr. SYMINGTON. The authority you say is there and what you need to find out is whether the money is there. Is this what prompted you to consider it at all at this point in time?

Dr. STEVER. It has been under observation for some time, and money has been spent in both USGS and NSF. The recent events which have called everybody's attention to this phenomenon have enlivened activity all around. But my personal feeling is that when the chips are down we are going to have to figure out how much money is needed by each of these agencies to do the job properly and which agency is to do it. That is the real problem.

Mr. MOSHER. Will the gentleman yield?

Mr. SYMINGTON. Yes.

Mr. MOSHER. Dr. Stever, are you implying that probably these agencies do not have sufficient funds at this time?

Dr. STEVER. My personal feeling is that we should strengthen the programs, and I think this is what we are trying to look at.

Let me turn to the programs of the National Science Foundation. Here my discussion will touch on the nature of the problem, the possibilities for adjustments to reduce earthquake impacts, and the NSF research program.

Earthquakes impact the community in three distinct ways: Through direct loss of life, injury, and property damage; through indirect losses and costs incurred in the operation of disaster relief and rehabilitation programs, loss of income due to business disruption, personal injury, and disaster-caused physiological problems; through current investments in capital structure, restructured land or facility use, and condemnation of hazardous structures to achieve adequate performance.

This latter point is particularly important since overinvestment to achieve community earthquake safety may retard the achievement of individual and community goals, just as underinvestment may increase future suffering. Clearly there are real costs in condemning buildings, changing building codes, and restructuring land use.

Current knowledge of earthquake vulnerability and the social and technical means to moderate earthquake impacts is not sufficient to chart an economic, practical course through the maze of actions that might be taken to affect earthquake impacts. The life loss, injury, property damage, and economic and social disruption caused by an earthquake occurrence result from public and private decisions made at virtually every level—from the individual to the corporation, from local to Federal Government. The majority of these decisions are made by private individuals or groups who are selecting alternatives for their actions—actions unconstrained by public regulation or requirements or constrained at most by some form of minimally prescriptive requirement—for example, building code, tax regulation, investment incentive.

The general objective of any individual or group attempting to deal with a potential earthquake is to control the consequences of the event through adjusting its impacts. Possible adjustments the decisionmaker may seek to accomplish are:

Control the event by prevention or modification of the event.

Construct facilities so as to perform acceptably during and after the event.

Plan for the warning, response, and recovery from the event.

Distribute the economic risk, for example, through insurance and redevelopment loans.

Generate and select alternative physical development plans.

Adopt and enforce zoning, construction, and management standards.

Clearly these adjustments are both physical and social in nature and they depend critically on each other. Moreover, a balanced combination of adjustments will undoubtedly yield the maximum benefit in relation to social and economic costs over a period of time. Some estimated benefits resulting from such adjustments are:

The restriction of population growth in high-damage-potential areas in the San Francisco Bay area could reduce the impact of a recurrence of the 1906 earthquake early in the next century by one quarter—if adopted now. That, of course, is entirely a decision of the people in the area, and I am not suggesting that the Federal Government should press for such action.

Reinforcement of hazardous structures in the 47 highest hazard counties in the United States could reduce losses by one quarter per year. The costs incurred could be enormous.

Replacement of hazardous buildings 10 years earlier than normal could reduce the Nation's loss from 5 to 10 percent by the turn of the century.

Improvement of building codes by the doubling of lateral force requirements for new construction could reduce the national annual loss by some 10 percent by the turn of the century.

The impacts of these adjustments are preliminary but indicative, and do not make allowance for the cost of achieving the adjustment. It is important to note, however, that better earthquake disaster policies will reduce the impact of other hazards such as accidents, explosions, and extreme winds. In addition, many of the benefits will accrue to the public at large as well as those directly affected. Public Law 93–288, the Disaster Relief Act of 1974, established a broad program of relief and rehabilitation for disaster-struck communities. Thus a reduction in an earthquake's impact translates directly into reduced Federal expenditures under this act to aid the victims and restore the community.

At this time, there is a crucial need to determine the full costs associated with achieving these beneficial adjustments. The development of effective methods to estimate these costs requires joint effort in the application of research, experience, and good judgment.

Since its inception, the National Science Foundation has supported research on earthquakes and their effects. Our program has two major thrusts: basic research in the Earth sciences and applied research in earthquake engineering and public policy.

Basic research is focused in the Division of Earth Sciences programs on geophysics and ocean sediment coring. The latter program's support of drilling in the central Atlantic has provided widely accepted evidence for the plate tetonic theory of the Earth's crust. This theory has greatly enhanced our understanding of the mechanisms of earthquake generation and has provided an explanation for the general location of most earthquakes along plate boundaries. The geophysics program has supported over the past two decades the Nation's principal academic activity in seismology, geophysics, and geology as they relate to earthquakes. The basic knowledge developed under its support sets the limits on that which can be expected to be accomplished in the near future.

Applied research is centered in the Foundation's research applied to national needs program (RANN). Earthquake engineering research has been supported by RANN since its inception. After the 1971 San Fernando earthquake, RANN broadened the scope of the program to include all those aspects of problem-focused research that could potentially reduce the public's exposure to earthquake losses.

The general objective of the earthquake engineering program is to develop methods that allow decisionmakers to control the consequences of earthquake occurrences. The specific objectives of the program are as follows:

DESIGN

Development of economically feasible design and construction methods for building earthquake-resistant structures of all types.

LAND USE

Development of procedures for integrating information on seismic risk with land use planning processes.

SOCIOECONOMICS

Development of an improved understanding of socioeconomic consequences of individual and community decisions on earthquake-related issues.

UTILIZATION

Presentation of program results in forms most suitable for the user communities.

The RANN program does not include the topics of the scientific basis for earthquake prediction and control. Basic and applied research in these areas are respectively supported by the NSF Earth Science Division and the USGS.

I would like to take a few minutes to discuss two specific initiatives that we have undertaken. The first is the cooperative Federal program on building practices for disaster mitigation which is a major utilization effort initiated and supported by NSF and conducted by NBS. The purpose of this work is to develop comprehensive, nationally applicable seismic design provisions for buildings through the integration of activities and resources in Federal agencies, professional organizations, private practitioners, State and local governments, and researchers. It involves a concentrated effort to update, expand, and substantially revise present seismic design provisions to incorporate the latest state-of-the-art research results. The public relies heavily on building codes to foster a constructed environment that protects life and limb from the hazards of fire, wind, and earthquake. For the most part, the seismic provisions adopted throughout the country are based on documents prepared in the 1950's. Thus, the products of the cooperative Federal program will fill a vital public need. The draft provisions are now out for review. The publication of the final provisions and associated commentaries will take place early next year. At that time, they will be available for incorporation into building codes. I am sure that you can appreciate the size and complexity of this unique effort to collect, evaluate, and synthesize the products of two decades into an economically realistic set of building provisions applicable in a national context.

The second initiative involves research on the public consequences of earthquake mitigation. As part of a comprehensive assessment of natural hazards, a major examination was made of the mix of available policies and procedures. This has formed in part the basis for future program development.

In addition, we have supported a major effort under Dr. Haas, an associate of Dr. White who will appear later in these hearings, to investigate the "socioeconomic and political consequences of earthquake prediction." I might add that earthquake prediction presents a number of problems not encountered in the warning programs associated with other hazards.

For the next decades, the earthquake vulnerability of our cities will be dominated by those older structures now standing that cannot be expected to withstand a major shake. The biggest challenge to the public official is to develop economically and politically realistic procedures and policies for the condemnation of substandard structures. And for their reinforcement, replacement, or abandonment. Earthquake prediction in conjunction with building practices to reinforce

these hazardous structures is in all likelihood the only economically and politically practical method to reduce life loss and property damage in the next few decades. The development of these building practices and the prediction capability are now limited.

The possibility of predicting events to take place 10 years hence greatly complicates the public policy decisions that must be made. It is important to note that the multiplicity of issues presented by such a prediction are at an early state of investigation.

This concludes my statement, Mr. Chairman, and I will be pleased to answer any questions that you and members of the subcommittee may have.

Mr. SYMINGTON. Thank you very much, Dr. Stever, for your fine statement. Clearly, there are some things happening in the Government and in the administration and elsewhere that have impact on the problem. I wonder if you could state again succinctly why you would object to this kind of congressional initiative at this time to essentially find and declare the States which are vulnerable to earthquakes and to set up a somewhat more systematic way of dealing with it?

Dr. STEVER. I guess, Mr. Chairman, my own personal feeling is that the problem is very heavily concentrated outside the Federal Government. Authorization to do many of the things that have been suggested in these bills seems to be there. It is clear in my view that we have not—although I am now speaking for myself—that we have not supported enough the work of prediction and the technological work that is the responsibility of the Federal Government, but the tremendous load still devolves onto the State, local, and private decisionmakers.

I will say this: The attention that has been brought to this problem by the authorization bills in front of us is very important. It has brought an understanding to the scientific community, the concerned community, the people who have these responsibilities in the local centers, and the general public who just worry that they are in danger. This attention has brought that understanding together; in that respect it is of great importance. I do come back to the point that the science may be outrunning our sociogovernmental capability.

Mr. SYMINGTON. That is why we want to address legislation to enable the political structure to catch up with science. Where is the locus of responsibility in the Government for earthquake prediction and measures to mitigate the damage today?

Dr. STEVER. I am sorry, is that a question, or I thought it might be a rhetorical question.

Mr. SYMINGTON. It is a question.

Dr. STEVER. I think the Disaster Assistance Act clearly says that it is the intent of Congress by this act to provide an orderly and continuing means of assistance by the Federal and State and local governments in carrying out their responsibilities to alleviate the suffering and damage which result from such disasters. One of these forms of assistance is achieving general coordination and responsiveness of disaster preparedness and relief programs.

Another is to encourage hazard mitigation measures to reduce losses from disasters, including the development of appropriate land use and construction regulations. And somewhere in the act there is something having to do with research.

In section 2, application of science and technology and research, the President is authorized to establish a program of disaster preparedness that utilizes the services of all the appropriate agencies, including the Defense Civil Preparedness Agency.

So authorization seems to be there, but with so many actions of government, authorizations may drift unnoticed, and, in fact, it takes emergencies or something to tell us that we are actually holding the authorization to do things and get these programs going.

Mr. SYMINGTON. That is a very broad range of responsibility that devolves upon the Government for disaster relief. I think the focus on earthquake prediction and mitigation is somewhat diluted there. It seems to have gotten lost in this shuffle. What Government initiative do you anticipate would bring it back into proper focus under the existing structure without any further assistance from Congress?

Dr. STEVER. There is going to have to be assistance from the Congress. I actually think that the appropriations must be strengthened. I think that the oversight function—asking what are we doing about coordinating these groups with respect to earthquakes—is a function of the Congress. And mind you, I am glad that what we see happening is happening because all of this discussion does represent a change in which the science has made progress to a point where maybe we can take some of the authorizations more seriously than we have in the past.

However, I do want to point out that just aiming at the money that will be spent by the Federal Government is only one small portion of the job.

Mr. SYMINGTON. The Disaster Relief Act kind of divides up responsibility among different agencies, doesn't it?

Dr. STEVER. It delegates it to HUD and with respect to earthquakes HUD has redelegated it to Interior and the Geological Survey for earthquake prediction and warning.

Mr. SYMINGTON. Doesn't anybody want to take it on; is that the trouble?

Mr. GOLDWATER. Mr. Chairman?

Mr. SYMINGTON. Yes.

Mr. GOLDWATER. I think we are getting into an area of the problem that we will have to address ourselves to sometime, that is, the proliferation in this whole area. I notice that our colleague from Kansas, Larry Winn, generated some interest in tornado work. I think that is now under NASA. They are doing most of that work; is that correct?

Dr. STEVER. I would think NOAA would be.

Mr. GOLDWATER. We have NOAA doing tornado work and USGS——

Dr. STEVER. And NSF does work in this area too.

Mr. GOLDWATER. Obviously, we want to call the expertise here into being, but who is the lead agency? I wonder if Dr. Stever has thought about this and how you see it. We have hurricanes and tornadoes and earthquakes and they all cause disasters.

It seems that the Federal Government has its hand in each disaster.

Dr. STEVER. I think, Mr. Goldwater, there is no question that coordination is one of the toughest things we do in the Government and we should do more and more effectively. I think the bill that has been

put out by this committee on the science advisory mechanism in the White House will help, but it will take more than that. I think it is very important to pinpoint the responsibility in agencies for these different disasters.

Mr. GOLDWATER. Where do you think the lead should be? Where is the logical place for all of this to be centered?

Dr. STEVER. For Federal Government action, I think the Department of the Interior and the U.S. Geological Survey, as far as earthquake prediction is concerned. But we still have a tough problem: a lot of the action to be taken that will save lives is the responsibility of the private sector and the State and local areas. We can coordinate and bring them together.

Your State, because of the repetition of earthquakes throughout its history, began a long time ago to take the correct action with respect to building codes.

Mr. GOLDWATER. I think the main concern here is the research and development, the R. & D. money spent to better understand these phenomena which then gives us some direction as to how we are going to respond.

Dr. STEVER. Mr. Goldwater, there is another important fact. The agencies that have to do with land use as opposed to building codes are terribly important in this effort, because, again, while your State has its building codes very well in hand, I think the land use problem in the State of California is one which will have to be addressed carefully.

Mr. GOLDWATER. You are not advocating that the Federal Government take over the land use problem.

Dr. STEVER. That is the point. That is not what I recommend.

Mr. SYMINGTON. Maybe they could just tell them when they have a disastrous land use policy.

Dr. STEVER. Mr. Symington, let me say another thing: While I did say I thought that some of the authorizing legislation being talked about here is repetitive and we already have it, the very fact that you bring out this point is very important, because you have to bring these matters to the attention of those land use groups in California or any other State—there are tens of thousands of them.

Mr. SYMINGTON. We will recess for a moment.

[Recess.]

Mr. BROWN. The subcommittee will reconvene.

The other members will be here shortly.

Dr. Stever, just a minor question: In the first part of your statement you made some reference to the area over which earthquakes could be felt which puzzled me a little bit. How do you define the area over which earthquakes are felt. Obviously, it depends on how sensitive your sensors are.

Dr. STEVER. This is subjective in the sense of whether citizens respond by saying my glassware shook or I shook in bed. Of course, this could be done much more technically by actually defining the regions. It varies from quake to quake and different quakes have different magnitudes.

Mr. BROWN. So you are really aiming at trying to determine whether there is some visual or perceptual indication?

Dr. STEVER. Yes.

Mr. BROWN. It occurred to me in this discussion of earthquake warning and earthquake disaster damage mitigation that we have some parallels with the situation that developed with regard to more common kinds of disasters such as floods. I could give you a small example in my own district. The Corps of Engineers prepared 40 or 50 years ago a small dam to mitigate the flood hazards within a certain runoff channel. Today they are considering vastly increasing that. The changes in the circumstances are, of course, that there has been a great deal more construction developed in the path of potential flood damage.

A $10 million dam of 50 years ago will be replaced by a $500 million dam at present. The cost-benefit justifies that.

Dr. STEVER. Mr. Brown, again, I think I made the point that the damage has only been $30 million per year in this last century from earthquakes. But because of the change in our population centers, what you say is now true. I do think that where the USGS has lead agency responsibility for monitoring and studying earthquake prediction that the NSF has been trying to think of ways to mitigate damage in the sense of building structures differently and so on. I think a great deal of progress has been made in both of those areas. They are quite different sciences. The science of earthquake prediction brought along by USGS and helped by NSF has gone a long way. The other one is going a long way. The change in our population location makes the point that you are talking about. Yes, I think it is a very good time to reexamine the total of where we stand in all of these aspects.

Mr. BROWN. The corps and other agencies have developed sort of benchmarks of what they call 100- and 200-year storms, for example. Of course, these can be measured and presumably earthquakes could be measured in somewhat the same fashion and there could be some prediction of what you could expect.

Dr. STEVER. It is pretty well known as to frequency and damage.

Mr. MOSHER. Mr. Chairman?

Mr. BROWN. Mr. Mosher, I will yield the remaining 5 minutes to you. Dr. Stever has to leave after that.

Mr. MOSHER. Dr. Stever, on page 6 you comment on the legislation that I have introduced with several cosponsors and you rightly, I think, raise an important question concerning our legislation. My bill essentially provides a coordinating mechanism and you suggest that that mechanism would be at best unwieldy and at worst unworkable.

Dr. STEVER. I changed it when I spoke to say: "It may be unwieldy."

Mr. MOSHER. Whatever you said, it is a valid comment. I don't quarrel with the comment at all. I recognize this is the crucial question about it. The emphasis though in the legislation I have introduced is to the effect that the present responsibilities in this important area are terribly fragmented within the Federal Government and some sort of coordinating mechanism I think is crucially needed. The very fact that attempting to pull them together in my legislation requires so many people and so many agencies, dramatically indicates how fragmented the present responsibility is.

Dr. STEVER. Mr. Mosher, may I interrupt to say that I personally agree with you in this respect: As I try to describe the problems I recognize that how they are seen really varies among quite different

kinds of persons—basic researchers and engineers and State and local officials and so on. And we might bring earthquake prediction to a high peak and have done nothing about mitigating loss.

Mr. MOSHER. That is right. The right hand needs to know what the left hand is doing.

Mr. BROWN. If you could yield for a moment, maybe I could ask Dr. Stever to comment on how many people were involved in the advisory group which he describes on page 5.

Mr. MOSHER. I was just going to get to that myself. Can I get to that in just a second, George?

Mr. BROWN. OK.

Dr. STEVER. Mr. Brown has a way of pricking all the bubbles.

Mr. MOSHER. You suggested that the objectives might be accomplished with a smaller more focused group and my legislation does emphasize the fact that this coordination should be done by a smaller group. In fact, specifically, as I remember it—I don't have it in front of me—it specifically proposes a 10-member executive group. Now I was just going to get to the point that Mr. Brown is mentioning on page 5 where you say that an advisory group on earthquake prediction and hazard mitigation held its first meeting on June 14. That date is rather interesting because it does indicate how recent this coordinating effort is because my legislation was prepared and introduced I think well before that time. So I am glad that we, or something stimulated the creation of the advisory group. Later you point again to the various formal and informal arrangements that now exist. And the question that Mr. Brown has just asked is, as you suggest, very pointed. How many people are involved in those informal arrangements by which you are hoping to achieve better coordination?

Dr. STEVER. First of all, that particular group is to give us advice on the earthquake predictions and earthquake mitigation warning and so on. It turns out that the number is 21.

Mr. MOSHER. That is only a limited aspect.

Dr. STEVER. That is only a limited aspect. I don't want to say that we have not been coordinating work. I already mentioned the interagency discussion group on disaster mitigation that RANN has run informally and within the FCST we have been coordinating with other agencies. The real point of the bills being brought up to date is that there is more focus on earthquake, and it may be that is what we should be doing right now.

What it is going to show, I think, is that we can strengthen some parts of our programs and there are some parts that the Federal Government has rated only on an informational basis.

Mr. MOSHER. I yield for one question by Mr. Goldwater.

Mr. GOLDWATER. Dr. Stever, is this S. 1174 incompatible with what you are doing now?

Dr. STEVER. No; I don't think so.

Mr. GOLDWATER. It is not?

Dr. STEVER. No. My colleague, Dr. Thiel, says it reads as if it were written from our program point of view. No; it is not incompatible and in that sense bringing attention to it would be helpful.

Mr. GOLDWATER. The only difference, it seems to me, is as to point 6:

The President shall, within 180 days identify the department, agency, or task force which shall have primary responsibility.

Dr. STEVER. We have primary responsibility in NSF for earthquake mitigation, design of structures, buildings and dams, and so on. USGS has primary responsibility for earthquake prediction and monitoring.

Mr. SYMINGTON. Do you have to leave at this time?

Dr. STEVER. Thank you. I do have to leave. I would be glad to answer further questions in written form.

[Further questions in written form were forwarded to Dr. Stever. The questions and responses follow:]

Earthquake
Questions and Answers

1. Q. Please submit a statement of the dollar amounts obligated by NSF for earthquake work in fiscal years 1974, 1975, 1976 and 1977 (planned). The statement should be broken down into major categories and further into subcategories if this is informative. In-house work should be separated from work under grants, contracts, or interagency transfers.

A. During the FY 1974, 1975, 1976, and 1977 (planned) the Foundation has initiated (plans to initiate) the following amounts in grants for the conduct of research on earthquakes. The table presents three items for each year; the amount spent for earthquake engineering, fundamental earthquake research, and the total amount obligated during each year.

Year	Earthquake Engineering	Seismic Research	Total
FY 1974	$7,982,900	$2,450,000	$10,432,900
FY 1975	5,356,372	1,970,000	7,326,372
FY 1976	7,150,000	2,600,000	9,750,000
FY 1977 (Est.)	6,800,000	3,500,000	10,300,000

2. Q. How would NSF utilize the funding that would be authorized by S. 1174 if that funding were made available ($20,000,000 in FY 1978, for example)?

A. The assumption is that the $20,000,000 referred to in S. 1174 would be the total funds available to the Foundation for the pursuit of earthquake related applied research. As currently structured S. 1174 does not provide for support of basic research in seismology, geophysics, and the earth sciences as they relate to earthquake prediction, control and hazard identification. If these funds are available, the RANN program in Earthquake Engineering and Societal Impact will focus in three principal areas:

1) Earthquake engineering, that is, the development of technical procedures to reduce the impact of earthquakes;

2) Societal response to earthquakes - that is the development of an understanding of the social, behavior, economic, and legal implications of earthquakes and how they may be managed to reduce the suffering of an occurrence and hasten the return of the community to its pre-quake functioning; and,

3) Utilization studies and activities whose purpose is to present to the public in a most appropriate and usable form the benefits of the Federal Earthquake Research Program.

Approximately 60% of the available funds would be directed at the objectives enumerated below:

1) Develop methods to characterize the nature of strong ground motion suitable for application in analysis, design, and planning;

2) Obtain a comprehensive data base of the response of soils and structures to earthquakes;

3) Develop methods to evaluate and control soil response and failure;

4) Determine appropriate models for the strong motion response of structures and structural elements from analytic and experimental studies;

5) Develop principles for local and regional planning that consider direct and indirect effects; and,

6) Extract from the above principles a set of guidelines that may be used to develop suitable criteria and reliable, practical simplified methods of design of structures.

Approximately 25% of the available funds would be expended on studies whose objectives are:

1) Define options for the mix of measures to mitigate earthquake hazards by considering research, social, economic, legal, and political barriers to policy implementation;

2) Assess public and private regulation impacts and develop alternatives;

3) Facilitate the beneficial utilization of earthquake hazard mitigation efforts by developing effective techniques for communicating information to the public and decision makers.

4) Increase the capability of public officials to implement earthquake hazard mitigation measures through land-use planning, preparedness planning, building inspection, and disaster response; and

5) Define alternatives the private sector could adopt for mitigating earthquake hazards.

Approximately 15% of the available funds would be expended on projects whose purpose is to facilitate the utilization of the results of this research program. Scientific and technical knowledge and its application generally should not be separated. These studies will be conducted as part of the ongoing research program. One of the most important aspects of facilitating improvements in the public's practice of earthquake mitigation is to make sure that those who perform research are aware of problems faced by practitioners. These needs will be met by conducting regular workshops of users to identify problems needing conclusions, surveying how practitioners use information, and by regular evaluation and priority assessment.

3. Q. Please provide a copy of the damage estimate report mentioned on page 2 of the testimony.

A. The report referred to in the National Science Foundation Testimony is "Budgeting Justification for Earthquake Engineering Research," prepared by the J. H. Wiggins Company. A copy is appended.

[Committee note: This report was received and is available for inspection in the Committee offices.]

4. Q. How will the establishment of the Office of Science and Technology Policy affect planning and coordination for earthquake hazard reduction?

A. The Office of Science and Technology Policy (OSTP) was recently established and provides a focus for the examination of science opportunities and the coordination of the Executive Branch science activities. Within the context of the question OSTP could provide a possible focus for the coordination and planning of civilian agencies research programs. However, the desire is to keep OSTP small, policy focused, and avoid the assignment of operational responsibilities. Many of the problems posed by earthquakes cannot be dealt with by research alone. Indeed the central issue in changing the public's vulnerability to earthquakes is how state and local governments and the private sector incorporate into practice that which is now known and that which may be developed under this accelerated research program. OSTP has responsibilities in science policy but does not have the capability to coordinate the manner in which Federal, state, local or private individuals or organizations might apply such knowledge. Thus OSTP presents a possible focus for research coordination and planning but would not be a logical focus for the coordination of actual earthquake hazards reduction programs.

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5. Q. Please provide the Subcommittee with a copy of the plan which NSF and USGS have been developing recently for research on earthquake hazard reduction.

A. A copy of the plan which the National Science Foundation and the U.S. Geological Survey prepared for consideration at the June 14th meeting of the Earthquake Advisory Group on Hazard Mitigation is appended. In addition, a copy of the draft plan prepared for the August 12th and 13th meeting is also appended.
[Committee note: This material was received and is available for inspection in the Committee offices.]

6. Q. How does NSF ensure that the results of its earthquake research programs get used?

A. The NSF/RANN program has undertaken an extensive program in research utilization for its Earthquake Engineering Research. This extensive program is multi-faceted and includes the following items:

1) Grants to the University of California, Berkeley, and the California Institute of Technology have established a National Information Service for Earthquake Engineering. The NISEE publishes on a regular basis an Abstract Journal in Earthquake Engineering summarizing the published literature throughout the world. They have established a Software Center which collects, validates, documents and distributes computer programs developed by NSF and other agencies, public and private, to the public and private sectors. The reference collection of these two institutions is now among the largest in the world and is used by a large variety of researchers and practicing professionals. They have collected an extensive library of strong motion earthquake response of the ground, and buildings, and other structures as measured during the occurrence of U. S. earthquakes. This catalog has been prepared for computer use and has been widely distributed.

2) Under a joint program initiated with the National Bureau of Standards called Building Practices for Disaster Mitigation, RANN has made substantial investments in the development of a new set of building design provisions, criteria, and standards which incorporate the latest information and experience in earthquake resistant design. These provisions are now nearing completion and have been prepared so that they may be readily incorporated into local, state and Federal building codes and regulations.

3) The Earthquake Engineering Program has supported a number of workshop conferences and meetings at which the results of research programs have been presented to practicing professionals, researchers, and public officials. Among these was a meeting hosted by the Association of Bay Area Governments, the nine San Francisco Bay counties, which met in January to examine the area's earthquake problem from a public perspective. The Society for Engineering Education under joint support of NSF and the Defense Civilian Preparedness Agency has conducted for the past two summers a course to inform continuing education instructors of the latest developments in earthquake mitigation procedures.

4) Each award pursued under RANN support must have a utilization strategy appropriate for that award's activities. These individual utilization activities complement the overall program thrusts which are illustrated above.

5) Each grantee is encouraged to participate in professional associations. This has led to a very extensive representation of RANN grantees in professional societies, standards setting committees and similar associations. Among these are the American National Standards Institute, American Society for Testing Materials, American Society for Civil Engineers, American Concrete Institute, the Structural Engineers Association of California, and numerous others. Grantees have also participated in a wide variety of state, local and regional commissions and bodies, e.g. Participation in these activities is often partially reimbursed by the award from the Foundation.

7. Q. What legislative authority does the National Science Foundation currently have to operate programs related to earthquakes? Please cite sections of the U.S. Code or Statutes.

A. The National Science Foundation's basic act provides authority for the NSF to engage in basic and applied research. The specific authority to engage in earthquake research is inferred through the Foundation's FY 1976 Authorization and Appropriations Bills. We have received specific legislation instructions to support earthquake engineering research through minimum expenditure levels established by NSF's Authorizations and Appropriations.

Mr. SYMINGTON. Thank you very much, Dr. Stever, for being with us this morning. It has been very helpful to us.

We now will be happy to hear from Director V. E. McKelvey of the U.S. Geological Survey accompanied by Robert Hamilton, Chief, Office of Earthquake Studies, USGS. We are glad to have you with us this morning, sir, and we look forward to your testimony.

[Brief biographical sketches of Dr. V. E. McKelvey and Dr. Robert M. Hamilton follow:]

Dr. VINCENT E. MCKELVEY

Vincent E. McKelvey has been Director of the United States Geological Survey since December 8, 1971. He was born in Huntington, Pennsylvania, on April 6, 1916, graduated with honors in Geology from Syracuse University in 1937, received his M.A. (1939) and Doctorate (1947) from the University of Wisconsin, and has been a member of the U.S. Geological Survey since 1941.

Special assignments have included: Consultant, Chief of Engineers, Manila, 1945; Chief, Western phosphate investigations, 1947–1949; Chief, radioactive mineral studies, 1950–1953; Minerals Specialist, USICA-Government of Jordan, 1958; Assistant Chief Geologist, 1960–1964; Department of the Interior Energy Policy Staff, 1961–1971; U.S. Representative and Advisor to Energy Committee, Organization for Economic Cooperation and Development, 1965–1967; Leader, Department of the Interior Study Group, Outer Continental Shelf Oil, Gas, and Sulfur Leasing Policy, 1968; U.S. Representative to Economic and Technical Subcommittee of United Nations Committee on Peaceful Uses of Seabed and Ocean Floor Beyond the Limits of National Jurisdiction, 1968; Chief Geologist, 1971; Chairman, Project Independence Blueprint Interagency Oil Task Force, 1974.

Research publications dealing with the geology of manganese, phosphate, uranium, mineral and fuel resources, marine resources, methods of estimating reserves, prospecting methods, stratigraphy, sedimentation, and mineral economics.

Honors include the Department of the Interior's Distinguished Service Award (1963), Henry Krumb Lecturer for the American Institute of Mining Engineers (1968), Seventh McKinstry Memorial Lecturer at Harvard University (1971), National Civil Service League Award (1972), Rockefeller Public Service Award (1973), and honorary Doctor of Science, Syracuse University (1975).

Dr. ROBERT M. HAMILTON

Dr. Hamilton received the degree Geophysical Engineer from the Colorado School of Mines, Golden, in 1958, and M.A. and Ph. D. degrees in Geophysics from the University of California, Berkeley, in 1963 and 1965, respectively. He engaged in research studies on earthquakes in New Zealand from 1965 to 1968 at Seismological Observatory of the New Zealand Department of Scientific and Industrial Research, then joined the USGS as a Research Geophysicist at the National Center for Earthquake Research in Menlo Park, California. In 1972, Dr. Hamilton moved to Washington, D.C. to become Deputy for Earthquake Geophysics, and in 1973 assumed his current position.

STATEMENT OF V. E. McKELVEY, DIRECTOR, U.S. GEOLOGICAL SURVEY, ON EARTHQUAKE DISASTER MITIGATION

Dr. MCKELVEY. Mr. Chairman, I thank the committee for this opportunity to discuss the Department of Interior's role in earthquake hazard reduction and mitigation and to comment upon several proposed items of legislation concerned with earthquake problems.

The Department is sympathetic to the general objectives of S. 1174, H.R. 13722, H.R. 13845 and is actively involved in the administration's program to accomplish the objective of reducing risks from earthquakes. However, we would point out that the objectives of the bills

can be accomplished under the existing authorities already available to Federal agencies. Indeed, as Dr. Stever has indicated, the National Science Foundation and the Geological Survey are identifying types of earthquake research and their practical applications in developing a research program plan to provide the underlying knowledge to deal with earthquake hazards. The plan is to be available in time for consideration in preparing the 1978 budget.

The U.S. Geological Survey within the Department now has the principal Federal responsibility for earth science aspects of earthquake hazards reduction. Our present program has evolved over the past decades under the administrative guidance of several agencies, including the U.S. Coast and Geodetic Survey and its successors under the Environmental Science and Services Administration, and the National Oceanic and Atmospheric Administration (NOAA). In 1973, the earthquake programs of NOAA were merged with those of the Geological Survey and the Survey was given the responsibility for Federal earth science earthquake research. The USGS also undertakes seismic engineering data-gathering and research on behalf of the National Science Foundation, which has the principal Federal responsibility for earthquake engineering research. As a result of a recent redelegation of authority under the Disaster Relief Act of 1974, the Survey also has the responsibility for issuing warnings of earthquakes and certain other kinds of geologic disasters such as volcanic eruptions and landslides, to the extent that they are predictable.

The Federal program in earthquake research and the Disaster Relief Act Amendments of 1974 were the result of the growing recognition that earthquakes are not only capable of causing enormous losses to life and property, but that the risk of such losses is increasing with urban growth in high risk areas. Dr. Stever has already provided the committee with estimates of damage and risk.

It is useful to think of the consequences of a major earthquake in terms of primary, secondary, and perhaps even tertiary effects—not in the sense of importance but in the sense of the sequence in which they develop. Primary effects are those directly involved in the crustal movement—strong ground shaking, warping of the Earth's crust, and vertical or horizontal movement along a fault at the Earth's surface. Strong ground shaking is the principal cause of damage during earthquakes. Rupture of the ground surface, although rarely the major cause of destruction, can destroy even the largest and best engineered structures that are located on the lines of rupture. Permanent warping of the Earth's surface also can have profound and long-term impact, resulting either in the flooding or draining of facilities along the coast.

These primary effects, of course, can be devastating in their immediate impact on manmade structures. In large earthquakes, however, the principal damage often results from the secondary and tertiary effects—the forces set in motion by the primary shaking and tectonic movement. Transient stresses generated by earthquake waves commonly trigger landslides, differential settlement, and liquefaction and lateral spreading of the ground.

Among the most terrifying secondary effects of some earthquakes are tsunamis. These large ocean waves, as much as tens of feet high, are generated by sudden vertical movement of the ocean floor. The

waves can travel thousands of miles and devastate coastal communities within their reach.

Other secondary effects include destructive seiches or oscillations of the surface of lakes or bays, caused by crustal tilting or major landslides. Flooding resulting from earthquake-induced dam or levee failure may be a greater threat to life and property in heavily populated areas than the primary effects of an earthquake.

Tertiary effects can also be highly devastating. They include fire storms, which are turbulent blasts of scorching air resulting from the large fires that may develop after the earthquake. They may also include the consequences of the panic of people under the stress of a terrifying disaster, and possibly disease and hunger resulting from the disruption of food and water supplies and the destruction of transportation systems. The latter effects were of great concern in the areas in Guatemala struck by the 7.5 magnitude earthquake on February and its aftershocks.

If appropriate measures are taken, damage from these effects can be much reduced and some of the secondary and tertiary effects—such as catastrophic floods from breacheed reservoirs and large fires and fire storms—can be avoided altogether. The capability for earthquake hazard reduction is already in hand to some degree and the results of research already achieved indicate that it can be much advanced by a combination of continued research and the determination to apply the knowledge already in hand. Earthquake hazard reduction involves several components: (a) Improved design of manmade structures to increase their resistance to earthquakes; (b) identification of active faults and areas subject to strong ground motion, landslides and other forms of ground instability as a basis both for improved construction design and engineering and for land use planning and zoning; (c) development of improved capability to predict the time, place, magnitude, and effects of earthquakes; (d) earthquake insurance to spread the economic losses; and (e) emergency preparedness, to utilize most effectively earthquake predictions and to have essential defensive measures at hand even for unexpected disasters.

Implementation of most of these actions is the responsibility of private individuals and State and local civil authorities. Federal agencies such as the Survey, NSF, the Federal Disaster Assistance Administration, and the Defense Civil Preparedness Agency also have responsibilities for implementation and can assist the other groups.

The Geological Survey's part in earthquake hazard reduction is a critical one, and its major program objectives include: (1) Acquisition and dissemination of information on earthquake occurrences; (2) mapping and evaluation of earthquake hazards; and (3) development of an improved capability to predict the time, place, and magnitude of earthquakes. I will briefly describe here some of our activities in these areas.

The Survey's National Earthquake Information Service locates and rapidly evaluates important earthquakes worldwide, provides data supporting the Tsunami Warning System operated by the National Oceanic and Atmospheric Administration, and notifies appropriate disaster authorities and the public within 2 hours of the occurrence. From these data, the Geological Survey publishes seismic risk maps that indicate expectable values of earthquake frequency and levels of

shaking; these are widely used by the engineering community in developing building codes and in assisting in the safe design of structures.

Geological Survey maps and reports on earthquakes hazards are used by planners to avoid areas of greatest potential danger from the destructive effects of earthquakes. Active faults are identified on the basis of seismologic and geologic evaluations. Areas are delineated that could be subject to surface faulting, strong shaking, ground failure, tectonic elevation changes, or earthquake-induced flooding from seismic sea waves or from dam failure. Methods for assessing these various earthquake hazards also are published to enable scientists in the academic community, State agencies, and the private sector to analyze the origin, distribution, and effects of earthquakes.

The Geological Survey also has underway research on the prediction of the time, place, magnitude, and effects of earthquakes. Mounting evidence from the United States and from China, Japan, and the Soviet Union indicates that technology can be developed to predict at least some large earthquakes. Our present efforts are concentrated heavily in central California near the town of Hollister, where small to moderate earthquakes are frequent. We have deployed there various kinds of instruments that monitor the state of the earth over this seismically active region continuously. The data are analyzed at our center in Menlo Park, Calif., to which they are telemetered. Reconnaissance networks of seismographs and other instruments are located in southern California and the San Francisco Bay area and other U.S. urban areas of high risk, but the density is sparse.

Earthquake disasters, of course, are an international threat. The Geological Survey has maintained close contact with hazard reduction efforts in other earthquake-prone nations, especially with regard to development of earthquake prediction techniques. Cooperative studies, including the exchange of scientists, are underway with the Soviet Union. We also participated in an exchange of delegations of earthquake specialists with the People's Republic of China. Geological Survey scientists currently are visiting China as part of a National Academy of Sciences team that is investigating prediction methods used by the Chinese in forecasting a potentially disastrous magnitude 7.3 earthquake that occurred in 1975.

Early this year, analysis of data from precise leveling showed that a large uplift has occurred in the past 15 years in the vicinity of the San Andreas fault in the Mohave Desert just north of Los Angeles, with the land surface rising nearly a foot in the central part of the uplift. The origin of this uplift and its possible relation to future earthquakes is not understood but there is clearly cause for concern. Such uplifts have preceded some earthquakes in the past; but in this very area one occurred earlier this century with no following earthquakes. Copies of our February 13 press release describing the uplift will be provided for the committee.

[The press release follows:]

DEPARTMENT of the INTERIOR

news release

GEOLOGICAL SURVEY

Forrester (703) 860-7444

For release: on Receipt (prepared February 13, 1976)

LAND SWELLING IN SOUTHERN CALIFORNIA DISCOVERED

Recent land uplift of as much as about 10 inches (25 centimetres) has been discovered astride a large section of California's San Andreas fault about 40 miles north of Los Angeles, according to scientists of the U.S. Geological Survey, Department of the Interior.

The land swelling, in the shape of a huge kidney, has a 120-mile axis oriented roughly east-west and extending from the Pacific Ocean into the Mojave Desert. This uplift is receiving close attention among USGS earthquake specialists because similar swelling has occurred prior to some earthquakes in California and elsewhere. The scientists emphasize, however, that such uplifts also have occurred without subsequent earthquakes.

Discovery of the uplift was made by R. O. Castle, J. P. Church, and M. P. Elliott, scientists at the USGS Menlo Park, California field center.

Centered north of Los Angeles near Palmdale in the western Mojave Desert, the swelling apparently began about 1960 near the junction of the San Andreas and Garlock faults. Since then, it has grown east-southeastward to include an area of about 4,500 square miles (12,000 square kilometres).

The uplift discovery resulted from analyses of repeated measurements taken over a number of years along precisely surveyed elevation lines crossing the southern California region. The measurements were made by various organizations, including the USGS, the National Geodetic Survey, and several southern California municipalities and counties.

The significance of the uplift is not fully understood, according to USGS scientists; they are concerned, however, because it occurs astride a sector of the San Andreas fault that has remained "locked" since a great earthquake in 1857. Thus, the scientists explain, considerable strain could be building up in this area.

(more)

Dr. Robert M. Hamilton, Chief of the USGS Office of Earthquake Studies at the Survey's National Center, Reston, Virginia, said that, following the 1971 San Fernando earthquake, analysis of data collected earlier indicated that similar swelling had preceded that quake. Uplift has also been determined to have preceded earthquakes in other parts of the world, including uplift in Japan that started ten years before a destructive earthquake at Niigata in 1964.

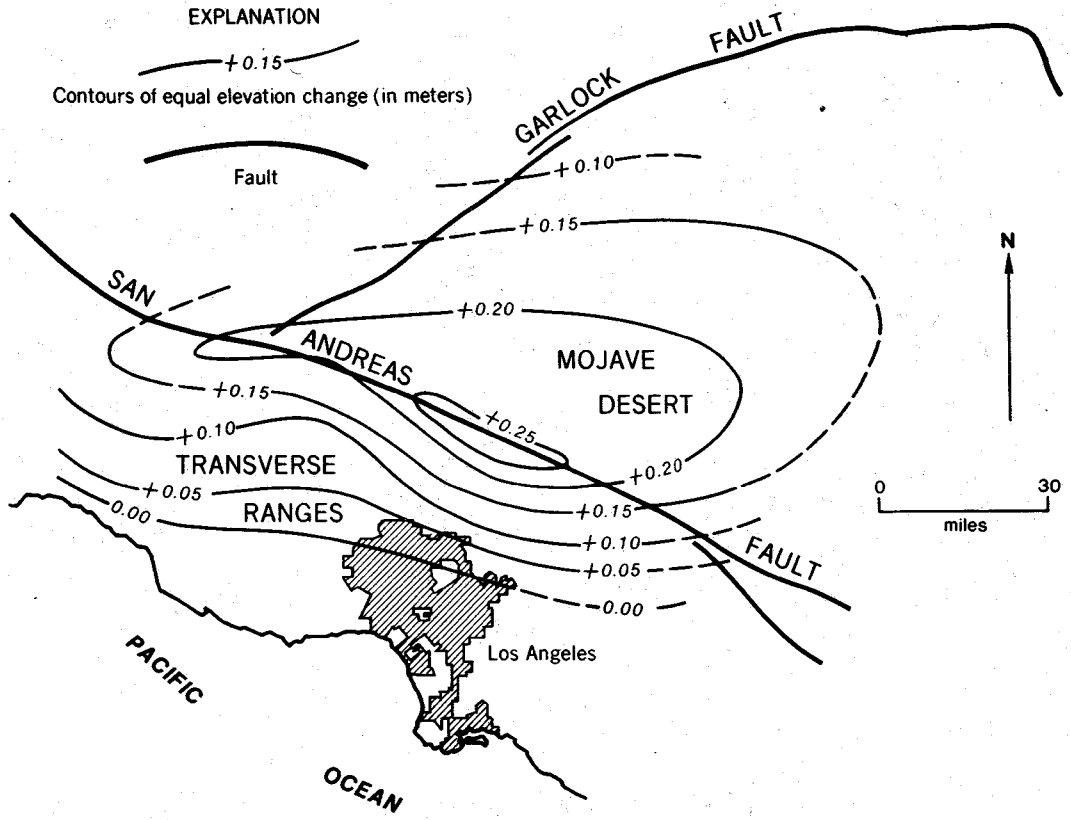
"However," Hamilton emphasized, "such uplift also has occurred without being followed by earthquakes. For example, an uplift may have occurred between 1897 and 1914 within the Transverse Ranges north of Los Angeles, but no large earthquake followed. Consequently, the present swelling may or may not indicate that an earthquake is coming. We must not jump to conclusions based on geodetic data alone."

"Considerable additional information on the land deformation and seismic activity in the region is needed before we will be able to evaluate the significance of the uplift," Hamilton said.

Hamilton reported that some new studies of a limited nature are being started aimed at getting a better understanding of the uplift occurrence. He said that the new studies include additional geodetic surveys, installation of seismometers and tiltmeters (devices for monitoring of minute changes in the ground surface), and surveys of the Earth's gravity field in the region. "We hope that these new limited investigations will provide at least some information on the cause of the observed uplift," Hamilton said.

# # # #

(Note to Editors: See attached diagram showing area of uplift.)


EXPLANATION
+0.15
Contours of equal elevation change (in meters)
Fault
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FAULT
+0.10
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ANDREAS
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MOJAVE
DESERT
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FAULT
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miles

Continued analysis of elevation of data by our scientists now demonstrates that the area of uplift is much more extensive than originally noted. A region of more than 10,000 square miles—extending from the Tehachapi Mountains to the Salton Sea—appears to have risen since 1962. Furthermore, analysis of horizontal geodetic data indicates that a period of anomalous horizontal shear strain coincided with the development of the uplift.

In March, we met with the staff of the California Congressional delegation and with the staff of Governor Brown to brief them on the uplift. The Geological Survey pointed out that while some evidence can be interpreted as precursory to a major earthquake in the south California region, there is no basis at present for predicting the time it will occur. The sum of the geologic and seismologic evidence, however, led us to warn that a great earthquake would take place in the region sometime in the future and that preparedness actions are justified.

Clearly, there is a critical need for evaluation of the significance of the southern California uplift. I am pleased to report that the President recently has approved increases in our fiscal 1976 earthquake budget to expand observation and analysis of the uplift. We have begun to monitor geophysical phenomena in the area of the uplift more intensely and will increase studies of potential earthquake hazards of the region. The National Oceanic and Atmospheric Administration, through its National Geodetic Survey, is cooperating in studies of the uplift. NGS now is involved in an intensive effort at evaluating all leveling and gravity data in southern California, and will work with the Geological Survey to provide an integrated picture of the land elevation changes in the southern California area.

I mentioned earlier the responsibility recently redelegated to the Survey with respect to the issuance of warnings of impending disasters of geologic origin. Frankly, however, the capability to issue warnings is very limited, particularly with respect to predictions as to the time an event will occur. As an initial step in responding to this expanded responsibility, however, the Geological Survey currently is reviewing its capabilities for prediction of natural disasters and is developing procedure for issuance of the tentative predictions we are able to make so that they can be used most effectively by local authorities.

In carrying out the responsibilities under the Disaster Relief Act, we will be in a difficult position while an earthquake prediction capability is being developed. The impact of incorrect predictions, a subject presently under review, could be socially and economically adverse. Prediction research is a complex and difficult program and the period of uncertain and inaccurate predictions could well stretch over the next few decades. We are looking at possible ways to reduce this period of uncertainty.

Mr. Chairman, in your June 9 letter to Secretary Kleppe inviting us to appear today, you asked that we discuss, among other things, how Interior's efforts are coordinated with those of other agencies and what is the expected future role of the Department of the Interior in earthquake hazard reduction. Speaking first to the matter of coordination, let me say that the reorganization accomplished in 1973 and the placing of responsibility for earthquake hazard reduction research in the Geological Survey and the National Science Foundation did

much to reduce the coordination problem. Between the NSF and the Survey, NSF is responsible for earthquake engineering and the Survey is responsible for Earth science aspects of earthquake hazards reduction, and coordination is accomplished by direct and frequent contacts between the two agencies.

Other organizations, however, have certain activities or interests in our research, including the National Oceanic and Atmospheric Administration, the National Bureau of Standards, the National Academy of Sciences, the Bureau of Reclamation, the National Aeronautics and Space Administration, the Nuclear Regulatory Commission, the Department of Housing and Urban Development, the Defense Advanced Research Projects Agency, the Veterans Administration, and the Federal Highway Administration. Representatives of these agencies are liaison members of the Geological Survey's Earthquake Studies Advisory Panel, which meets twice a year to review the USGS earthquake research program. This panel has been very effective in permitting the exchange of information and in the coordination of program development.

Currently, we are working closely with Dr. Stever to prepare a program plan identifying types of earthquake research and applications for reducing earthquake hazards. The plan will be considered in developing the 1978 and future budgets. This planning effort is intended to assure that Federal earthquake studies are well designed and coordinated, and that research products will be effectively utilized by State and local governments and the private sector. Last week, Dr. Stever convened a panel of earthquake specialists from outside the Federal Government to help develop this comprehensive program plan.

Three bills are under review today:

S. 1174 as passed by the Senate would authorize increased levels of research in earthquake hazards reduction research by the Geological Survey and the National Science Foundation and would establish earthquake disaster mitigation as a national objective. It also would provide a new coordinating structure for a national earthquake program. The bill would authorize specific amounts of appropriations in three parts—for the USGS, for the NSF, and for the general program.

A key element of S. 1174, as passed, would be the establishment of an advisory committee to the President composed of representatives of the research community (including the design professions), and Federal, State, and local entities concerned with earthquake hazards, and qualified individuals experienced in earthquake hazard research, planning, implementation, or preparation. This advisory committee apparently would perform a similar function to the USGS Earthquake Studies Advisory Panel, but have a somewhat broader scope.

H.R. 13722 would establish Federal and National councils to develop comprehensive programs for earthquake prediction and preparedness that would be submitted to the President and Congress.

The bill would establish a Federal Council composed of six heads of Federal agencies or organizations concerned with earthquakes. The Council would be required to develop and submit to the President and the Congress a plan for all aspects of Federal earthquake research and hazard reduction.

The research would be conducted by the Geological Survey and the National Science Foundation in coordination with research efforts of State and local governments and the academic community.

The bill would also establish a National Board on Earthquake Prediction, Preparedness, and Coordination composed of eight heads of Federal agencies concerned with earthquakes and four representatives of the States. The Board would be required to develop and submit to the President and the Congress a plan for seismic risk mapping, a proposed earthquake prediction system (to be operated by the Geological Survey), and a program for expanded preparedness planning. The Federal Disaster Assistance Administration would be responsible fo rconducting the earthquake preparedness program.

H.R. 13722 is concerned primarily with the development of a program plan for Federal research into earthquake prediction and emergency preparedness, and with coordination of research efforts with those of State and local governments, the academic community, and foreign governments. As I have already mentioned USGS and NSF currently are developing such a program plan in conjunction with a broadly representative panel of non-Federal experts.

H.R. 13722 assumes a much more advanced state-of-the-art in earthquake studies than actually exists. For example, it specifies that the program plan of the National Board shall divide the country according to relative seismic risk. H.R. 13722 would also specify an earthquake prediction system for areas of high seismic risk without considering that earthquake prediction itself is in a research phase and that the methods and instruments for forecasting have not been fully determined.

H.R. 13845 seems to emphasize earthquake prediction over other hazard mitigation aspects. It calls for earthquake preparedness planning without giving adequate attention to the development of capabilities in earthquake engineering and the mapping and evaluation of earthquake hazards.

H.R. 13845 would establish a management structure for a national earthquake hazards program that would coordinate activities of existing agencies. A Conference of Federal, State, and private sector representatives would evaluate the status of earthquake hazards reduction and recommend appropriate legislation.

The Conference is a committee comprised of 29 members, including 23 who are officials of Federal agencies or organizations concerned with earthquakes and 6 who are appointed by the Secretary of HUD and are not in the Federal Government. In addition, there would be four nonvoting members from Congress. An Executive Committee of the Conference would also be established.

Although the concerns addressed by H.R. 13845 are real, the bill would nevertheless establish a very cumbersome mechanism for assuming responsibilities that would normally belong in a Government agency. The oversight function is partially being carried out by the USGS Earthquake Studies Advisory Panel, which has liaison representatives from all agencies with a strong interest in earthquakes. We also note committee representation would include many agencies that have only a minor interest in earthquake problems. Furthermore, insofar as H.R. 13845 establishes a new mechanism to evaluate the

earthquake problem, it duplicates and retraces the steps of numerous published studies both in and out of government.

One of the duties of the Conference is to establish an earthquake prediction board to evaluate predictions and issue authenticated predictions. This warning responsibility currently is assigned to the USGS under the Disaster Relief Act of 1974 and subsequent redelegations of authority.

The Conference would be authorized to issue contracts for research and implementation studies. This authority currently rests with the USGS and NSF.

It appears that the authority for accomplishing an effective earthquake hazards reduction program is presently available to the executive branch. Indeed, we recommend against enactment of any of the bills because we believe adequate authority to conduct, research, and to coordinate existing Federal efforts already exists. But let me add that the administration is moving to survey its present efforts with the objective of evaluating possible substantive additions to the program and assuring a specific program of coordination; and, as Dr. Stever has mentioned, will recommend legislation if it is needed to supplement existing authorities.

The research program plan being developed by USGS and NSF has not been completed, but its form is clear. It will be based on research in three broad areas: Earth sciences, engineering, and socioeconomic problems. The objective of these studies is an understanding of earthquakes sufficient to predict their occurrence, modify their activity, reduce structural damage, and provide the information needed for decisionmakers to design the institutions necessary to prepare our citizens for both preparation for earthquakes and the recovery from earthquakes. Our knowledge in each of the three research areas varies in quantity and quality—for example, prediction is at an embryonic stage, whereas zoning for earthquake hazards is being implemented by local and State entities. A major operational program in all aspects of earthquake mitigation, therefore, would be premature at this time.

Concerning earthquake research, one of our primary problems is the structure of such a broad ranging program. Within the administration, considerable attention is being given to determining the priority among program elements, both with regard to timing and funds. Some problem areas may simply not be benefited by rapid expenditures, while others may effectively be addressed by relatively brief, intensive studies.

For example, the payoff to society in prediction research is highly dependent upon the leadtime and accuracy of any prediction capability we develop. A very accurate prediction with a long leadtime can provide substantial benefits and will exact relatively low costs. For example, unsafe structures would be evacuated, reservoirs would be lowered and other measures would be taken for only short periods. These measures could be quite costly if our prediction capability cannot be made reliable. Two questions we must consider are, How good our prediction capability must become in order to justify spending significant sums on earthquake prediction, and will significant funding provide this capability? Such questions may also be posed for other elements in our earthquake program. Indeed they are common to all research where the outcome is uncertain.

Mr. Chairman, that concludes my testimony. Dr. Hamilton and I will be glad to answer the committee's questions.

Mr. SYMINGTON. Thank you, Dr. McKelvey.

Dr. Hamilton, did you wish to speak at this time?

Dr. HAMILTON. I have nothing now.

Mr. SYMINGTON. I want to thank you for that thorough exposition of the on-going work of the Government in this area. I think it would be helpful to the committee if you could submit a statement of the dollar amounts obligated by your organization to earthquake work in 1974, 1975 and 1976 and the plan for 1977.

Dr. MCKELVEY. We would be happy to do that.

Mr. SYMINGTON. We would like that broken down into major categories or even into subcategories, if possible, and we would like to have shown the separation of the inhouse work from those things done under grants and contracts outside and where those went, a real breakdown of the budget for earthquake relevant work.

Maybe you could tell us a little bit about your support for data collection and instrumentation at the Palmdale uplift, the dollar amounts and the number of instruments. Perhaps you could tell us something about that now.

Dr. MCKELVEY. I will ask Dr. Hamilton to give some details on this, but I may just say that we have, since we recognized the uplift in the latter part of 1975, taken steps to augment our observation program there. And the National Geodetic Survey, as I mentioned in my testimony, has joined with us in a resurvey of a number of the leveling lines in that area to acquire more recent information and we are in the process of installing additional instruments in a stepped up program authorized by the President and also described by Dr. Stever, which amounts to an increase of $2.1 million for studies in that area.

I will ask Dr. Hamilton to supplement that with more detail.

Dr. HAMILTON. $2.6 million is being made available for augmented studies in southern California. It includes $2.1 million for the uplift studies and $500,000 for restoration of requested cuts in the earthquake program. The $2.6 million is being provided 50–50 by the NSF and the Geological Survey. The $1.3 million from NSF has been received by the USGS in the form of a grant. The funds from the Geological Survey are currently awaiting approval from congressional committees, the House Appropriations and Senate Appropriations Sub-Committees. The request has gone from the Department of Interior and we expect action perhaps by the end of the week, at least from the House committee.

Mr. GOLDWATER. Are these reprogramed funds?

Dr. HAMILTON. Yes.

Mr. GOLDWATER. So you are just waiting for approval of the reprograming?

Dr. HAMILTON. Yes. We have a request for reprograming $1.1 million of fiscal year 1976 and $200,000 of the fiscal year 1977 effort to make the total of $1.3. What we are currently awaiting is the approval for the reprograming of the $1.1 million.

The $2.1 million for studies of the uplift would be used primarily for instrumentation of the uplift region to detect further anomalies and also for studies predicting the effects of a possible earthquake in the Los Angeles region. The funds will be spent both within the Geo-

logical Survey and outside. We have estimated that about $1.24 million will be spent outside through contracts with universities, private industry, and State and local governments, and $860,000 will be spent inside. We have just issued a request for proposal; the closing date on that is July 30.

We will be funding approximately $1 million through the request for proposals. The studies will be comprehensive. They will include a wide variety of instrumentation, seismographs, magnetometers, and tiltmeters and a lot of surveys—leveling, triangulation, et cetera.

Mr. SYMINGTON. Mr. Mosher, do you have any questions?

Mr. MOSHER. Mr. Chairman, maybe I should mention that I recently had the privilege of spending several hours at Menlo Park, the center there. I found it fascinating and impressive and I would urge that other members of the committee go there. They are going to be moving into larger, more efficient headquarters. And I think that will be helpful. I was impressed.

You now have been delegated the authority, and, I judge, the responsibility to issue warnings of impending earthquake disasters but you really don't as yet have the capability to give very precise warnings. Dr. McKelvey indicates on page 8 that it may be several decades before you actually have adequate information. This must be very troubling to all involved as to just how you go about living up to this responsibility within your capacity. I notice, Dr. McKelvey, that on page 7 you say that in March you met with the staff of the California congressional delegation and the staff of the Governor. Is that the procedure that you probably would follow now as you get evidence that there is a serious earthquake impending, even though you cannot say precisely when or where?

Is that the first step in meeting your responsibility, to sort of informally and behind the scenes discuss this with the State and local officials? Is that the extent to which you dare go as of now?

Dr. MCKELVEY. I would not call it informally and behind the scenes.

Mr. MOSHER. I did not mean that in any derogatory sense.

Dr. MCKELVEY. We are presently trying to develop procedures that we would follow and will follow, recognizing that we are at the very beginning of an entirely new process and whatever we develop and conclude now certainly will be modified by experience as time goes on.

Last November we held a conference in San Francisco to which we invited the Governors of nine Western States, the mayors of some of the larger cities, and other public officials for the purpose of discussing just how we would handle the prediction problem.

We outlined a plan at that time which was generally well received. When a prediction is developed we would have a process for authenticating it and then for notifying the State and civil authorities who then would have the responsibility for issuing a warning in the sense of both a prediction and advice or instructions as to what to do. That authority clearly rests with the civil authorities and is beyond both the authority and competence of the Geological Survey and other Federal agencies.

Mr. MOSHER. You are indicating that the responsibility for going public with this in terms of potential newspaper headlines and that sort of thing lies with the local authorities?

Dr. McKELVEY. What we proposed, tentatively, at that time was that we would first notify the State and local authorities and would delay perhaps for a day or two a public announcement of the prediction in order to give the State and local authorities a little bit of leadtime in developing a warning that would accompany the prediction. But certainly a public announcement would need to be made rather quickly following authentication of the prediction. We would not propose delaying that long if the State authorities did not themselves make the announcement.

Mr. MOSHER. In other words, your agency would not hesitate to make a public announcement?

Dr. McKELVEY. No; quite to the contrary, Mr. Mosher. We feel a very weighty responsibility to the public to make known the results of any prediction that would be developed by the Geological Survey.

Mr. MOSHER. Even though that could bring down upon your head furies of all sorts?

Dr. McKELVEY. We are aware of that possibility and shudder to think about it, but it is a responsibility that we cannot imagine could be vacated by the Geological Survey. I certainly agree that the prospects that we face, in the period in which the development of predictions will involve some uncertainty, is very disturbing and worrisome to all of us.

I mentioned the components of a prediction as consisting of a prediction of the kind of event that will take place, where it will take place, what its magnitude and effects will be, and when it will take place. It is that time component in which there is greatest uncertainty now and which will give us the most trouble.

This is the kind of uncertainty involved with the Palmdale uplift. We know that there is going to be a very large magnitude earthquake in that area sometime, but we don't know when. That kind of uncertainty may plague us for a very long time into the future. The kinds of premonitory phenomena that we are recognizing are ones in which there is a buildup over a period of time and then some sort of return to normalcy just before the earthquake takes place.

Until those very near-term premonitory signals are recognized all you know is that you are building up for an event sometime in the future. In the case of the Palmdale uplift, we know that uplifts of this kind have preceded some earthquakes, so we have to regard this as a premonitory signal. We felt that even though we were unable to say when, that it was incumbent upon us to inform the civil authorities of what is going on and its possible significance. I was very pleased, Mr. Mosher, in our meeting with the Governor's staff in Sacramento in March that they recognize the value and significance of having that kind of a warning even though we are unable to even approximate the time at which such an event would occur. And they indicated that they would take steps to respond to it and indeed have since then.

Specifically, a statement was made that as public officials responsible for public safety in California they recognize that even a very long-term prediction is one that is important for them to know about in order to take steps to defend against the disaster that might be involved.

Mr. MOSHER. Mr. Chairman, just let me make one further comment: It seems to me that the gist of Dr. McKelvey's testimony and also that

of Dr. Stever for that matter, is that the various executive agencies are fully aware of the problem and also feel that they now have adequate authority to do what needs to be done.

They might welcome some more money, but probably OMB does not give them the authority to ask for more money. I judge they are sort of telling us not to panic. Don't push us too fast. We have the authority and we're trying to pull ourselves together to do the job.

Dr. McKelvey, does that accurately indicate the gist of your testimony and if it does, are you satisfied with the present coordinating mechanisms in this area? Do you feel that the various right hands know what the various left hands are doing, or do you think it is necessary to find some mechanism to carry out these responsibilities? Even though it is out on the fringe, you referred to the bill I introduced as bringing in some people having very meager responsibilities or interest, but nevertheless we do bring them in. Do you feel that the present mechanisms are adequate?

Dr. McKelvey. Mr. Mosher, I feel that in the area of the research effort on both the science and engineering side that the coordination efforts presently in place are adequate. Through the mechanism that Dr. Stever mentioned, the informal group that meets frequently, and also through the USGS Earthquake Studies Advisory Panel, which meets at least twice a year, all of the agencies with a direct concern in those areas are well coordinated. I am sure anyone who has attended them will attest that those meetings have been very effective in keeping the agencies informed of each other's activities and in a very broad way coordinating their efforts.

However, there is the problem of coordination in the broader sense, as Dr. Stever indicated, which is difficult. I am sure it is adequately addressed. I am not sure that either your bill or any of the other ideas as to how to go about it really would be effective with regard to the problem.

Certainly, there are many agencies beyond those I mentioned in my testimony with a more or less direct concern with regard to earthquake studies. Beyond them there are many other Federal agencies that would have some involvement in an earthquake disaster if one should occur. For example, there is the Small Business Administration which is not mentioned here. It has a direct interest in earthquakes. But if there were a major disaster and it was anticipated, certainly the officials of the Small Business Administration would be concerned in preparing for it. Similarly, I expect the Internal Revenue Service would too.

One can go on through agency after agency. I think someone counted upward of 50 Federal agencies that might have some involvement or need for preparedness actions. The question of just how to address that is very difficult.

With respect to the matter of earthquake prediction, per se, the Geological Survey proposed in the plan that I described to you and which was presented at the conference in San Francisco last fall an earthquake prediction council which would have the responsibility of authenticating a prediction made within the Geological Survey or submitted to it from someone on the outside. We proposed at that time that the council would be composed both of Geological Survey experts and members from the outside, experts on earthquake prediction. But

as we have turned that around and recently discussed it with our Earthquake Studies Advisory Panel, we have come to realize that that formal body might really be too inflexible to deal with some of the kinds of problems that might be faced. Precursor signals might appear possibly only a day or two in advance of an earthquake. It might be very difficult to even convene such a formal body on such short notice. So our own thinking with respect to that part of the problem has been that we could need to shift to a more flexible arrangement, still maintaining the general structure of reviewing and authenticating an earthquake prediction but without establishing a formal body responsible for it. That is the kind of problem I think which has to be recognized in this general area.

Mr. GOLDWATER. Dr. McKelvey, I assume the answer is no.

Dr. MCKELVEY. I tried to indicate, Mr. Goldwater, that I think the coordination problem is adequately——

Mr. GOLDWATER. Why does the administration come up with a program that obviously does not address the question? Why don't you and Dr. Stever and who else get together and come up with a comprehensive program, not just prediction and warning, but research, the whole program?

Dr. MCKELVEY. Part of the program is under development. And as Dr. Stever and I indicated, the administration will come out with it.

Mr. GOLDWATER. I do not think the program is under development. You have a study out which talks about one aspect of it. You are talking about USGS and National Science Foundation in the area of research and dollars and predictions and scientific work. But you have talked here with response to the question Mr. Mosher asked you, are you satisfied that we have a program? You said no and then you went on to enumerate numerous areas that were not adequately treated.

Now this study that you have out is not going to address all of those areas.

Dr. MCKELVEY. It is not presently addressing the coordination problem. But, as I indicated, I think that this is an extremely difficult problem and one that needs to be looked at.

Mr. GOLDWATER. It becomes less difficult when you begin addressing it. I would like to ask you, Dr. McKelvey, did you make a prediction here today? You said that there will be an earthquake in the Los Angeles area, around the Palmdale uplift, is that a prediction?

Dr. MCKELVEY. It is a prediction of a kind.

Mr. GOLDWATER. Has it been publicized in the Los Angeles area?

Dr. MCKELVEY. Yes; I think it was well publicized by the California press.

Mr. GOLDWATER. You have not given a certain date, have you?

Dr. MCKELVEY. Indeed not.

Mr. GOLDWATER. I thought we would make some news here today and issue a warning.

Dr. MCKELVEY. We are unable to do that, that is, to issue or predict when such an event will occur, but we can say with great certainty that an earthquake of large magnitude will occur in the future.

Mr. GOLDWATER. Is this supported in the scientific community?

Dr. MCKELVEY. Yes; it is, Mr. Goldwater.

Mr. GOLDWATER. I was interested in your discussion with Mr. Mosher. There are two things involved here. We have prediction which is a

scientific technical accomplishment and you have warning which is a political phenomenon.

Do I understand correctly that the policy of at least the USGS is not to get involved in a political decision, the political aspects of earthquake warning and leave that up to the local elected officials?

Dr. McKelvey. Mr. Goldwater, we are presently developing, as I indicated, the procedures that would be followed. Whatever we do certainly will be on a provisional basis.

Mr. Goldwater. In other words, you do not have a policy today in that regard?

Dr. McKelvey. Our thinking today is—and this is what we have already followed in the case of the Palmdale uplift—that we would distinguish between a prediction and a warning, a prediction being a forecast that an event is going to happen and the warning consisting of instructions or advice as to what to do about it. The warning would be issued by civil authorities who have that responsibility.

Mr. Goldwater. Are those Federal civil authorities?

Dr. McKelvey. No; State and local civil authorities. The Disaster Relief Act of 1974 establishes the responsibility for issuing a warning and that responsibility, as I indicated, has been redelegated to the Geological Survey. It does not make a distinction between prediction and warning.

Mr. Goldwater. There should be, should there not?

Dr. McKelvey. I believe there should be.

Mr. Goldwater. And do I understand, yes or no, that USGS has a policy in this area?

Dr. McKelvey. The policy we have at the present time is that we would issue the prediction and the civil authorities would issue the warning.

Mr. Goldwater. How long has the USGS been involved in the earthquake business?

Dr. McKelvey. Probably 75 or 80 years in one way or the other.

Mr. Goldwater. OK, just recently to the magnitude you are today? How recent is that? I guess what I'm trying to get at is: Is your activity, the current activity, a recent phenomenon?

Dr. McKelvey. The direct funding of earthquake studies I believe began about 10 years ago at the level of about $1 or $1.5 million per year and then as a result of studies that were made and recommendations developed in the scientific community. In fiscal 1973, the program was stepped up to a level of about $5.6 million and in 1974 to a level of $8.7 million. So the acceleration in the earthquake hazard reduction studies took place about 3 years ago and you might say that the focus on earthquake hazard reduction took place in the late sixties.

Mr. Goldwater. Thank you.

Dr. Hamilton, it occurs to me that we are fortunate to have you involved in this program. I notice by your background that you have a long association in these areas of concern that we are talking about today and that you are a graduate of the Colorado School of Mines and Berkeley and have taken part in a number of research programs concerned with earthquakes. I am wondering from your vantage point—we have heard about the China phenomenon—are we realistically close to dealing with and predicting earthquakes accurately?

Dr. HAMILTON. I am very familiar with the China phenomenon. I was privileged to travel there in October 1974 with the American delegation and so I had a firsthand view of the work going on there.

Mr. GOLDWATER. I believe you wrote a paper on that.

Dr. HAMILTON. I was one of the authors of the comprehensive report published on earthquake research in China. The Chinese achievement is certainly a great one. There is no doubt that they saved tens of thousands of lives through their prediction. They have also made numerous false predictions. They readily concede this. There have been many errors in the program. So the capability that they have is not a reliable capability, but indeed it has saved many lives. In the United States, we are now in the situation where we have deployed many instruments and we are observing signals that show anomalies similar to what have been observed in other countries.

So we are faced with the problem of trying to interpret those anomalies and provide the best information we can. The difficulty is that we do not have enough experience to have established a track record as to how these anomalies behave. For example, the earthquake that occurred in central California on Thanksgiving Day a couple of years ago showed a magnetic anomaly that occurred before it, a very clear anomaly. That is the only anomaly we have seen. It was a variation in the Earth's magnetic field that preceded the earthquake.

Mr. GOLDWATER. And you were able to measure this?

Dr. HAMILTON. Yes. But that is one anomaly and one earthquake. Now the next time we see an anomaly we will think there is probably going to be an earthquake, but maybe that time there won't be one. Then we will have a 50–50 record. What I am trying to say is that while we are trying to develop a sound theoretical basis we are largely in an empirical situation where we can base our predictions only on the track record.

Mr. GOLDWATER. Do we have a cooperative effort around the world in this so we can maximize the experiences?

Dr. HAMILTON. There is very good cooperation. We have a good exchange program with the Soviet Union, a fairly good exchange program with Japan, and the exchange with China is picking up. We have a delegation there right now. Those are the main countries engaged in earthquake research. We feel that we have fairly good access to the progress that is being made.

Mr. GOLDWATER. Is everybody talking the same language and is all of the information going to be compatible so far as standards and instrumentation?

Dr. HAMILTON. Pretty much. I do not think there is any reason to try to standardize on instrumentation at this point. There are still so many questions unresolved that diversity is of great value. But we are all talking to each other. We know each other and there is a lot of communication back and forth. I think we in the United States are in an excellent position to pick up on any new developments in these three countries.

Mr. GOLDWATER. Thank you, Mr. Chairman.

Mr. SYMINGTON. Thank you, Mr. Goldwater. It has been a very interesting discussion. I wish we could pursue it. Just one last quick question, and I'm hoping for a brief answer from Dr. McKelvey:

Given the fact that there is some kind of time bomb situation involving an earthquake in California and the need to improve the prediction skills so that you can get closer to the precursors and all of the different varieties and possibilities, do you think the funding that is currently invested in an effort to refine our prediction is sufficient? And if not, do you have a level which would appear to be appropriate and which you would recommend?

Dr. McKelvey. I do not think it is sufficient to develop the prediction capability as rapidly as it probably could be developed with the capability that exists.

Mr. Symington. On that point, as I asked you earlier, as to the 1977 dollar amount which you are going to submit—do you happen to have it in your head at the moment?

Dr. McKelvey. The 1977 request before Congress presently is for $10.5 million.

Mr. Symington. Do you consider that adequate?

Dr. McKelvey. I do not believe it is adequate to develop a prediction capability as rapidly as could be done.

Mr. Symington. Do you have in mind a figure that would?

Dr. McKelvey. We have proposed various levels, Mr. Chairman, and this is presently one of the tasks that we are working on with NSF and that will be reviewed by the panel that Dr. Stever spoke about in time for consideration in the 1978 budget.

Mr. Symington. I understand, but in the consideration of the 1977 budget you settled on a figure of $10.5 million which you yourself do not think is adequate. I am asking you what in your own mind would have been better suited to absorb these talents which are available to you today. You must have a prediction?

Dr. McKelvey. I don't know that I can give off the cuff, Mr. Chairman, figures that were considered in the development of the 1977 budget.

But certainly, as you indicated, more could be used. Scientific talent in this area could have carried out a larger effort than was actually proposed.

Mr. Symington. Were you involved in those discussions?

Dr. McKelvey. I was involved in the discussions in the development of the survey's budget.

Mr. Symington. I mean the discussions that led to the decision to go with $10 million for 1977.

Dr. McKelvey. No, I was not.

Mr. Symington. Did anybody report to you as to how the discussions went?

Dr. McKelvey. No, I did not receive any information as to any discussions.

Mr. Symington. Were you consulted as to whether or not $10 million was an adequate figure?

Dr. McKelvey. As the President's budget is finally drawn up, of course, priorities have to be balanced.

Mr. Symington. I understand that, but before you can compromise you have to know what the extremes are. So I just wondered if you were consulted and if you had indicated your feeling that you could not really get what was necessary. Could you tell us what the figure was?

Dr. McKELVEY. I am not sure I understood your question, Mr. Chairman.

Mr. SYMINGTON. Before they decided on the figure of 10 they undoubtedly considered other figures. Wouldn't you say that is so? They just didn't pull it out of the air? Would that be true?

Dr. McKELVEY. They certainly considered the proposed level submitted by the Department.

Mr. SYMINGTON. Department of the Interior?

Dr. McKELVEY. Department of the Interior.

I can't recall, Mr. Chairman, what the level of funding that was recommended or requested by the Department actually was.

Mr. SYMINGTON. Would it be possible to get that figure for the committee?

Dr. McKELVEY. Yes.

Mr. SYMINGTON. I take it that figure would be closer to a reflection of your concern as to what could profitably be used.

Dr. McKELVEY. The Department also has to balance its priorities, Mr. Chairman.

Mr. SYMINGTON. That brings us down to your own original figure which was cut by the Department and again by OMB. What would that be?

Dr. McKELVEY. I would have to supply that, Mr. Chairman.

Mr. SYMINGTON. So now we can have three figures. The first we know, since it is in the budget. The second is what Interior proposed and the third is what you proposed internally. Would that be possible?

Dr. McKELVEY. Yes.

Mr. SYMINGTON. That would be fine because we are anxious to know what people who are intimately connected with this process have to say about it. That is why we have you here as a witness. It shouldn't be any secret really. We want to hold everybody accountable in the Federal bureaucracy for the proposals they make. And if we do not know what they are, it is difficult for us to perform that function.

Are there any other questions for Dr. McKelvey?

[No response.]

Mr. SYMINGTON. If not, I want to thank you very much for your thorough and informative testimony.

Dr. McKELVEY. Thank you, Mr. Chairman.

[Further questions in written form were submitted to Dr. McKelvey. The questions and responses follow:]

1. Q: Please submit a statement of the dollar amounts obligated by USGS for earthquake work in fiscal years 1974, 1975, 1976 and 1977 (planned). The statement should be broken down into major categories and further into subcategories if this is informative. In-house work should be separated from work under grants or contracts.

A: The total funds obligated for the Earthquake Hazard Reduction Program are:

Fiscal Year	1974	1975	1976
Funds	$8.6M	$10.9M	$11.1M

The apparent increase from 1974 to 1975 resulted from a transfer of earthquake programs from NOAA to USGS.

In FY 1977 the President requested a reduction of $0.7M in the Earthquake Hazard Reduction Program. Both the House and Senate appropriation subcommitteees restored the reduction, as did the conference committee.

A detailed breakdown of the fund distribution for FY 1975 on the next page shows the program balance according to topic and internal vs. external project. The percentages for FY 1976 are very similar.

Earthquake Hazard Reduction Program

(1,000$)

Program Objective	FISCAL 1975 Internal Projects	USGS Service in Support of External Proj.	External Projects	Total
EARTHQUAKE DATA SERVICES	159.5	1,726.4	--	1,885.9
% of Grand Total				17%
EARTHQUAKE HAZARDS:				
Risk and Ground Motion	660.4	--	55.5	715.9
Recurrence	118.1	--	20.0	138.1
Ground Failure	150.0	--	--	150.0
Mapping & Evaluation	662.0	--	170.1	832.1
Earthquake Tectonics (Geophysics)	644.6	--	227.0	871.6
Earthquake Tectonics (Geology)	962.2	--	19.7	981.9
Subtotal	3,197.3	--	492.3	3,689.6
% of Grand Total				34%
EARTHQUAKE PREDICTION:				
Seismic Studies	1,579.3	85.8	970.1	2,635.2
Crustal Deformation	1,238.3	--	259.1	1,497.4
Electrical Resistivity	--	23.8	123.3	147.1
Geochemical Indicators	--	--	35.0	35.0
Fluid Pressure Effects	--	--	145.7	145.7
Rock Properties at High P&T	246.6	--	89.9	336.5
Source Studies	227.8	--	42.8	270.6
Stress Determination	69.2	--	72.0	141.2
Subtotal	3,361.2	109.6	1,737.9	5,208.7
				48%
OTHER	23.6	75.8	7.7	107.1
% of Grand Total				1%
TOTALS	6,741.6	1,911.8	2,237.9	10,891.3
% of Grand Total	62%	18%	20%	100%

2. Q: What are past, present and planned USGS efforts in earthquake modification?

A: Geological Survey efforts in earthquake modification followed the discovery in 1966 that pumping of fluid underground into a deep disposal well was responsible for the triggering of earthquakes near Denver, Colorado.

In order to test speculations that earthquakes might be controllable, the USGS conducted a field experiment from 1969 to 1974 in an oil field at Rangely, Colorado. Variations in local earthquake activity were produced by alternately injecting and recovering water from wells that penetrated an earthquake-generating zone. The experiment conclusively demonstrated that earthquake activity at Rangely could be increased by injection of fluid and decreased by pumping out fluid.

Following the Rangely experiment, geologic and geophysical studies were carried out in Western Nevada in order to identify a possible area for a full-scale earthquake modification experiment on a natural fault. Such an experiment, however, cannot be mounted within the present budget.

Laboratory and theoretical studies of fluid pressure effects on faulting also were begun. A modest effort in laboratory-scale simulation of earthquake control currently is being carried out.

In addition to the possibility of modifying the behavior of active faults, earthquake modification research is important because of the light it may shed on reservoir-triggered earthquakes. Filling of reservoirs

behind dams apparently has triggered earthquakes, in a few cases as large as magnitude 6.5, causing damage and loss of life. At present, there is no sound basis for evaluating which reservoirs might trigger damaging earthquakes, nor what to do about earthquake activity once it is stimulated. The Rangely experiment suggests that certain engineering actions may be available to limit reservoir-induced seismicity.

Present USGS research in earthquake modification is limited to small-scale laboratory experiments. Studies that could be undertaken include: (1) study of the effects of reservoirs on seismic activity; (2) study of the physical properties of fault zones in relation to possible modification experiments; and (3) conduct of an earthquake-control experiment on a remotely situated active fault.

3. Q: Please describe USGS support for data collection and instrumentation at the Palmdale uplift including dollar amounts, number of instruments and other descriptive material (if needed). Instruments for measuring at least the following should be mentioned: earth movements, earth dimensions, tilts, electrical resistivity, well levels, magnetic field, and gravitation field.

A: Proposed Studies of the Southern California Land Uplift. Projects are included for observation, analysis, and interpretation of variations in geophysical phenomena in the region of the uplift, and for prediction of effects of a large earthquake in the region of the uplift on the Los Angeles area. Special attention is given to data dissemination to facilitate and encourage research studies.

Project	Estimated Funds in Thousands of Dollars: USGS Project	Non-USGS Project	Total Cost
I. Monitoring and Analysis of the Uplift - The significance of the uplift can be assessed by observation and evaluation of geophysical phenomena that have been reported as precursors and that are associated with the accumulation and release of strain energy in earthquake generation.			
A. Strain Techniques - Deformation of the Earth's surface has been observed before earthquakes and theories of earthquake mechanics suggest the occurrence of observable strain in response to the buildup of stress. Observations of strain will provide important constraints for theoretical development and may yield earthquake precursors.			
1. Level Surveys - Carry out precise leveling traverses to determine changes in land elevation with respect to elevation at time of earlier surveys and to establish a base for future surveys. Relate historic vertical deformation to current tectonic processes and to Holocene deformation.	175	25	200
2. Trilateration Surveys - Measure the distance between 100 pairs of bench marks semi-annually to determine horizontal land deformation.	100	0	100
3. Gravity Measurements - Measure gravitational attraction continuously at 5 sites and along traverses to determine elevation and/or mass changes.	30	110	140
4. Strainmeters - Monitor horizontal and volumetric strain continuously at several sites in rock masses to measure deformation.	5	75	80
5. Water Well Monitoring - Measure water level in wells to measure dilatational strains.	0	50	50
6. Tiltmeters - Monitor land tilt continuously at 5 new sites and 35 existing ones to measure warping of the land surface.	60	40	100

Project	USGS Project	Non-USGS Project	Total Cost
7. Fault Creep Studies - Determine the location of fault movement by repeat geodetic surveys and measure continuously the amount of fault slip by creepmeters.	0	45	45
8. Modeling of the Uplift - Develop theoretical and numerical models to account for the observed strain and to predict future geophysical phenomena.	50	50	100
B. Stress Techniques - Evaluation of the magnitude and orientation of rock stress deep in the Earth will permit the assessment of earthquake potential.			
1. Hydraulic Fracturing - Inject fluid into holes about 2000 feet deep to determine the state of absolute stress.	80	0	80
2. Magnetometers - Measure differential magnetic field variations at 8 sites continuously to provide measurements that can be interpreted in terms of changes in rock stress.	70	0	70
C. Electromagnetic Techniques - Variation in electrical resistivity has been recognized as an earthquake precursor. Additional observations are needed to confirm electromagnetic techniques as useful for earthquake prediction.			
1. Apparent Resistivity - Measure induced electric currents to detect variations in electrical properties of rocks.	0	70	70
D. Seismic Techniques - Variations in seismic wave velocity have been widely reported as earthquake precursors. Seismic data also indicates precursors in variations of seismicity patterns, focal-mechanism solutions, and frequency content of seismic waves. Accurate earthquake locations are needed for all earthquake prediction studies.			
1. Seismograph Network - Establish continuously recording seismograph stations of 20 components to record seismic waves for locating earthquakes and detecting seismic earthquake precursors.	0	110	110
2. Velocity Monitoring - Monitor explosions periodically to detect variations in seismic wave travel times.	0	50	50
3. Special Analysis of Seismic Data - Analyze existing and future seismic data to recognize anomalies in seismicity preceding moderate or large earthquakes.	50	50	100

Project	USGS Project	Non-USGS Project	Total Cost
II. Evaluation of Earthquake Hazards Associated with the Uplift - A large earthquake in the area of the uplift would cause intense shaking over large areas and localized ground fracturing. The location and degree of these effects can be anticipated. Earthquake mitigation plans can then be guided toward the most effective actions.			
A. Definition of Tectonic Framework and Fault Hazard Assessment - Investigate geologic faults in the uplift area to define the tectonic framework within which the uplift has occurred and must be analyzed and to evaluate fault activity and earthquake recurrence.	75	130	205
B. Prediction of Ground Shaking - Predict nature and character of ground shaking in populated regions for postulated large earthquakes in the uplift area.	150	85	235
III. Dissemination of Data - Studies of the uplift will be carried out by many organizations, including many that are not supported under this program. Data produced under this program will be generally available to all qualified scientists. Procedures will be established and equipment will be provided to facilitate data access.			
A. Inter-Institutional Communications - Establish a computer-based teleconferencing system among the organizations most involved in studies and decisions related to the uplift.	15	0	15
B. Data Center - Establish computer capabilities for real-time and off-line processing of uplift data and dissemination of data to research scientists.	0	350	350
Totals	860	1240	2100

4. Q: How would USGS utilize the funding that would be authorized by S.1174 if that funding were made available ($25,000,000 in FY 1978, for example?)

A: Funding to the Geological Survey authorized by S.1174 would be used for program expansion in the following areas:

Earthquake Data Services

- Reestablish maintenance program for and upgrade the Worldwide Standardized Seismograph Network

Earthquake Hazards Evaluation

- Expand hazards mapping in western United States urban areas at high seismic risk
- Begin hazards mapping in eastern United States urban areas at high seismic risk and improve estimates of the earthquake vulnerability
- Develop and improve methods for estimating damage and loss, and define more accurately earthquake risk on a nationwide and regional basis
- Increase studies of earthquake activity in selected areas of the eastern U.S. to improve estimates of eastern U.S. seismic risk and to determine geologic and seismologic reasons for the differences in damage patterns between eastern and western U.S.
- Expand studies to estimate frequency and maximum size of earthquakes by region using geologic as well as historical seismicity data
- Increase studies of strong ground shaking and geologic factors that affect earthquakes losses

- Initiate a seismic zonation demonstration project in the San Francisco Bay Region to develop products suitable for land use decisions at State and local levels
- Undertake utilization programs to bring together Federal, State, local and private individuals for more effective use of geologic information for earthquake hazard mitigation

Earthquake Prediction Research

- Monitor and evaluate the southern California land uplift
- Upgrade earthquake prediction instrumentation and computer-processing capabilities in California
- Expand studies of several types of earthquake precursors that are presently poorly studied, if at all, including water well fluctuations and geochemical variations
- Deploy networks of instrumentation for earthquake prediction experiments in Seattle, Reno, Salt Lake City, and south-central Alaska regions to accelerate rate of observation of earthquake precursors
- Expand theoretical, analytical and modeling studies to provide a physical basis for interpreting all types of earthquake precursors
- Establish a computer and communications capability to monitor earthquake precursors in real time
- Expand laboratory studies on properties of earth materials pertinent to earthquake predictions and laboratory analogues of the earthquake process

- Increase efforts to develop more reliable instrumentation for monitoring possible earthquake precursors, including especially instruments for measuring strain with long-term stability
- Initiate a field experiment and supporting laboratory studies on earthquakes caused by reservoirs to develop criteria for avoiding inadvertantly triggered, damaging earthquakes
- Cooperatively install earthquake prediction instrumentation in foreign countries to substantially increase the rate of observation of earthquake precursors

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5. Q: Please provide a statement of the likely future development of earthquake prediction and how it depends upon the level of funding provided.

A: Earthquake prediction, in recent years, has emerged from the realm of soothsaying to become a serious scientific endeavor with a significant likelihood of a short-term technological breakthrough. Observations reported primarily from the U.S., China, Russia, and Japan indicate that clearly observable phenomena precede some large earthquakes. The time scale over which these phenomena emerge prior to the event is measured in years to hours, thus providing the potential for socially useful predictions of forthcoming destructive earthquakes.

Earthquake prediction depends on detecting precursors prior to earthquakes. Reliable prediction depends on observing a variety of precursors, understanding their causes, and understanding the basic physics of the earthquake source. Thus a prediction research program must be broad based and will depend heavily on observations of precursors of earthquakes within networks of a variety of densely spaced instruments. The rate of progress toward a prediction capability is directly linked to the rate at which precursors are observed. Multiple observations on a variety of instruments are needed to develop an accurate physical model for earthquake precursors. Dense instrumentation of an active fault zone with a wide variety of sensors costs about $12K per kilometer of fault to install and about $7K per kilometer to operate each year.

The existing U.S. effort, funded at about $5 million in FY 1976, has progressed significantly. Reliable instruments for detecting

most suspected precursors have been developed, tested, and deployed in small prototype arrays. Real-time and automatic data processing techniques have been developed. Hypotheses as to the nature of the earthquake source and the cause of precursors have been developed and partially tested in the laboratory. Now that this groundwork has been laid, expansion of the national effort can be undertaken efficiently.

Considering the rate of occurrence of earthquakes of magnitude 5 and greater and the costs of operating observational systems in the various seismic regions of the U.S., the most economical and effective approach is to instrument selected regions of high seismicity in California and Nevada. Some monitoring, however, should be done in regions on the coast of Alaska where the likelihood of major earthquakes seems high.

It appears likely that the basis for a prediction capability can be established after the precursors for on the order of 10 earthquakes of magnitude 5 or greater are clearly recorded within a dense observational network. At the current level of funding it is estimated that these observations will be gathered in about 20-25 years. If the level of funding were that authorized by S.1174, it is estimated that the requisite observations would be gathered in about 5-10 years.

6. Q: What was the DOI request for EQHRP funding in the FY 1977 Process? What was the USGS request to DOI?

A: The USGS requested a major increase of $17.8 million for a total program of $29.8 million (including geomagnetic observatories).

The DOI initially requested an increase of $1.0 million for a total program of $12.1 million. In a subsequent proposed budget amendment, the DOI requested an EQHRP increase of $16.6 million for a total program of $27.7 million (excluding geomagnetic observatories).

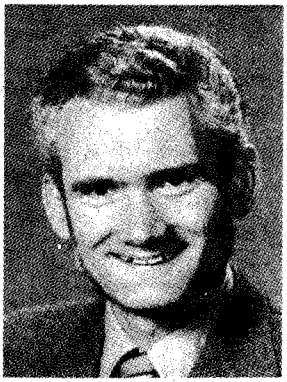
7. Q: What legislative authority does the Geological Survey currently have to operate programs related to earthquakes? Please cite sections of the U.S. Code or Statutes.

A: The Geological Survey was established by the act of March 3, 1879 (20 Stat. 394; 43 U.S.C. 31), which provided for "The classification of the public lands and the examination of the geological structure, mineral resources, and products of the national domain." The Act of September 5, 1962 (76 Stat. 427; 43 U.S.C. 31 (b)), expanded this authorization to include such examinations outside the national domain. Further indication of the authority of the Geological Survey in earthquake hazards investigations can be obtained from the U.S. Government Organization Manual, which states that the Survey undertakes "research into geologic principles and processes to provide guidance for significant geologic interpretations; specialized research in geochemistry, geophysics, and paleontology in support of the geologic and mineral resource investigations."

Mr. SYMINGTON. We will now be pleased to hear from Richard Wright, Director of the Center for Building Technology, NBS, accompanied by Samuel Kramer, Deputy Director.

Dr. Wright, as so often happens, being at the end of the list you have patiently waited for a long time. We appreciate that, and we would also appreciate it if under the circumstances you could give your testimony fairly briefly and we will certainly make your full paper a part of the record.

[Brief biographical sketches of Dr. Richard N. Wright and Mr. Samuel Kramer and the complete prepared statement of Dr. Wright are as follows:]



RICHARD N. WRIGHT

Date of Birth: May 17, 1932

Birthplace: Syracuse, New York

Education: (Degrees)

Syracuse University, B.S. Degree, Civil Engineering, 1953
Syracuse University, M.S. Degree, Civil Engineering, 1955
University of Illinois, Ph.D. Degree, Civil Engineering, 1962

Position:

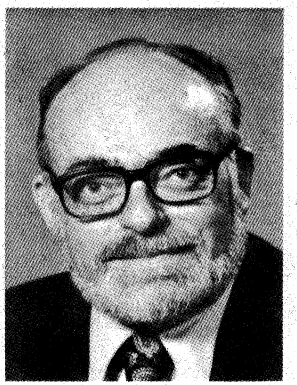
Director, Center for Building Technology

Dr. Wright was appointed Director of the Center for Building Technology in June 1974. As Director, Dr. Wright is responsible for programs encompassing the scientific, technological and professional interests needed to identify and conduct research on measurement problems arising in building design, construction, operation and maintenance. The scope of its operations range from research and consultation on single building materials, components and subassemblies, to whole buildings and entire building sites.

From 1957 to 1974, Dr. Wright served on the faculty of the University of Illinois, Department of Civil Engineering. While on leave from the University, Dr. Wright headed the Structures Section of the Bureau's Building Research Division, 1971 to 1972, and was Deputy Director--Technical of the Center for Building Technology, 1972 to 1973.

Dr. Wright's research activities have included structural design for dynamic loads; flow and fracture in structural metals; mechanics of thin-walled beam structures; optimum design procedures; formulation and processing of design criteria; reliability and performance criteria for buildings. At the National Bureau of Standards, Dr. Wright has been responsible for structural engineering research on loadings due to wind and occupancy, structural performance in serviceability and ultimate limit states of building systems, and criteria for structural performance; development of a cooperative Federal Program on Building Practices for Disaster Mitigation; led an NBS team investigating the performance of buildings in the 1972 Managua, Nicaragua earthquake; and conducted a review of the Nicaraguan building regulatory system for the Agency for International Development and the Organization of American States.

Dr. Wright is a member of the American Society of Civil Engineering, the American Concrete Institute, the Column Research Council, Reunion Internationale des Laboratoires d'Essais et de Recherches sur les Materiaux et les Constructions, the International Association for Bridge and Structural Engineering, Sigma Xi, Phi Kappa Phi, and Tau Beta Pi. He is registered as a professional engineer in New York and as a structural engineer in Illinois.



SAMUEL KRAMER

Date of Birth: June 2, 1928

Birthplace: New York City, New York

Education: (Degrees)

Bachelor of Civil Engineering, College of the City of New York
Graduate School of Public Administration, New York University

Professional License: Registered Professional Engineer (P.E.)

Position:

Acting Deputy Director
Center for Building Technology

Mr. Kramer, who serves as Acting Deputy Director, Center for Building Technology, is a graduate civil engineer and has done graduate study in the field of public administration.

Mr. Kramer was in the military service from September 1950 through August 1953, during which he served both in the United States and overseas. His primary assignment was as a battalion staff officer with an engineering construction battalion that was responsible for the construction of the major facilities in Europe.

Mr. Kramer was in the private construction industry before joining the Corps of Engineers, where he served as a civilian engineer for 10 years. At the Corps of Engineers, Mr. Kramer was responsible for the development of design criteria and the design and construction of military projects throughout the United States. He received 12 citations and awards from the Corps for outstanding engineering.

Subsequently, he joined the Bureau of the Budget, now the Office of Management and Budget, Executive Office of the President, where he served for over four years. Mr. Kramer had responsibilities in a number of major program areas, including the environmental quality programs, the Federal Water Quality Control Administration of the Department of the Interior, the Tennessee Valley Authority, the Panama Canal and interstate and Federal-interstate compacts. He also served on many Executive Office and White House task forces as well as on sub-Cabinet-level and inter-agency committees.

In July 1970, Mr. Kramer joined the National Bureau of Standards as the Federal Building Research Program Coordinator in the Institute for Applied Technology's Building Research Division. In July 1972, when the Center for Building Technology was formed at the National Bureau of Standards, Mr. Kramer was appointed Chief of the Office of Federal Building Technology. In September 1974, he assumed the position of Acting Deputy Director, Center for Building Technology.

Mr. Kramer is a registered professional engineer (P.E.) and is a member of the American Society of Civil Engineers and the American Society for Public Administration. He is the recipient of numerous awards and honors and was elected to Tau Beta Phi and Chi Epsilon, National Honorary Engineering Organizations. He is also active in community, educational and religious organizations.

Statement on Earthquake Hazard Reduction Legislation

by

Dr. Richard N. Wright
Director, Center for Building Technology
Institute for Applied Technology
National Bureau of Standards
Department of Commerce

Committee on Science and Technology
U.S. House of Representatives
June 22, 1976

Introduction

Mr. Chairman, Members of the Committee, thank you for this opportunity to testify before your Committee today. It is a pleasure for me to comment on this important legislation and to describe the National Bureau of Standards' disaster mitigation program.

Recently, we have witnessed earthquakes in Guatemala, Italy, and the Soviet Union. Thousands of lives were lost and millions of people were left homeless. Property damage was estimated in the billions. Fortunately, we have not experienced a major earthquake in the United States in five years. We may not continue to be as fortunate. Studies by the Office of Emergency Preparedness (OEP) and the Federal Disaster Assistance Administration, for example, indicate that a repeat of the San Francisco earthquake of 1906 could cause approximately 10,000 deaths, 40,000 injuries and billions in property damage. Losses on this scale could also occur following a large earthquake in the Los Angeles area.

Although people normally equate the earthquake hazard with the State of California, other regions of the United States are also susceptible to this disaster. Although the probability of a serious earthquake occurring at any given place and time is relatively low, studies show that earthquakes pose a potential threat to over 70 million people in 39 States who live in areas of high or moderate earthquake risk. Clearly, the earthquake problem is a national one.

Since earthquakes could potentially cause great human suffering and property losses in all regions of the U.S., we need a balanced program of earthquake hazard reduction, which includes earthquake risk assessment, mitigation and relief. Risk assessment identifies the frequency and severity of future earthquakes. Earthquake mitigation provides preventive measures such as improved building practices for hazard reduction. Earthquake relief, a most familiar term, furnishes assistance for earthquake victims.

The success of a balanced earthquake program requires the cooperation of Federal, State, and local governments and the private sector. In the past, most Federal programs have been aimed solely toward disaster relief. Some work has been done in projecting the earthquake risk and improving building practices, but too often we have been reacting after-the-fact instead of taking corrective steps before the disasters occur. It is imperative that the Federal Government continue to provide relief for disaster victims, but we must also strive to develop ways for reducing potential losses. It is preferable to save lives and to ensure that buildings stand than to spend greater amounts of money rehabilitating earthquake damaged areas.

The need for such a balanced program was recognized in the OEP report on disaster preparedness to the Congress in 1972, in response to Section 203(h) of P.L 91-606, the Disaster Relief Act of 1970. This Executive Report was the first comprehensive examination of all natural hazards. The report stated that: "Land use and construction regulations

containing strong disaster mitigation features can in the long run alleviate losses caused by natural disasters." The Congress addressed land use and construction regulations and promoted a balanced program when, in 1974, the Disaster Relief Act of 1974, P.L. 93-288, was enacted. The Act requires State and local governments to use Presidentially-prescribed standards for land use and construction practices as a prerequisite for disaster loans and grants. The coupling of disaster relief and mitigation reversed the trend of much legislation and provided a more appropriate perspective.

National Bureau of Standards' Disaster Mitigation Program

The National Bureau of Standards' Institute for Applied Technology houses the largest and most comprehensive building research laboratory in the United States. Its Center for Building Technology (CBT) which has a staff of 240 and an annual budget of $12 million, provides the focal point for the NBS disaster mitigation program. Other NBS units also contribute to technology for reducing the earthquake hazard.

The Center provides technical information, measurement methods and criteria for improving the usefulness, safety and economy of buildings. Our research focuses on the performance concept which leads to the development of criteria and test methods that give building designers,

manufacturers, and contractors maximum opportunity for innovation. For example, we developed criteria for solar heating and cooling systems called for in P.L. 93-409, the Solar Heating and Cooling Demonstration Act, which has been strongly supported by this Committee. We are now assisting the Department of Housing and Urban Development (HUD) and the Energy Research and Development Administration (ERDA) in the planning and evaluation of the solar demonstration. This is representative of our role as a laboratory resource for the more than 30 Federal agencies with building programs.

Our staff includes architects, engineers, physical scientists, psychologists, economists, and other specialists from over 30 disciplines. Our interdisciplinary approach considers how buildings should perform to meet building occupants' needs. To accomplish this task, we work closely with all elements of the building community: design professions, builders, organized labor, building regulatory authorities of State and local governments, researchers in universities, national standards writing bodies, building user organizations, and Federal agencies. With your permission, Mr. Chairman, I would like to introduce for the record two background papers delineating our interactions with these groups of the building community and terminology for codes and standards.

The NBS has a long history of disaster mitigation research. Beginning with our pioneer work on the fire problem in 1910 and progressing from the 1920's to the present with our research on the effects of winds on structures and on the performance of masonry, the NBS program has focused

on the development of improved building practices to reduce damages caused by various types of natural disasters, such as tornadoes, hurricanes, earthquakes, and floods. Since buildings are subjected to many types of natural hazards, we consider all substantial risks in the design and use of buildings. Earthquakes and extreme winds, as well as explosions and some accidents, produce similar effects on a building. Integrated attention to all these hazards costs little more than treatment of earthquakes alone and provides substantially increased benefits. However, since the scope of S. 1174, H.R. 13722, and H.R. 13845 deals with earthquake hazard reduction, we will discuss only this subject.

We have participated in post-disaster investigations in San Fernando, California in 1971; Managua, Nicaragua in 1972; Guatemala in 1976; and recently in Italy. We apply the knowledge gained from these investigations to develop improved building practices. We assisted Nicaraguan authorities in evaluating damaged buildings and in upgrading their building regulatory system. Following the San Fernando earthquake, our assessment of earthquake damage to residences was used by field investigators of the Small Business Administration to validate Federal loans. We also testified before the House Committee on Public Works at a field hearing in California on February 23, 1971 and discussed the damage to the San Fernando area. We accompanied that Committee in its own inspection of earthquake damage to help them assess the need for disaster relief and subsequent legislation.

The San Fernando earthquake of 1971 showed the need for a balanced approach to earthquake mitigation. The National Science Foundation (NSF), NBS, Department of Housing and Urban Development (HUD), and OEP planned a cooperative Federal program on building practices for disaster mitigation in 1972. With sponsorship from NSF, the NBS conducted a workshop for experts in the building community including architects and engineers, building code officials, standards writers, and planners, to develop a national plan for disaster mitigation activities. The workshop participants synthesized current knowledge on building practices for insuring the safety of building occupants in new and existing buildings. They made recommendations to four audiences: 1) policy makers in Federal, State and local governments, for guidance on disaster mitigation laws, regulations, policies, and programs; 2) practitioners, such as architects, engineers, and building contractors, for guidance on the best current practices to be used in making decisions about building construction; 3) standards writers and those responsible for developing recommended practices, such as building code officials, for guidance on the deficiencies in present practices; and 4) researchers, for guidance on needs for new knowledge.

This plan and the proposed recommendations to users in the building community, as presented in NBS document Building Practices for Disaster Mitigation (Building Science Series 46), provided an integrated approach to disaster mitigation through research and the implementation of improved building practices.

One workshop recommendation was to update the seismic provisions of building codes. The last major revision to these provisions occurred in the 1950's. Since that time, there have been significant advances in knowledge. Based on the workshop recommendation, the National Bureau of Standards, sponsored by the National Science Foundation and NBS, initiated a three-year $1.3 million program to develop improved seismic design criteria which could be used nationwide in new buildings and in the rehabilitation of existing buildings. We have used the Applied Technology Council of the Structural Engineers Association of California as a principal resource.

Eighty experts from all sectors of the building community are participating in the development and implementation of the design criteria. In selecting these experts, NBS chose people from all areas of the country, with strong participation by representatives from California and other high seismic risk areas, to ensure consideration of various localities' needs and effective implementation. Current seismic provisions are based on California seismic conditions and building practices. The nationwide representation in development of the new criteria assures consideration of all types of construction and degrees

of seismic risk. This nationwide involvement of building regulatory officials and designers will promote more rapid adoption in State and local building codes.

The new seismic design criteria differ in scope from past code provisions, since they include non-structural, as well as structural, aspects of the building. During earthquakes, many people are killed or seriously injured from improper designs of such non-structural elements as bookcases, internal partitions, and light fixtures. The inclusion of these non-structural elements makes the proposed design criteria much more comprehensive.

These seismic design criteria have been reviewed by over 400 professionals, trade associations, and regulatory officials. We plan to release the final provisions early in 1977.

In this NBS/NSF program on seismic design criteria and in all disaster mitigation activities, implementation is the key to success. Research which is not used provides few benefits. Likewise, developing improved building practices without planning their implementation serves no one. Too often, practicing engineers are left to synthesize the research results and develop improved building practices on their own. This gap between research and use has long been evident to both practitioners and researchers.

Using NBS research, Federal agencies have worked to close this gap. Based on our prior work on disaster mitigation, NBS, for the Defense Civil Preparedness Agency (DCPA), developed a procedure to evaluate the safety of existing buildings from wind and seismic forces. This procedure provides an economical approach to evaluate rapidly all buildings in a city or specific buildings such as hospitals, fire stations and other emergency facilities. The DCPA and design professionals are using these procedures. The General Services Administration (GSA) also is employing NBS procedures to develop surveys for evaluating buildings in response to Section 401 of P.L. 93-288 which requires Federal agencies to evaluate the natural hazards to which their facilities are exposed and take appropriate action to mitigate these hazards.

Following the San Fernando earthquake of 1971, the Veterans Administration (VA) began a comprehensive program to identify and strengthen hazardous hospitals in seismic zones. At their request, we developed procedures based on our laboratory research, for measuring the strength of masonry walls in existing buildings. These procedures are being used by the VA in their requirements for earthquake resistant design of hospital facilities.

A number of other NBS programs support earthquake hazard reduction. We serve as a liaison member to the U.S. Geological Survey's Earthquake Studies Advisory Panel which examines earthquake prediction and other earthquake programs. We use the USGS findings on seismic risk in our research and identify for USGS the geological research needed by the building community.

We also work with a variety of national and international groups concerned with earthquake hazards. One of the CBT staff serves as the U.S. Chairman of the U.S.-Japan Panel on Wind and Seismic Effects which supports cooperative research programs and exchanges information on these two natural hazards. Presently, I serve as the Chairman of the Earthquake Engineering Research Institute (EERI) Committee on Research Needs. We have identified eight topics as candidates for high research priority which are: 1) development of standard procedures for setting site specific design conditions, 2) development of standard procedures for the evaluation, strengthening, and repair of existing facilities, 3) development of procedures for definition of acceptable levels of risk for new and existing facilities, 4) development and implementation of procedures for defining, predicting, and documenting the strong motions arising from earthquakes, 5) development of standard procedures for interpretation of strong motion records for design purposes, 6) defining the effects of earthquake prediction on engineering practices, 7) development of design standards for industrial structures, that is, facilities and equipment other than buildings, and 8) development of methods and procedures for design and regulation, and materials for programs of professional education. These interactions assist us in developing our own research and in providing technical support for other Federal agencies.

Needs for Earthquake Hazard Reduction

The need for earthquake hazard reduction is well documented by the history of past earthquakes and the projected effects of future earthquakes in

many parts of the country. Normally, we think of four ways to reduce the potential earthquake hazard: 1) induced reduction of the earthquake intensity, 2) evacuation of the area, 3) avoidance of the hazard by not using the area, i.e., land use control, and 4) prevention of the damage by improved building practices. All four of these solutions have their limitations.

Physically reducing the potential force of the earthquake, by such methods as pumping water into the ground, is a possible solution to reducing damage. However, such procedures are still in the research stage.

Evacuating threatened areas can achieve hazard reduction if predictions are certain and give adequate time. However, disruption of normal activities and adverse economic consequences are still a problem.

Land use control practices can reduce hazards of faulting, unstable earth, flooding below dams and tsunamis. For some of these earthquake hazards, such as faulting, this approach is the most economical, but often people are reluctant to cease building in otherwise desirable areas even if there is high seismic risk.

Earthquake resistant building practices are the most effective approach to minimizing earthquake damages from ground shaking which causes over 90 percent of the damages. Even if an earthquake is predicted and the residents have evacuated the area, we still need to reduce the damage to

buildings and other facilities. Obviously, if there has been no advance warning and no evacuation, the need for safe buildings is critical. For simplicity, I will confine the following discussion to buildings but the same concepts apply to other facilities.

To reduce the earthquake hazard, we must know how buildings are used, what earthquake environment is likely, and how buildings perform during an earthquake. We know from our field investigations that buildings can be built economically to resist earthquake effects, but there is still need to reduce the high cost of identifying and correcting hazardous buildings and making new seismically safe construction more cost effective.

Experience shows that the greatest earthquake hazard results from unsafe existing buildings. Buildings not constructed in accord with adequate seismic design provisions should be evaluated to determine whether they are unduly hazardous. Such buildings should be strengthened or replaced. The procedure for evaluating existing buildings developed for VA and DCPA are steps toward these goals. Improved technologies are needed to make the hazard identification and strengthening procedures more economical. One approach that deserves study is the removal of financial barriers for abating hazardous buildings to speed hazard reduction.

New construction should not add to the earthquake hazard. Seismic design criteria providing appropriate resistance should be incorporated in building regulations and enforced. The seismic design criteria we are developing with NSF address this need.

In summary, any effective program for reducing earthquake losses must include research on building performance and the development and implementation of improved building practices. The nation's research base includes characterization of earthquake hazards by USGS and the basic research funded by NSF. The NBS is prepared to carry out the additional research to develop performance criteria and test methods for evaluating how well buildings and their components would perform. The integration of all this research with our continuing work with design professionals, industry, organized labor, builders, code and standards-writing groups, Federal agencies, and the State and local building regulatory agencies would facilitate the development and implementation of improved building practices.

Public policy should encourage the building communities to use effective earthquake hazard reduction practices. Authority exists in most areas under State or local building codes. However, up-to-date earthquake design standards must be included in codes by the State or local governments, designers must learn to apply these standards in design, builders must follow approved details in construction, and regulatory authorities must check plans and inspect construction. The model code organization of building officials, the National Conference of States on Building Codes and Standards, the newly-formed National Institute of Building Sciences, and the professional societies of architects and engineers provide appropriate mechanisms for achieving this implementation of earthquake resistant building practices.

Summary

NBS and the Administration agree with the goal of earthquake hazard reduction--saving lives and avoiding serious economic losses. Part of this goal can be met by a vigorous implementation of improved building practices. Seismological, engineering and social research can be cost effective in improving the reliability and economy of these practices. These implementation and research activities require cooperative and well coordinated activities of Federal agencies, State and local governments, professional groups, and the private sector.

The research and technical service capabilities of NBS have contributed to the development and implementation of current building practices and can aid in their improvement. We expect to continue working with Federal building and research agencies, university researchers, design professions, building regulatory agencies, and standards-writing organizations in the common effort to achieve earthquake hazard reduction.

As Dr. Stever and others have indicated, the Federal agencies already have sufficient legislative authority to undertake research and are working on a program plan that can be used to make budgetary decisions. With regard to mechanisms for coordination, I have discussed some aspects of this coordination that now exist. Dr. Stever has mentioned that the

Administration is scrutinizing this subject to see if a new coordinating body is needed and whether any additional legislative authority should be proposed by the Administration. In this respect, NBS will be working actively with Dr. Stever.

We appreciate the opportunity to appear before you, and I will endeavor to answer any questions you may have.

INTERACTIONS WITH BUILDING COMMUNITY

1) Federal Agency Research at NBS

Since 1901, NBS has provided a focal point for transferring building technology and measurement systems to Federal agencies with building-related programs. NBS also has conducted research for numerous Federal agencies. Currently, NBS has memorandums of understanding with the Department of Housing and Urban Development, the Energy Research and Development Administration, the Federal Energy Administration, the Occupational Safety and Health Administration, and the National Parks Service and interagency agreements with many others. NBS is the only Federal laboratory with a comprehensive building research program.

2) Federal and Industry Workshops and Conferences

In 1969, the Office of Management and Budget requested that NBS transfer information on building standards, criteria, and test methods to the other Federal agencies. In response, NBS conducts monthly and special workshops which are attended by architects, engineers, and building experts. In cooperation with various industries, NBS also hosts a number of other workshops and conferences.

3) National Academy of Sciences/National Bureau of Standards Technical Evaluation Panels

NBS has formed technical evaluation panels for each of its major programs. These panels review and make recommendations for existing and new technical programs. Top technical people from each major field of technology serve on these panels.

4) Department of Commerce's Building Technology Advisory Committee

This advisory committee advises the Department of Commerce on matters relating to the Nation's needs in building research and technology. The committee provides policy guidance and a forum for discussion by experts on the complex building community and its diverse interests. Representatives from all segments of the building community also serve on the advisory committee.

5) National Conference of States on Building Codes and Standards and Model Building Codes Groups

Due to the multiplicity of jurisdictional authorities, the States in 1967 formed the National Conference of States on Building Codes and Standards to improve intra- and inter-State compatibility among the Nation's building regulatory jurisdictions. The Conference provides a national forum for the State and local governments, industry, and other interested parties to discuss issues bearing on building regulations, to identify current problems, and to use national resources for the development of solutions. NBS provides technical assistance and the administrative secretariat for the Conference.

At the request of the Conference, NBS performs research on building regulatory procedures including building laboratory accreditation, uniform procedures for building evaluation, methods for the efficient formulation and expression of building standards and codes, and implementation aids for performance-oriented building standards. Such functions also are provided to model code organizations of local building officials and the newly-formed organization for building officials of the 30 largest cities.

6) Committees of American National Standards Institute (ANSI), American Society for Testing and Materials (ASTM), American Society for Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), Etc.

NBS supports the national voluntary consensus standards process through more than 200 memberships on committees which promulgate building standards. NBS provides technical inputs from research to the committees and responds to the priority needs for building standards of ANSI.

7) Postdoctoral Program and Intergovernmental Personnel Act

In cooperation with the National Research Council of the National Academy of Sciences, NBS established an ongoing postdoctoral program to provide awards to scientists for basic and applied research.

Under the Intergovernmental Personnel Act of 1970 (P.L. 91-648), NBS has sponsored a number of university faculty and graduate students to do research at NBS. Some local and State government personnel also have participated in this program.

8) Research Associate Program

Under this program, industry personnel work at NBS laboratory facilities on joint research which is of mutual interest. This research is both long and short range and enables NBS and industry to identify further research needs. All research findings are available to the public.

9) Occupational Safety and Health Administration (OSHA), National Institute for Occupational Safety and Health (NIOSH), Environmental Protection Agency (EPA), Federal Power Commission (FPC), and Justice Department

In recent years, Congress has established new Federal regulatory programs which mandate certain building requirements. These Federal programs have set new demands on the design, construction and operation of buildings and have placed further responsibilities on the local building code officials. Through liaison and research programs for these agencies, NBS provides a technical focal point for those who must implement new Federal regulations.

10) NBS' Center for Fire Research and Center for Consumer Product Technology

These two new technical centers provide research programs on fire safety and life safety for the consumer. Research results in these areas have strong impact on codes and standards.

11) International Standards, United States Committee, RILEM and Cooperative Research

With increased international business interactions and corporations, strong participation in international standards is essential. Joint cooperative and complementary research with other foreign government research organizations provides more comprehensive research, avoids duplication and permits sharing of facilities and technical staff.

12) American Institute of Architects (AIA)-NBS Architect-in-Residence Program and Membership in all Professional Societies

A strong relationship is maintained with all professional groups within the design community. The AIA/NBS architect-in-residence program places an architect from an architectural/engineering firm for one year at NBS. This program encourages NBS research with the architectural profession and informs NBS of the research needs of this profession.

Clarification of Terminology: Codes, Standards, Guidelines and Performance and Prescriptive Theory

Building regulatory terminology, particularly codes, standards, guidelines and performance and prescriptive theory, is often misinterpreted since no authoritative definitions have been developed. These terms are frequently used in different contexts. Diverse interpretations of these terms creates a misunderstanding of how they are ultimately used in building regulations. The terms: code, standard, guideline, performance and prescription, as well as other terms, are used to describe legal documents, inputs in legal documents, and approaches (or philosophies) used in developing the inputs for legal documents. The following outline may be useful in clarifying the use of these terms.

I. Description of Legal Documents includes the terms:

   A. Building Code
   B. Federal Regulation

II. Description of documents used as inputs in legal documents:

   A. Model Building Codes
   B. Standards

III. Terms used to describe approaches (or philosophies):

   A. Performance
   B. Prescription

IV. Other Terms

   A. Guidelines
   B. Condition of Participation

I. Terms used to describe legal documents:

Building specifications are regulated by States or local jurisdictions to provide for the health and safety of the community. Every designer and builder must meet the minimum requirements contained in the State or local government's building code. The term building code, as used in this discussion, pertains to the total set of legal requirements for the entire building. Many jurisdictions do have codes which pertain to only portions of the building, i.e., fire code. Building code requirements are legally binding by their incorporation in city ordinances or by other legal actions. An average building code contains approximately 450 standards, through reference, through incorporation in the test, or through modification and incorporation.

Although building regulation is primarily a State responsibility, Congress can, and has in the past, establish Federal building-related regulations. For example, the Occupational Safety and Health Act of 1970 establishes Federal regulations for safety in the workplace, including certain building regulations. The minimum legal requirements, in this case established by the Secretary of Labor, would be Federal regulations. These Federal regulations, like building codes, would also utilize standards (usually the same standards as those used in codes and serve as legally enforceable documents which establish minimum requirements for the buildings under their jurisdiction.) As will be discussed in subsequent sections, either prescriptive or performance standards can be used in writing these documents.

II. Terms used to describe inputs in legal documents:

Building codes and Federal regulations are large documents which are extremely technical. Usually, they are developed over a long period of time, utilizing the work of many organizations and individuals. The work of these organizations and individuals goes into the development of model building codes and standards that become the basis or inputs for building codes and Federal regulations.

A model building code is a comprehensive document of minimum requirements which has no legal basis. However, many jurisdictions adopt these model building codes in entirety and thus, for their jurisdiction, make these minimum requirements legally binding. Other jurisdictions adopt these model building codes with minor changes based on their local needs. Some jurisdictions, most notably the large cities, do not use these model building codes at all. Like legally enforceable building codes, model building codes reference approximately 450 standards. Model building codes are developed by private organizations, such as the International Conference of Building Officials (Uniform Building Code), Southern Building Code Congress International (Southern Standard Building Code), and the Building Officials and Code Administrators International (Basic Building Code).

A standard describes a technical document issued by an approved standards-generating organization that establishes a uniform procedure, method or convention. Virtually all standards-generating organizations are private organizations. These organizations include the National Fire Protection Association (NFPA), American Society of Civil Engineers (ASCE), American Society for Testing and Materials (ASTM), and others. Approval of the standards developed by these organizations comes from the American National Standards Institute (ANSI), also a private organization, based on the standards adherence to published rules on standards development. Federal agencies are rarely authorized to promulgate standards by Congress. An exception would be NBS' authority to promulgate the standards of basic measurement. Unlike building codes, standards are not comprehensive and only relate to a narrow portion of the total building.

The term, standard, is not without its ambiguities. A standard can relate to a test method, a design procedure, a building product, or some other facet of the total building industry. Also, standards are used for different purposes. For example, there is a need to standardize test methods so building researchers can compare their results; there is a need to standardize the number and type of building products available so that one part of an industry can procure these products from another; there is a need to standardize definitions so that technical communications will be facilitated. This discussion focuses on those standards which are either promulgated by an approved standards-generating organization, or are used in building regulation, either through building codes or Federal regulations. These standards may be either prescriptive or performance based and are developed from building research and expert opinion.

III. Terms used to describe approaches (or philosophies) used in developing the inputs for legal documents:

The two terms used to describe approaches (or philosophies) in developing the inputs for these standards and model code documents, are prescription (or prescriptive) and performance.

Prescriptive is a term used as a prefix to standard, building codes, and Federal regulations to describe the contents of those documents. The prescriptive approach dictates the manufacturer's models, engineering types, dimensions, materials or other terms which are allowable. For example, the statement, a wall shall have six inches of type R-21 insulation is a prescriptive requirement that may be contained in a prescriptive standard or in a prescriptive building code. Generally, it is recognized that prescriptive statements, like the illustrated one, are not adequate since (1) the user (the building occupant and/or owner) is not particularly interested in what type of insulation or in how much is used (i.e., the means) but rather is interested in saving energy or money (the end objective); (2) such statements, when adopted in legal documents, effectively prohibit the use of alternative solutions that may be more effective but are not specifically mentioned; and (3) such statements are not effective over large geographical areas (i.e., Minneapolis vs. Miami).

Performance is also a term used as a prefix to standards, building codes and Federal regulations to describe the contents of those documents. The performance approach describes allowable end goals. A performance standard might read: a building of a particular size and a particular use should utilize x BTU's per year. This statement is essentially an end objective and does not specify the means which the designer, builder or homeowner must use to achieve the end objective.

There are degrees to which a document contains prescriptive statements or performance statements. For example, the American Society for Heating, Refrigerating, and Air-Conditioning Engineers has developed an energy standard, ASHRAE Standard 90-75, which is generally considered a performance document rather than a prescriptive document, but it is not as totally performance-oriented as a BTU energy approach would be. With respect to building codes, it also should be recognized that these codes contain thousands of requirements; some of which are performance and some of which are prescriptive.

IV. Other related terms:

Guidelines suggest a variety of opportunities without specifying any required minimum level of performance. That is, guidelines provide some helpful recommendations of specific (or prescriptive) solutions, but they are not legally enforceable minimum requirements. Guidelines is not a term used to describe a legal document (such as building codes or Federal regulations). However, one might want guidelines to inform the building designer about which design solution may (or may not) meet the applicable building code or Federal regulation. Such guidelines could be developed by any individual or organization and commercially marketed as a text book. To assist in meeting OSHA safety requirements, private organizations have developed guidelines for business. In this sense, guidelines are helpful suggestions on design solutions that the author feels may meet the building code or Federal regulation. The user of these guidelines could choose to disregard the guidelines' advice but could not choose to disregard building codes or Federal regulations.

We could also say that the term, guidelines, is not used to describe inputs in legal documents, as model codes and standards are used. However, guidelines could be developed, again by any individual or organization, to provide helpful information for any interested designer. Again, they could be disregarded. By definition, guidelines could not be standards since the substance is different; that is, guidelines relate to the suggestion of building alternatives that could be deemed acceptable. If they were developed and promulgated as a standard, they would cease being guidelines and become standards. If adopted by a legal jurisdiction, they then would become prescriptive building requirements.

Conditions of Participation: In some cases, when Congress authorizes financial assistance to private individuals, organizations, corporations, or States or local agencies, it places stipulations on receiving these finances. Congress has required minimum conditions of participation by the recipient. In the building area, examples of this minimum condition of participation would include HUD's FHA Minimum Property Standards or HEW's Hill-Burton Minimum Requirements.

STATEMENT OF DR. RICHARD N. WRIGHT, DIRECTOR, CENTER FOR BUILDING TECHNOLOGY, NBS, ACCOMPANIED BY SAMUEL KRAMER, DEPUTY DIRECTOR

Dr. WRIGHT. Mr. Chairman, members of the committee, thank you for this opportunity to testify before your committee today. It is a pleasure for me to comment on this important legislation and to describe the National Bureau of Standards' disaster mitigation program.

Since you, Dr. Stever and the other witnesses have discussed the potential impact of future earthquakes, I will not repeat that portion of the testimony. In view of the time available, I will highlight the other portions of my statment. If you wonder where I am during my discussion, I will be happy to call out the page. I will begin at the middle of page 3.

The National Bureau of Standards' Institute for Applied Technology houses the largest and most comprehensive building research laboratory in the United States. Its Center for Building Technology (CBT) which has a staff of 240 and an annual budget of $12 million, provides the focal point for the NBS disaster mitigation program. Other NBS units also contribute to technology for reducing the earthquake hazard.

The Center provides technical information, measurement methods and criteria for improving the usefulness, safety and economy of buildings. Our research focuses on the performance concept which leads to the development of criteria and test methods that give buildings designers, manufacturers, and contractors maximum opportunity for innovation. For example, we developed criteria for solar heating and cooling systems called for in Public Law 93–409, the Solar Heating and Cooling Demonstration Act, which has been strongly supported by this committee. We are now assisting the Department of Housing and Urban Development (HUD) and the Energy Research and Development Administration (ERDA) in the planning and evaluation of the solar demonstration. This is representative of our role as a laboratory resource for the more than 30 Federal agencies with building programs.

Our staff includes architects, engineers, physical scientists, psychologists, economists, and other specialists from over 30 disciplines. Our interdisciplinary approach considers how buildings should perform to meet building occupants' needs. To accomplish this task, we work closely with all elements of the building community: design professions, builders, organized labor, building regulatory authorities of State and local governments, researchers in universities, national standards writing bodies, building user organizations, and Federal agencies. With your permission, Mr. Chairman, I would like to introduce for the record two background papers delineating our interactions with these groups of the building community and terminology for codes and standards.

We have participated in postdisaster investigations in San Fernando, Calif., in 1971; Managua, Nicaragua in 1972; Guatemala in 1976; and recently in Italy.

We apply the knowledge gained from these investigations to develop improved building practices. We assisted Nicaraguan authorities in

evaluating damaged buildings and in upgrading their building regulatory system. Following the San Fernando earthquake, our assessment of earthquake damage to residences was used by field investigators of the Small Business Administration to validate Federal loans. We also testified before the House Committee on Public Works at a field hearing in California on February 23, 1971, and discussed the damage to the San Fernando area. We accompanied that committee in its own inspection of earthquake damage to help them assess the need for disaster relief and subsequent legislation. The San Fernando earthquake of 1971 showed the need for a balanced approach to earthquake mitigation.

The National Science Foundation (NSF), NBS, Department of Housing and Urban Development (HUD), and OEP planned a cooperative Federal program on building practices for disaster mitigation in 1972. With sponsorship from NSF and NBS, the NBS conducted a workshop for experts in the building community including architects and engineers, building code officials, standards writers, and planners, to develop a national plan for disaster mitigation activities.

The workshop participants synthesized current knowledge on building practices for insuring the safety of building occupants in new and existing buildings. They made recommendations to four audiences: (1) policymakers in Federal, State and local governments, for guidance on disaster mitigation, laws, regulations, policies, and programs; (2) practitioners, such as architects, engineers, and building contractors, for guidance on the best current practices to be used in making decisions about building construction that have to be made every day; (3) standards writers and those responsible for developing recommended practices, such as building code officials, for guidance on needs for new knowledge.

Exactly as recommended by Mr. Goldwater, this plan and the proposed recommendations to users in the building community, as presented in the NBS document, "Building Practices for Disaster Mitigation" (Building Science Series 46), provided an integrated approach to disaster mitigation through research and implementation of improved building practices. One workshop recommendation was to update the seismic design provisions of building codes. The last major revision to these provisions occurred in the 1950's. Since that time, there have been significant advances in knowledge. Based on the workshop recommendation, the National Bureau of Standards sponsored by the National Science Foundation and NBS, initiated a 3-year $1.3 million program to develop improved seismic design criteria which could be used nationwide in new buildings and in the rehabilitation of existing buildings. We have used the Applied Technology Council of the Structural Engineers Association of California as a principal resources in this program.

We are working very closely with the private sector, the trade associations, the State and local building regulatory officials and the concerned Federal agencies in the development of seismic design criteria.

In this NBS/NSF program on seismic design criteria and in all disaster mitigation activities, implementation is the key to success. Research which is not used provides few benefits. Likewise, developing improved building practices without planning their implementation

serves no one. Too often, practicing engineers are left to synthesize the research results and develop improved building practices on their own. This gap between research and use has long been evident to both practitioners and researchers.

Time does not permit me to read fully the prepared testimony outlining our efforts to close this gap, but I have offered representative reports on this subject to this committee.

The need for earthquake hazard reduction is well documented by the history of past earthquakes and the projected effects of future earthquakes in many parts of the country. Normally, we think of four ways to reduce the potential earthquake hazard: (1) Induced reduction of the earthquake intensity, (2) evacuation of the area, (3) avoidance of the hazard by not using the area, that is, land use control, and (4) prevention of the damage by improved building practices. All four of these solutions have their limitations.

Physically reducing the potential force of the earthquake, by such methods as pumping water into the ground, is a possible solution to reducing damage. However, such procedures are still in the research stage.

Evacuating threatened areas can achieve hazard reduction if predictions are certain and given adequate time. However, disruption of normal activities and adverse economic consequences are still a problem.

Land use control practices can reduce hazards of faulting, unstable earth, flooding below dams and tsunamis. For some of these earthquake hazards, such as faulting, this approach is the most economical, but often people are reluctant to cease building in otherwise desirable areas even if there is high seismic risk.

Earthquake-resistant building practices are the most effective approach to minimizing earthquake damages from ground shaking which causes over 90 percent of the damages. Even if an earthquake is predicted and the residents have evacuated the area, we still need to reduce the damage to buildings and other facilities. Obviously, if there has been no advance warning and no evacuation, the need for safe buildings is critical. For simplicity, I will confine the following discussion to buildings, but the same concepts apply to other facilities.

To reduce the earthquake hazard, we must know how buildings are used, what earthquake environment is likely, and how buildings perform during an earthquake. We know from our field investigations that buildings can be built economically to resist earthquake effects, but there is still need to reduce the high cost of identifying and correcting hazardous existing buildings and to make new seismically safe construction more cost effective.

Experience shows that the greatest earthquake hazard results from unsafe existing buildings. Buildings not constructed in accord with adequate seismic design provisions should be evaluated to determine whether they are unduly hazardous. Such buildings should be strengthened or replaced. The procedure for evaluating existing buildings developed for Veterans Administration and Defense Civil Preparedness Agency are steps toward these goals. Improved technologies are needed to make the hazard identification and strengthening procedures more economical. One approach that deserves study is the removal of financial barriers for abating unsafe buildings to speed hazard reduction.

New construction should not add to the earthquake hazard. Seismic design criteria providing appropriate resistance should be incorporated in building regulations and enforced. The seismic design criteria we are developing with NSF address this need.

In summary, any effective program for reducing earthquake losses must include research on building performance and the development and implementation of improved building practices. The Nation's research base includes characterization of earthquake hazards by USGS and the basic research funded by NSF. The NBS is prepared to carry out the additional research to develop performance criteria and test methods for evaluating how well buildings and their components perform. The integration of all this research with our continuing work with design professionals, industry, organized labor, builders, codes, and standards-writing groups, Federal agencies, and the State and local building regulatory agencies, would facilitate the development and implementation of improved building practices.

Public policy should encourage the building communities to use effective earthquake hazard reduction practices. Authority exists in most areas under State or local building codes. However, up-to-date earthquake design standards must be included in codes by the State or local governments, designers must learn to apply these standards in design, builders must follow approved details in construction, and regulatory authorities must check plans and inspect construction. The model code organization of building officials, the National Conference of States on Building Codes and Standards, the newly formed National Institute of Building Sciences, and the professional societies of architects and engineers provide appropriate mechanisms for achieving this implementation of earthquake-resistant building practices.

As Dr. Stever and others have indicated this morning, the Federal agencies already have sufficient legislative authority to undertake research and are working on a program plan that can be used to make budgetary decisions. With regard to mechanisms for coordination, I have discussed some aspects of this coordination that now exist. Dr. Stever has mentioned that the administration is scrutinizing this subject to see if a new coordinating body is needed and whether any additional legislative authority should be proposed by the administration. In this respect, NBS will be working actively with Dr. Stever.

We appreciate the opportunity to appear before you, and I will endeavor to answer any questions you may have.

Mr. BROWN. Mr. Goldwater?

Mr. GOLDWATER. Mr. Wright, how long have you been with the National Bureau of Standards?

Dr. WRIGHT. I have been in my present appointment for 2 years.

Mr. GOLDWATER. Previous to that?

Dr. WRIGHT. Prior to that I was with the National Bureau of Standards for 2 additional years, in interrupted service. I have worked in structural design for dynamic loads since 1955, in the U.S. Army and at the University of Illinois.

Mr. GOLDWATER. During the 1971 earthquake in the San Fernando Valley many of the freeway overpasses fell, collapsed. In fact, one fell on a truck and I think it flattened it out to less than 2 inches. What has changed as a result of that experience due to the National Bureau of Standards' efforts in the design of freeway overpasses specifically?

Dr. WRIGHT. Due to the center's mission, we have not been active in research on transportation structures. The Federal Highway Administration has an active research and laboratory program. However, I am aware of their research and the work that the National Science Foundation has sponsored at the universities. To avoid repetition of that very unfortunate event you mentioned, they have changed the highway design criteria to allow more space for bridge movements during an earthquake and to improve connections to piers.

Mr. GOLDWATER. So the National Bureau of Standards is not involved in transportation.

Dr. WRIGHT. We have not been involved in earthquake reduction research for transportation structures or in the development of their standards.

Mr. GOLDWATER. But you are involved with houses.

Dr. WRIGHT. Yes; we do work on housing and building structures.

Mr. GOLDWATER. As I recall, the railroads were twisted like spaghetti.

Dr. WRIGHT. Yes.

Mr. GOLDWATER. In the area of buildings has any change really resulted due to your work? Have you noticed any application of standards at which you arrived?

Dr. WRIGHT. We have made contributions, through work for the Department of Housing and Urban Development, in updating the minimum property standards. These standards indeed do affect the way buildings are constructed throughout the United States.

Mr. GOLDWATER. You were deeply involved in the San Fernando Valley earthquake and post evaluation?

Dr. WRIGHT. Yes.

Mr. GOLDWATER. I assume you followed it up with further research and inspection of the various buildings and structures. Were you involved at all in making recommendations for upgrading of codes?

Dr. WRIGHT. Yes, we have, as I noted in my testimony, been very active in a program for updating seismic standards.

Mr. GOLDWATER. This Building Science Series 46, Practices for Disaster Mitigation, provides an integrated approach to disaster mitigation, research, and implementation of improved building practices. That's a lot of words. What does it really mean and what is happening?

Dr. WRIGHT. That document, sir, was the result of a detailed study of natural hazards by experts from the National Bureau of Standards and from many other institutions in the country. Following this evaluation of the current state of practice and research knowledge, the representatives of the workshop developed a large number of recommendations.

Some of these recommendations have been implemented, and others have greatly influenced the research programs at the National Bureau of Standards and elsewhere. However, not all of the recommendations in that document have yet been carried out.

Mr. GOLDWATER. Let me understand. In this earthquake business we have the public Law 93–288, the Disaster Relief Act of 1974, giving authority to the National Science Foundation and USGS to look into earthquake prediction and warning. Were you likewise given authority from HUD? Is that how you got your authority?

Dr. WRIGHT. While we have no specific mandate for earthquake research activities under that legislation, we do have broad authority for building under the NBS Organic Act. We do work with HUD, the National Science Foundation and a number of other Federal agencies on research and technology transfer programs aimed at reducing disaster hazards including earthquakes.

Mr. GOLDWATER. Do you belong to any interagency coordinating committee?

Dr. WRIGHT. Yes, we are an active participant in the interagency task force of the National Science Foundation.

Mr. GOLDWATER. Specifically concerning earthquakes?

Dr. WRIGHT. We are not working solely on earthquakes. We are active in wind hazards, and we have done some work on flood hazards.

Mr. GOLDWATER. Do you feel there is adequate coordination for this whole area of earthquakes from your standpoint? Do you feel as if you are working in a vacuum, or do you feel you are making a significant contribution as a part of a total effort? Or do you feel we could do maybe a little better job.

Dr. WRIGHT. There are very strong coordinating activities and we feel that we have been an effective participant in many of them. I have a personal feeling that the attention which has been focused on research has been appropriate. There also is need for much stronger attention to developing improved building practices from the research knowledge and seeing that they are prepared in a useable form and delivered to the users in the private sector and to State and local governments. The NBS document recommends a number of these activities which would lead to the development and effective implementation of improved building practices.

Mr. GOLDWATER. How much money does the National Bureau spend in the area of earthquake research standardization?

Dr. WRIGHT. If you focus on the work we are conducting in our own laboratories apart from the work we are doing with many participants in the building community in developing revised seismic design provisions NBS is currently spending approximately $300,000. We will furnish exact figures for the record.

Mr. GOLDWATER. I assume you are going to spend $1.3 million on the seismic criteria?

Dr. WRIGHT. About $1.3 million is being spent on the development of seismic design criteria?

Mr. GOLDWATER. By the National Science Foundation?

Dr. WRIGHT. The National Science Foundation and the National Bureau of Standards are supporting this program.

Mr. GOLDWATER. Are you putting up any of the money?

Dr. WRIGHT. Over 3 years, we are contributing about $300,000.

Mr. GOLDWATER. Thank you, Mr. Chairman.

Mr. BROWN. Dr. Wright, I am interested in the amount of research being done on structures from the standpoint of earthquake resistance in other agencies. For example, I presume there is work being done in ERDA and the Nuclear regulatory Commission in connection with design standards for nuclear powerplants including standards of earthquake resistance; is that right?

Dr. WRIGHT. Yes, the work done originally by the Atomic Energy Commission and continued by the Nuclear Regulatory Commission

has led in the development of improved earthquake resistant practices. They were studying the problem well before the San Fernando earthquake. The technical approaches being developed for general building use relate closely to those developed for nuclear reactors.

Of course, nuclear reactors are a special type of building so considerable technical modification is required in the adaptation of these practices to housing and office buildings.

Mr. BROWN. Can some of the design criteria, say, having to do with the anticipated severity of the earthquake and the resultant earth movements be transformed over to other structures after being developed by the Nuclear Regulatory Commission?

Dr. WRIGHT. The fundamental knowledge most definitely can be transferred. However, the acceptable risk of failure is a function of the consequences of failure so the acceptable risks for nuclear reactors, of course, are much smaller than they are for conventional buildings. There is a substantial amount of additional work to be done to develop this technology in a usable form for adoption in conventional building practices, but the underlying scientific and technical knowledge is being used.

Mr. BROWN. What about the work being done within the Defense Department for the hardening of missile sites and things of that sort?

Dr. WRIGHT. This work is also usable. The work which has been done for the Department of Defense, some in which I participated, has done a great deal to increase our understanding of the behavior of structures under extreme loads.

This knowledge is being used in the improvement of our design practices for earthquakes, winds, and other natural disasters.

Mr. BROWN. Can you give me some indication of the cost effectiveness of earthquake designs which would be suitable to a layman? I am thinking basically of what is the additional cost to design for reasonable earthquake hazards and the degree to which that cost is perhaps reflected in longer life of the building or greater safety from other standpoints as well as the earthquake standpoint, so that I can get a general understanding of the economics of an adequate earthquake safety design program.

Dr. WRIGHT. The problem you mention is really an easier one. If you begin with an architectural layout and structural scheme which is conducive to good earthquake resistance. The additional cost for achieving such resistance is relatively small, usually less than 5 percent of the structural cost of the building. However, making existing buildings seismically safe is much more severe because it is harder to change existing structures than it is to revise plans on the drawing board. The cost of making existing buildings seismically safe can be extremely high. We need more research in this area. We do not know enough about the way some older types of buildings behave and what types of strengthening procedures are the most effective.

Mr. BROWN. I presume a rational program would focus on establishing adequate standards for new buildings and then as a second priority, those existing buildings which for one reason or another would have the highest priority such as schools, hospitals and things of that sort. Would that be the logical way to go about this program?

Dr. WRIGHT. This is certainly the procedure which has been taken in the State of California where seismic design criteria were applied

proactively to new construction and retroactively only to important public buildings such as schools. This is certainly the cheapest way to achieve eventual earthquake hazard reduction. However, we must recognize that the half-life of buildings is rather long and our existing seismically hazardous buildings will be with us for a long time unless deliberate efforts are taken to identify those which are unduly unsafe and to abate those hazards.

Mr. BROWN. I am interested in this half-life concept. We can assume that the half-life of some more or less average structure is what? Forty years?

Dr. WRIGHT. Forty or fifty years is a reasonable estimate of the average life.

Mr. BROWN. And the expected frequency of an earthquake is only every 100 years. What are the economics of trying to retrofit existing buildings?

Dr. WRIGHT. This is an extremely strong justification for the type of research activity that the Geological Survey is carrying out. If they can develop the ability to predict that a particular area will not have an earthquake for another 50 or 100 years, then we need not worry much about the existing buildings in that area.

However, that competence does not exist at present. In many parts of the country, it may be a long time before that ability is with us.

Mr. BROWN. So a rational program would then look, as far as existing buildings is concerned, not only at their earthquake resistance, how close they come to meeting reasonable standards, but also the possibility of a serious earthquake in the area where they are located?

Dr. WRIGHT. Yes. There is the capability today of making relatively imprecise estimates of whether there is a 1-percent chance or a one-tenth of a percent chance that a strong earthquake will strike any particular area, say, in the next year. Based upon this information of the degree of risk, it is possible to derive cost effective procedures to determine where hazardous buildings should be identified and what level of hazard is acceptable.

Mr. BROWN. As I understand the fragmentary data that we have on earthquake prediction, there seems to be some indication that the more serious an earthquake might be the longer period of time we might anticipate seeing precursor developments in the way of tilts or strains or bulges or whatever. Is that accepted?

Dr. WRIGHT. I am not a seismologist. While I have heard these statements, I would like to defer the response to that question.

Mr. BROWN. We will defer it. The point I was really getting at is if we have reason to predict a serious earthquake and we have say a year or 2 years or maybe up to 5 or 10 years indication that a serious earthquake will occur in that particular region, would that not allow us to focus on that reason for purposes of structural modification in order to obviate the worst effects of that?

Dr. WRIGHT. Yes, indeed. This type of predictive capability would be extremely valuable since it would allow us to focus corrective building actions in areas where they are most needed.

Mr. BROWN. Now, Dr. Hamilton, would you care to educate me as to whether the statement I made is roughly correct as to the leadtime anticipation of occurrence?

Dr. HAMILTON. The answer to your question is yes, there is evidence to indicate that the really great earthquakes have signals that may precede the event by as much as 10 years.

Mr. BROWN. Certainly that gives adequate planning time, if we had the research data necessary to make those predictions. Thank you.

I have a number of other questions I would like to ask but in view of the time I will defer these and request that if we provide you some questions in writing would you be willing to cooperate?

Dr. WRIGHT. Sir, we would be very happy to answer questions in that form.

Mr. GOLDWATER. Mr. Chairman?

Mr. BROWN. Yes.

Mr. GOLDWATER. Just one observation I would like to make. You would think that when we spend taxpayers' money we would produce something that would be a useful document for the layman or the practitioner in the field who winds up having to implement policy that Government legislators or bureaucrats have promulgated. I have been looking over this document edited by you, "Building Science Series 46, Building Practices for Disaster Mitigation" and can you explain to me what the purpose of this is supposed to be? What are you supposed to get out of it and who is supposed to read it?

Dr. WRIGHT. This was intended for a number of audiences, sir. One important audience was the group of people at the National Bureau of Standards and the National Science Foundation who are concerned with planning research programs and the implementation of improved practices for natural disasters. If you will look at the last pages which list the workshop participants, you will see that we have representatives of local building regulatory authorities, local land use planners, design engineers, representatives of trade associations such as the American Institute of Steel Construction. There was a diverse group of people from the building community and they were speaking to their peers and indeed to the policymakers who control the evolution of building practices.

Mr. BROWN. The problem probably is that you didn't have enough Congressmen at that point.

Mr. GOLDWATER. But they sure had the same types, a lot of intellectuals. You didn't have a person there who had ever swung a hammer or who was a contractor who built buildings. You had engineers. You had consultants. The point is that when you read what was written here it doesn't make sense. I just turned to page 19 because I was interested in building loads or something here having to do with dampening. It seemed to me that in the San Fernando Valley that was one of the problems, the ability of a structure to withstand—I think you call it dampening.

Dr. WRIGHT. Dampening is the ability to absorb energy rather than having intensity of motion build up.

Mr. GOLDWATER. That was one of the problems. One of the problems with the buildings in the earthquake was that they found that cement just did not give you a good dampening effect because it crumbled. One of the things we learned is to put more steel into a building.

I turn to this page to look and learn a lot more and here is what it tells me: "Surveys following the disaster, et cetera, et cetera, et cetera, could have been prevented had proven structural details been

used in the affected buildings." Well, that is commonsense. Why did we have to spend money just to find that out?

Dr. WRIGHT. This is one of the things which I think you are pointing out with your own remarks and, that is, that commonsense is sometimes an uncommon quality.

Mr. GOLDWATER. Only when it gets out of the hands of the practitioner or the person who has to do the work.

Dr. WRIGHT. Essentially I think I am saying much the same thing you are. One of the great problems in disaster mitigation is to have people such as those who are tying steel in building re-inforced concrete structures understand how important seemingly minor details are in achieving safety.

One of the saddest things I have seen in my life occurred a year after a major earthquake overseas. I inspected the site of a major hotel in the stricken area with a group of local builders, architects and engineers, people directly involved in the reconstruction, and I saw improperly tied steel. The building community there had a construction manual which showed the importance of carrying the ties in concrete columns back into the core so that if a column starts to crack and the shell falls off, the ties don't become loose and ineffective. If you can keep the ties anchored in the core of the column, the column, though it cracks a bit, will hang together and people won't get killed. The local architects, engineers and contractors should have known this because very simple documents had been made available to them.

One of the real problems is transferring the research knowledge to the worker who is tying steel on the job. He must know that if he does not do his job right, he is risking the lives of the people who use that building. That is one part of the delivery problem that we all have to work on.

Mr. GOLDWATER. Yes; but I don't quite understand how this is going to bridge that gap.

Dr. WRIGHT. This document recommends ways to bridge this gap.

Mr. GOLDWATER. But you spent a lot of time and a lot of effort and a lot of people were involved. The question is: Who is going to benefit from this document? This was put out in 1973. Have you seen the fruits of this?

Dr. WRIGHT. We are working very closely with the model code groups throughout the United States. Most of our local building officials belong to one of three professional organizations, the Southern States Building Code Conference in the South, the International Conference of Building Officials in the West and the Building Officials Conference of America in the Central and Northeastern parts of the country. We are working very closely with these building officials, the people who are responsible for checking the plans. We work with them on these problems to develop practices which are suitable for implementation and helping them translate research knowledge into usable forms. It is through them, practicing engineers and builders organizations, such as the National Association of Home Builders, that these practices can be carried to the people in the field. The National Bureau of Standards is a small organization and we are not able to do this job alone.

Mr. GOLDWATER. I understand that, but I don't see where this is such a great document. I read down here and it says: "When a detailed

analysis is not economical. * * *" What does that mean: "You should eliminate potential hazardous conditions."

Well, OK, fine, but so what? Where is this going to go? Is it just being filed someplace?

Dr. WRIGHT. It has been used as a guide for us and a large number of other people in disaster mitigation research and implementation programs. Again, I would say this recommendation is directed to research organizations and building officials organizations to help them understand what should be done actually implementing these practices through work with professional building regulatory officials, and with professional societies of design engineers and architects.

Mr. GOLDWATER. It sounds to me like a lot of people had a nice time in Boulder, Colo. It would seem to me that also if we are going to put things out like this that we should put something out of a practical nature. I would like to see, for instance, the results of your laboratory work leading to better buildings, the better use of material, specifically, more steel.

Dr. WRIGHT. We need the right type of steel in the right place.

Mr. GOLDWATER. Right. Have you followed up in the San Fernando Valley and looked at the structures and what have you? And what have you learned from that? Have you taken what was learned into the laboratory and done it again and again to make sure that our recommendation is going to hold up, and our recommendation is that we need more steel. We don't need a lot of fancy intellectual words here that not too many people will understand, first of all, and second of all, will ever read. But maybe a contractor could actually pick it up and actually apply it to a building or an architect could apply it in the design of a building or a bridge. That is where it seems to me that all of this effort should lead, the actual application of what we have learned from the disasters. There is a lot of commonsense here but it is something that we should already know. What I think we need is more lessons from what we have learned from disasters. I would like to see a document if you have one that takes a look at material structures based on your observations of the San Fernando earthquake. Do you have something like that and recommendations back to the State as to building codes to upgrade them? Do we have anything like that available?

Dr. WRIGHT. I agree with you so much. I do not want to sound platitudinous, but this document was a planning document, not an implementation document. We have continued in working on the development of improved practices which includes a major program of developing seismic design provisions which are practically and nationally applicable. We are advised in our latest publication by a group of building code officials and consultants, people drawn from the building regulatory agencies throughout the country and practicing design engineers, to make sure that the seismic design provisions will be practical and useful. We work with the conferences of building officials in advising them on their code changes and in helping them translate the research reports into language suitable for adoption. We work with the National Conference of States on Building Codes and Standards, representatives of the Governors of the 50 States who have the primary responsibility for building safety regulations. We work with them to develop knowledge in a form which is suitable for application

and practice. We can give you examples of this from the wind area, the earthquake area, the energy conservation area, the solar area and many other areas of building technology.

Mr. GOLDWATER. I would hope so. I would like to see that kind of material rather than holding something like this up as a panacea for all of our problems.

Dr. WRIGHT. Indeed it is not meant as a panacea, but as a program plan.

Mr. BROWN. Dr. Wright, I want to thank you and Mr. Kramer for your testimony this morning. You have held up very well under the circumstances and we appreciate your testimony very much.

Dr. WRIGHT. Thank you, Mr. Chairman.

[Further questions in written form were submitted to Dr. Wright. The questions and responses follow:]

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1. Please submit a statement of the dollar amounts obligated by NBS for earthquake work in fiscal years 1974, 1975, 1976, and 1977 (planned). The statement should be broken down into major categories and further into subcategories if this is informative. In-house work should be separated from work under grants and contracts. Please indicate whether the source of funding is direct appropriations or other agency funding.

Information on the dollar amounts obligated by NBS for earthquake work in fiscal years 1974, 1975, 1976, and planned for 1977 are provided in the following Table. The expenditures are listed in categories reflecting the thrust of each activity. An explanation of each of these research categories is attached to the Table.

Of the total funding for FY 1974, 1975, and 1976, 45 percent was allocated for in-house work and 55 percent of the funding was spent for contract work. The majority of this contract work complemented the NBS/NSF program for developing improved seismic design provisions by allowing us to use many experts and building practitioners from varied fields to support the program. The in-house work is directed toward the development and implementation of new building technologies and measurement methods for improved building practices. Approximately 70 percent of the NBS total funding for earthquake related building research is funded by other Federal agencies.

FUNDING FOR EARTHQUAKE MITIGATION

Center for Building Technology
Institute for Applied Technology
National Bureau of Standards

Category	FY 1974		FY 1975		FY 1976 & T.Q.		FY 1977 (planned)	
	NBS Direct Funding	Other Agency Funding	NBS Direct Funding	Other Agency Funding	NBS Direct Funding	Other Agency Funding	NBS Direct Funding	Other Agency Funding
Disaster Investigations	20	3.6	15	6.7	17	-	15	-
Improved Design Criteria for Masonry	94	51	47	42.2	40	42	10	96.7
Building Practices for Disaster Mitigation	30	230	40	432	88	422.3	60	60.7
Behavior of Concrete Members Subjected to Earthquakes	-	-	-	-	-	18	-	132
Seismic Performance Requirements for Building Service Systems	-	-	-	-	35	-	10	-

Note - Funds are Expressed in Thousands of Dollars

Description of Research Activities in Funding Table

Disaster Investigations:

Post earthquake investigations in San Fernando, California in 1971; Managua, Nicaragua in 1972; Guatemala in 1976; Italy in 1976 were conducted to evaluate building performance, to identify needed research and to provide technical assistance on reconstruction.

Improved Design Criteria for Masonry:

Conduct laboratory tests to determine the strength of masonry elements subjected to earthquake loads to develop procedures for determining the strength of masonry in existing buildings and to develop design requirements for inclusion in standards, model codes and Federal regulations.

Building Practices for Disaster Mitigation:

Develop a national plan for disaster mitigation activities, participate with other Federal agencies in coordinating earthquake research activities, develop comprehensive seismic design provisions for use nationwide in model codes and Federal regulations.

Behavior of Concrete Members Subjected to Earthquakes:

Laboratory tests to evaluate the performance of large-scale concrete members.

Seismic Performance Requirements for Building Service Systems:

Develop performance requirements for service systems including power, water, ventilation, and others for use in designing critical facilities, such as hospitals, which must remain functional following an earthquake.

2. What work does NBS have under way or planned for earthquake-resistant public facilities (roads, bridges, pipelines, dams, powerlines, etc.)?

As stated in our testimony, the National Bureau of Standards' disaster mitigation program encompasses research on earthquake-resistant design and implementation of improved building practices for all types of buildings. The NBS Organic Act gives us broad authority for building research, but our mission is not directed toward other types of structures or systems such as pipelines, dams, bridges, and roads. However, in our capacity as a research laboratory for the Federal Government, NBS does provide technical support to the Department of Transportation (DoT), which is responsible for the safe design of all transportation facilities, and to 30 other Federal agencies.

Although DoT does have its own research organization which examines the effects of earthquakes on transportation structures, that agency has applied our building research findings to similar situations for bridges, dams, and roads. One example is the Federal Highway Administration's proposed application of our procedures and results from the current development of seismic design criteria for buildings mentioned in the testimony. A second example is the NBS/DoT cooperative work on evaluating the effectiveness of various epoxy coatings in extending the life of bridge decks.

As the chairing organization for the U.S.-Japan Panel on Wind and Seismic Effects, NBS works with representatives from DoT and 15 other Federal agencies to support information exchange and cooperative research programs on extreme winds and earthquakes between Japan and the United States. At the recent joint meeting at NBS in May 1976, Panel members discussed work done on earthquake-resistant design of roads, bridges, pipelines, and dams to determine those areas which need additional research.

3. What areas of opportunity are there for future earthquake work at NBS?

There are three important areas in which NBS can provide continued contributions to the development and implementation of improved building practices for reducing earthquake losses. These include: (1) research and development of methods to predict building performance during earthquakes as needed for design, evaluation of hazards in existing buildings, and assessment of alternatives

for strengthening and repair; (2) technical support to Federal agencies, State and local governments and the private sector; and (3) technical assistance to the National Science Foundation (NSF) and the U.S. Geological Survey (USGS) in formulating and conducting their research programs and translating the results to improved building practices.

The NBS has a continuing role in the development of criteria which describe how buildings perform and of test methods which confirm the buildings' compliance with specified characteristics. Because of our interdisciplinary staff, NBS is able to incorporate users' needs in developing such performance criteria which provide a maximum opportunity for building innovation. Representatives throughout the building community have indicated the need for NBS to develop such performance standards. Specifically, they have indicated the need for NBS to do research for ensuring that building service systems, such as lighting, heating and ventilating, waste disposal, and water supply will remain usable following an earthquake. The American Society of Plumbing Engineers has emphasized the need for research which examines the ability of plumbing systems to withstand earthquakes.

The NBS sees further need for the development of uniform evaluation procedures for existing buildings and handbooks which explain how the homeowner, builder, or the architect should proceed in repairing a building following an earthquake. Although the Federal Government has procedures for reconstruction, the homeowner is frequently unaware of what steps he should or should not take. For example, following the Alaskan flood in 1967, many homeowners pumped the water out of their basements before the flood waters had sufficiently subsided. Although common sense would tell you that you should remove the water, doing so before the flood waters are lowered causes extreme pressures to build up on the home's foundation. In many cases, the basement foundations pulled away from the houses which resulted in costly damage to the buildings. Following this flood, NBS investigators provided instruction to the public on how to dry out buildings. Complying with our recommendations saved many homeowners from making more costly repairs to their homes. The NBS could conduct the research needed to prepare handbooks which describe in non-technical terms what the homeowner should do. A second handbook for builders and design professionals also could be prepared.

Through the technical support we provide other Federal agencies and our relationship with the private sector, we have the opportunity to synthesize research knowledge and facilitate implementation of improved building practices to achieve earthquake hazard reduction. The NBS has established communication with the numerous affected sectors; that is, the building regulatory agencies, State and local governments, the professional design community, university

researchers, and other Federal agencies. These continual interactions have provided the National Bureau of Standards with the vehicle to ensure that research results are implemented. An example of this cooperative activity is the NBS/National Science Foundation program on seismic design criteria. The American National Standards Institute (ANSI), the largest standards-writing organization in the United States, is already working to include these criteria in a consensus standard.

Working through Federal agencies and organizations such as the Conference of American Building Officials which represents the three model codes, we can extend the work we carried out for the DCPA mentioned in our testimony and develop uniform procedures for determining hazards posed by existing buildings. Working through the American National Standards Institute, we are in a position to implement the earthquake design loads developed from USGS work.

Technical assistance to NSF and USGS provides the opportunity for cooperative research efforts and for NBS to contribute to research program planning activities. For example, we use the seismological information developed by USGS to define design loadings for earthquake-resistant buildings. The program to develop nationally applicable seismic design provisions, which also utilizes research results developed by USGS, is another example of cooperative efforts. We are currently involved in conducting a national workshop to determine research needs for earthquake resistant masonry construction. Results from this workshop can be used by NSF for program planning purposes. Utilizing NBS involvement with the private sector, we can work with NSF to expedite the translation of research into practice.

4. In your statement, you mention that NBS works with "design professionals, industry, organized labor, builders, codes and standards-writing groups, Federal agencies, and the State and local building regulatory agencies."

Several of these groups would appear to benefit from design requirements that are costly. None of the groups would appear to benefit from cost-saving design. Would you comment on those appearances and describe how NBS ensures its recommendations are cost effective.

Although it might appear that some of these groups would benefit from costly design requirements, this is not the case. All groups who participate in the commerce of building: designers, industry, labor and builders, are keenly interested in less expensive design requirements to reduce their own costs and to increase their volume of work. To maintain the freedom for diversity in buildings and the livelihood

of many industries, various sectors of the building community are dependent on economical designs which provide equal opportunity for differing materials, design and construction methods.

Building owners and users, including Federal agencies, and State and local governments seek less costly design requirements to reduce their capital costs and the operating and maintenance costs for buildings they use. Obviously, they have other pressing needs for their funds. Due to the tight constraints on governmental budgets, this concern for saving money is particularly true now.

Codes and standards-writing groups and building regulatory authorities often are more concerned with safety and reducing property losses than with initial building costs. These groups consider the cost of changing building code provisions and the corresponding impact on the building industry. In many cases, revised codes and standards which reduce hazards may be cost effective, especially when one considers the value of a human life.

As indicated in our testimony, the NBS research focuses on the performance concept which examines how buildings, components, and systems should perform rather than what specific materials or techniques should be used. Our performance approach is not biased toward any particular technique, material, or company. Performance requirements provide the maximum opportunity for innovation and can stimulate a competitive atmosphere which results in cost-saving design and construction.

The NBS measures the consequences of building practices by examining the costs of design, construction, operation, maintenance, functionality, and safety. These explicit measures allow public authorities to weigh both the subjective and objective costs and benefits and to establish cost-effective levels of performance for buildings.

Mr. BROWN. Our last witness this morning will be Mr. Thomas Dunne, Director of the Federal Disaster Assistance Administration, Department of Housing and Urban Development. We owe you an apology, Mr. Dunne, for the lateness of the hour. We hope you will be able to reschedule your lunch that you had planned to have an hour ago. Your full text will be inserted in the record and if you choose to abbreviate or summarize——

STATEMENT OF THOMAS DUNNE, DIRECTOR, FEDERAL DISASTER ASSISTANCE ADMINISTRATION, DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

Mr. DUNNE. Mr. Chairman, with your permission I would like to submit my written statement for the record and give you a summary.

[A brief biographical sketch of Mr. Thomas P. Dunne and the complete prepared statement of Mr. Dunne are as follows:]

THOMAS P. DUNNE

Thomas P. Dunne, 39, Administrator of the Federal Disaster Assistance Administration, U.S. Department of Housing and Urban Development, is responsible for supervising the relief activities of governmental and private agencies following an emergency or major disaster declaration by the President.

Mr. Dunne was appointed to the position by the Secretary of HUD when Reorganization Plan No. 1 renamed the disaster functions of the Office of Emergency Preparedness and moved FDAA to HUD on July 1, 1973.

From March 1972 until joining HUD, Mr. Dunne had been Deputy Assistant Secretary for Operations of the Economic Development Administration in the Department of Commerce. Starting in November 1969, he held a series of increasingly responsible positions in Economic Development, which included on occasion working with disaster devastated communities.

Prior to entering public service, Mr. Dunne was Midwestern advertising representative of Nation's Business from 1965 to 1969. He previously served as an advertising representative with several agencies, as an insurance agent, and as an accountant.

A native of Chicago, Mr. Dunne attended the University of Illinois and Southeast Junior College. He is married to the former Carol Lucas of Chicago and they have four children.

TESTIMONY OF MR. THOMAS P. DUNNE, ADMINISTRATOR, FEDERAL DISASTER ASSISTANCE ADMINISTRATION, DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, ON A NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

Mr. Chairman, I am Thomas P. Dunne, Administrator of the Federal Disaster Assistance Administration (FDAA), Department of Housing and Urban Development. I am pleased to have the opportunity to appear before your Committee to discuss the general subject of earthquakes.

My remarks will cover the activtities of the Department of Housing and Urban Development in the areas of earthquake disaster assistance, preparedness, and mitigation. I shall conclude with observations on the two bills before your Committee—H.R. 13722 and H.R. 13845—and on the Senate-passed S. 1174.

I. DISASTER ASSISTANCE

To provide assistance after a declaration of a major disaster is a primary responsibility of the Department. Most of the authorities of the Disaster Relief Act of 1974 (PL 93–288) have been delegated to me as Administrator of the Federal Disaster Assistance Administration. This Act provides assistance to State and local governments and individuals that suffer losses as a result of major disasters declared by the President. This includes earthquake disasters.

Providing assistance under this Act is the primary function of FDAA. The authroities of the Act have proved adequate to cope with the 72 major disasters that have received a Presidential declaration since the enactment of PL 93–288.

We are supported in delivering assistance by a number of other Federal agencies that have the authority and capability to assist us. I believe that there is sufficient legislative authority on the books to deal with earthquake disaster assistance. We have established procedures and ties with other Federal agencies to implement this authority in case of an earthquake. It is significant to note that these ties also extend to State and local agencies responsible for disaster assistance.

We recognize that a strong earthquake striking a large metropolitan area will create problems because of the sheer size of its impact. These problems, however, are in the areas of managing the resources. We have identified many of these potential problems and are working with Federal agencies and with State and local governments in idenitfying means of dealing with them.

II. DISASTER PREPAREDNESS

This brings me to the second topic of interest to your Committee: earthquake disaster preparedness.

FDAA has funded studies to estimate the damage and casualties likely to result from large earthquakes that may strike the greater San Francisco, Los Angeles, Salt Lake City and Puget Sound Areas. The studies were conducted by United States Geological Survey staff. Many of the consultants and experts who assisted in these studies were from the potentially affected areas. The studies have been used as a basis for assisting all levels of government by identifying potential problems.

An earthquake response plan is now being developed for the San Francisco Bay Area. A complementary State and local plan is also being developed. These plans identify actions to be taken by each level of government. FDAA will coordinate the Federal effort and the California Office of Emergency Services will perform the same function at the State level. Variations of these same earthquake preparedness plans are in different stages of formulation in three other earthquake-prone locations studied—Los Angeles, Salt Lake City, and Puget Sound.

FDAA funding of State work in earthquake preparedness is also available under PL 93–288. Each State is allowed up to $250,000 to develop plans, programs, and capabilities for disaster preparedness. All States (and other jurisdictions defined as "States" in the Act—57 in all), except the Canal Zone, are participating. The initial emphasis is being given to the development of basic State emergency plans and other emergency response measures. Once this requirement is satisfied, grant funds may be used to prepare for unique responses to specific kinds of disasters and to address hazard mitigation problems. This would include response to and mitigation of earthquakes. Several States have noted their intention to do some earthquake response or mitigation work under these grants.

III. EARTHQUAKE MITIGATION

Preparedness plans are only one means to mitigate the earthquake hazards, as the other Federal witnesses this morning have stated. To complete the overview that they have provided you, let me now turn to other HUD activities. Specifically, those programs aimed at more earthquake-resistant buildings.

The Department has allocated more than one and a half million dollars to research and investigations dealing with natural disaster mitigation. Through fiscal year 1977, HUD research studies related to earthquake mitigation alone will have totaled about $1 million. Following is a summary of HUD funding in the area of natural disasters.

[In thousands of dollars]

Categories	Fiscal year—				
	Pre-1974 and 1974	1975	1976 [1]	Transition quarter [2]	1977 [3]
Disaster housing		298	809	360	600
Environmental planning and earthquake hazard reduction	[3] 467				300
Estimates of earthquake losses	407				
Total	874	298	809	360	900

[1] Preliminary.
[2] Estimated.
[3] Of this total about $250,000 was expended for earthquake hazard reduction.

This HUD research draws upon more basic work in this area done by other agencies rather than duplicating it. Thus, our research dollar can be devoted to our operational role.

HUD has primary legislative responsibilities for housing and community development matters. The overall emphasis of our earthquake mitigation research is on design and renovation of residential structures. The results of these studies provide a means to assist local communities in protecting themselves against earthquakes.

There are five studies that I believe would be of interest to this Committee.

1. Seismic design for single family dwellings

This study was initiated as a result of the rather extensive damage to single-family residences in the San Fernando earthquake of 1971. The project will be completed this summer. The end result will be a manual containing detailed design and construction features that can be incorporated in a single-family dwelling. The manual has already been presented to industry representatives on the West Coast and has received favorable reactions.

2. Cost impact of seismic resistance

This effort is about to start. Properties insured by HUD must meet certain Minimum Property Standards—or MPS. For seismic design, the MPS require conformance with standards published by the American National Standards Institute, specifically ANSI A58.1. The nature of these requirements varies with the degree of seismic risk in the area. They have been changed recently as a result of the New Uniform Building Code Seismic Risk Map of the United States. The HUD cost-impact project is designed to provide definitive and credible data on the added cost of designing these seismic safeguards into residential buildings in areas in which the seismic requirements have been increased. It will supply needed information to governments at all levels, to the construction industry, and to individuals.

3. Seismic behavior and design guidelines

This project is investigating through laboratory tests the behavior of single-story masonry residential buildings under seismic loads expected to obtain in Zone 2 (moderate damage) of the Seismic Risk map. The experimental results of these tests will be translated into design and construction guidelines for the industry. Working with HUD, the Structural Engineers Association of California will prepare the manual. This is one example of the Department's cooperation with professional groups.

4. Seismic rehabilitation of existing buildings

A trend has emerged to remodel multi-story buildings. This is primarily due to the rising costs of new construction. Many such products are to be used for elderly persons. Seldom do these existing buildings incorporate adequate seismic safety features. HUD will prepare a manual setting out a systematic methodology, incorporating these safety features, for renovating such buildings. It will also include relevant cost/benefit data. Thus, management decisions can be made on the economic feasibility of the rehabilitation effort. Incidentally, the methodology in the manual will draw heavily on work performed by the National Bureau of Standards. This is another indication of HUD and other agencies coordinating their respective efforts and drawing upon the results of each other's work.

5. Environmental planning guidance and earthquake hazard reduction

This 5-year program has been conducted cooperatively by HUD, USGS and California's Association of Governments. Much information dealing with soil conditions and seismology and water control has been developed. This data is to be made available in a form that can be incorporated into the day-to-day decisions of local governments. Some examples of this are: exact location of active faults and landslide- and flood-prone areas and techniques for land-use planning and incorporating natural hazard risk considerations applicable to other geographic areas. A final report will provide guidance to community planners and decision-makers on earthquake hazard reduction.

IV. PROPOSED LEGISLATION

Now I come to the several bills on earthquake hazard reduction being considered by your Committee, specifically the Senate-passed S. 1174, H.R. 13722 and H.R. 13845.

The specifics in each one of these bills are different. The main purpose of all three of them, however, is to provide a focal point for a program of earthquake hazard reduction. The intentions of the Committee are worthwhile. In considering the means to achieve them, however, the Department has several comments that I would like to share with you.

Let us first examine the most significant duty of this focal point that would be created by the bills—be it a "lead agency," a "council" and a "board," or a "conference." That main duty would be to formulate a national program of earthquake hazard reduction. As the Committee has already heard, the National Science Foundation and the United States Geological Survey are working closely together on one aspect of the problem—identifying what further research needs to be addressed. HUD is also participating in this formulation process by way of a Memorandum of Understanding with NSF. An Interagency Coordinating Committee meets regularly to discuss current and future projects. This provides for exchanging of research results, avoiding possible duplication, and exploring the possibility of jointly funded projects.

The same comment can be made about the other earthquake-related activities—including validation of earthquake predictions and procedures for disseminating them to State officials; research in the earth and engineering sciences and in the social sciences as well; seismic risk mapping; development of instrumentation; a clearinghouse function to make available to potential users new information in usable form; participation in exchange of data with relevant foreign countries—to cite only the most significant topics.

H.R. 13845 would also give the "National Earthquake Hazards Reduction Conference" the authority to coordinate a national program of earthquake mitigation. In our opinion, this duty is already being adequately performed through a number of informal mechanisms. The activities of the relevant agencies are coordinated through an Interagency Discussion Group on Disaster Mitigation that meets about once a month—with NSF acting as an informal host organization. The member agencies present results of ongoing efforts; discuss objectives, scope, and funding of projected programs; and exchange other relevant information.

Further, any number of other frequent informal exchanges of information and views take place between affected Federal agencies. For example, USGS and FDAA maintain close coordination on earthquake prediction matters. Only recently Dr. McKelvey, Director of the USGS, briefed FDAA fully on the Palmdale uplift and on his agency's efforts to establish procedures to disseminate earthquake predictions to State officials. Also, the Secretary of HUD has delegated to USGS, among others, some of the warning responsibilities contained in Section 202 of the Disaster Relief Act of 1974.

V. CONCLUSION

In summary, Mr. Chairman, we believe there are already sufficient authorities to carry out the purposes of the bills: a research program is being formulated, a national earthquake hazard reduction program is ongoing, and the necessary coordination is taking place. Further, the existing authorities provide the Executive Branch with flexibility to adjust to management needs that may arise as a result of developments in this rapidly moving technology. The creation of an additional body, like those proposed in the three bills before your Committee, does not appear to be necessary.

However, as you have heard here this morning, there are a number of studies and activities that are now underway to better identify the issues and the options to be taken in this important area. I would, therefore, suggest that further action by the Congress be postponed until those issues and options are better defined.

Thank you, Mr. Chairman. Now if there are any questions I will try to answer them.

Mr. DUNNE. My statement covers three major activities of the Department related to earthquakes: Disaster assistance, preparedness, and mitigation.

Disaster assistance. The Disaster Relief Act of 1974 provides supplemental assistance to assist States and local governments in their responsibilities of alleviating damage, loss, hardship, and suffering. This assistance is provided when the Governor of a State requests the President to provide Federal relief. At the determination of the President, he may declare a "major disaster" or an "emergency." This act provides assistance to individuals such as food, temporary housing, loans, and

grants. It also provides funds for the State and local governments to assist them in the repair and reconstruction of public facilities. The authorities of the act have been adequate to cope with 74 major disasters declared by the President since enactment.

Disaster preparedness. The Disaster Relief Act of 1974 authorizes preparedness activities. Studies have been conducted for four major metropolitan areas to estimate potential damage and casualties resulting from earthquakes striking these areas. These studies have served as a basis for joint Federal, State, and local earthquake response plans.

The act also allows for a $250,000 development grant to each State to be used in developing its plans, programs, and capabilities. All States are participating. Several States are using part of this grant for earthquake response or mitigation work.

Earthquake mitigation. The Department has allocated more than $1½ million to research and investigation dealing with natural disasters. Through fiscal year 1977, HUD research related to earthquake mitigation alone will have totaled about $1 million.

The overall emphasis of the Department's earthquake mitigation research is on design and renovation of residential structures. There are a number of studies currently in progress. Among these are studies dealing with (1) seismic design for single family dwellings, (2) a cost impact study to determine the added cost of designing these seismic safeguards into residential buildings, (3) laboratory tests on the behavior of single-story masonry residential buildings under seismic loads, (4) seismic rehabilitation of existing buildings, and (5) studies identifying exact locations of active faults to be used in land-use planning. Each of these studies involves a close coordination with other Federal agencies, the private industry, and local governments.

Mr. Chairman, in my opinion, these varied but closely related activities are being well coordinated. There is continuous communication among the involved agencies. As you may have heard here this morning, there are a number of studies and activities that are now underway to better identify the issues and options to be taken in this important area. I would, therefore, suggest that further action by the Congress be postponed until those issues and options are better defined.

Thank you, Mr. Chairman. Now if there are any questions I will try to answer them.

Mr. BROWN. Thank you very much.

I raised a question earlier with regard to what you might call the cost impact of seismic activities and I notice you have an effort in that area. Have the results of your studies reached any tentative conclusions as to what the additional cost of meeting adequate seismic standards would be for various types of dwellings?

Mr. DUNNE. Mr. Chairman, that effort is just about to start and it will be a 12-month effort. So we have no reliable data to submit at this particular time.

Mr. BROWN. Mr. Goldwater, do you have any questions of these witnesses?

Mr. GOLDWATER. Have you been with the program since 1973?

Mr. DUNNE. I took over officially July 1, 1973, when the Office of Emergency Preparedness was abolished and the natural disaster program was transferred to the Department of Housing and Urban Development.

Mr. GOLDWATER. That was General Lincoln?

Mr. DUNNE. I believe he left OEP in January 1973. There was an Acting Director of OEP in the interim before the agency was abolished.

Mr. GOLDWATER. I think he is the one I dealt with during the San Fernando activity. Were you in Government at that time?

Mr. DUNNE. I was Deputy Assistant Secretary for Economic Development Operations at the Department of Commerce for 4 years previously.

Mr. GOLDWATER. Does your office get involved with international relief?

Mr. DUNNE. No; we don't, but we do coordinate closely with the people at State and AID. As a matter of fact, 2 or 3 weeks ago I took my senior staff over to the State Department for a review of the Guatemala earthquake and the Italian earthquake that recently occurred. We were exchanging information on the unique types of resources that had to be brought to bear during those peculiar types of disasters. We have a continuous dialog with AID.

Mr. GOLDWATER. In evaluating the damage after a natural disaster, who do you look to for information?

Mr. DUNNE. Let me briefly take you through what occurs. Under our procedures, the Governor describes what the damage and losses are. In one of the uses of the preparedness grant, we are asking the States to develop a better capability to make damage estimates.

However, we do verify the State estimates and we use a variety of Federal agencies whose personnel have been trained in this area. We use the Corps of Engineers, the Federal Highway Administration, the Department of Housing and Urban Development, the Interior Department's Bureau of Reclamation, as well as other Federal agencies with disciplines in particular functional areas.

Mr. GOLDWATER. You never utilize the private sector?

Mr. DUNNE. Yes; in this respect, we do use the American Insurance Association quite frequently. We have a standing agreement with them which I signed about 2 years ago. They complement our efforts, so we do get at least an idea of how much of the damage is insured.

Mr. GOLDWATER. Did you ever use their adjustors?

Mr. DUNNE. No; we have not. But the Small Business Administration, I think, going back to 1972 during Hurricane Agnes, did use the General Adjustment Bureau. I do not know if SBA is using them actively any more, but they are a potential resource.

Mr. GOLDWATER. In the studies that you are undertaking on the four cities—I have not read your testimony—what are you trying to find out there?

Mr. DUNNE. This effort was brought about because of the 1971 San Fernando earthquake and it started in the Office of Emergency Preparedness. We contracted with the U.S. Geological Survey to undertake a vulnerability study for each area which would tell us under the worst possible conditions what type of damage and what level of casualties are likely to occur. And this would be the basis for the joint Federal, State, and local planning effort for responding to that disaster.

It was not a mitigation study. It was designed to provide a basis for response planning. In the San Francisco area, we hope that by the

end of this calendar year all three levels of government will have completed their joint preparedness planning and will be able to exercise their plans. We hope that toward the end of next year the Los Angeles area plans will be completed and then we will be looking to complete Puget Sound and Salt Lake City area efforts some time in the future. But the vulnerability analyses have been done and published. They present the likelihood of what will occur in terms of deaths and injuries or damage to critical facilities such as dams, hospitals and transportation networks.

Mr. GOLDWATER. You are developing preparedness plans. Are these really plans of action?

Mr. DUNNE. That is correct. They will assign responsibility to each Federal agency. Within the State of California, they will identify the action agencies at the State level and what plans, programs and procedures they will follow and describe what resources will have to be brought to bear that may not be readily available in that area.

For instance, we know after having a serious earthquake in Los Angeles or San Francisco that we will have to provide an enormous amount of temporary housing. People will be displaced. We may not be able to find that temporary housing in the immediate area. We will have one of two decisions to make. Maybe the Governor will wish to evacuate and will order it, otherwise we will want to bring mobile homes or prefabricated types of buildings into the area. We have to identify who will be responsible for that activity and how it will be coordinated among the various levels of government and where we will get the resources from.

Mr. GOLDWATER. Do you get into such concerns as commonality of communications equipment and rescue equipment, et cetera?

Mr. DUNNE. We have communications on the Federal side through the civil defense system.

Mr. GOLDWATER. You would want it to be compatible with the State?

Mr. DUNNE. The State communications systems are already tied in with the Federal Government by the civil defense network communications systems.

Mr. GOLDWATER. One of the things we found in the 1971 earthquake was that there was inadequate communication. There was also no commonality of frequencies used in the radio system.

Mr. DUNNE. We do have a regional and State by State national communications system and we do work with the communications specialists. For instance, right now we are dealing with the typhoon disaster in Guam. We did find that the only communications in and out of Guam were through Navy facilities. The territorial government in Guam did not have any communications except with the Navy. Certainly, the area of communications is one of the areas we are dealing with and communications specialists on both the Federal and State level will be working together and will have a coordinated function.

Mr. GOLDWATER. I hope that means that everybody will be using the same frequency.

Mr. DUNNE. I hope so too.

Mr. GOLDWATER. Are you satisfied that they are?

Mr. DUNNE. The plan is not completed, and until it is exercised I cannot be satisfied with anything.

Mr. GOLDWATER. One of the inadequacies of Federal planning in response to disasters is the inability to deal with private do-gooders, volunteers, people who have CB radios, and jeeps, people who want to contribute clothing and medicine and volunteer their services or their houses. It often amazes me that the Federal Government as well as State and local governments feel that only they are capable of putting together the necessary resources to respond to a disaster. And yet we have all of this manpower, all of this volunteerism and goodwill spirit of Americans flowing forth and wanting to be a part of disaster mitigation only to be ignored by those in command.

This was so grossly evident in the Guatemalan earthquake recently when literally tons and tons of material was just stockpiled. Most of it was not useful, but the point is that none of the effort was coordinated. These people felt they wanted to be a part of the program, but they weren't made to feel that they were. I wonder, did you get into that at all?

Mr. DUNNE. Yes; as a matter of fact, our law allows us to coordinate, with their agreement, the various volunteer organizations, and we already have signed agreements with the American Red Cross and the Salvation Army. I think what you are really addressing is not the regular volunteer agencies but the splinter groups who want to send clothes or want to donate money, et cetera. We have been able for the most part to cope with that fairly well on the domestic side in recent years because we can identify what that group is. We have asked them to come under and work with the regularly-structured volunteer agencies. The worst thing in the world is to have undisciplined people who are highly emotional and who have not been trained going out trying to help their neighbor, which we applaud, but oftentimes getting in the way and not really helping. When people say they want to send food or clothing or money, we ask them to donate to the existing volunteer organizations and work with them. I think in most cases it has worked out quite well, but occasionally we do run into a group which forms its own organization overnight and wants to respond, and we do have some problems. But it has not been a monumental problem, at least in the last 3 years I have been with this program.

Mr. GOLDWATER. I would like to yield to my colleague from West Virginia who has had firsthand experience with disasters.

Mr. HECHLER. Not only in West Virginia but also Guatemala. I had an opportunity to go down there. I think what the gentleman from California has observed is absolutely correct. There is not enough effort exerted to mobilize some of the excellent goodwill that always springs up at the time of disaster. However, I would add that there is also a great deal of unnecessary material that people clean out of their attics and doctors clean some of their old samples off their shelves, some of which are outdated. At the same time though I think the gentleman's point is very well taken, that there ought to be a better way to try to mobilize and draw in the tremendous amount of assistance that is offered on a voluntary basis.

All too often the Federal Government and even the private relief agencies will say, just give us money and don't give us anything

else. I think a good deal more could be done to try to utilize this type of voluntary assistance.

Mr. GOLDWATER. The thing I found in the Guatemalan situation and in California was the lack of authority coming down from the top, speaking with one voice and saying today we need blankets and tomorrow we need shoes. There was no one person in command that the churches and groups could look to. As a consequence, they cleaned out their closets and dumped it in a box and carried it down to a warehouse and stashed it. And that presents other problems.

Mr. HECHLER. And a good deal of time was spent in Guatemala simply sorting this out. Incidentally, we had an unusually able Ambassador there, Francis Meloy, who just lost his life in the tragedy in Lebanon. And he did a remarkable job after the earthquake. However, a good deal more needs to be done for advance planning so you don't have this type of confusion.

Mr. DUNNE. I would like to add one thing to that, Congressman. For the most part the volunteer agencies need money. They don't need food. If the availability of food is a problem, we have mechanisms to get food into an area, and there are always food stamps available on an emergency basis. Clothing can be taken care of. The American Red Cross does a splendid job. The problem lies in educating people not to send goods unless they are asked for, but to send money, because the goods that are supplied by the volunteer agencies cost money and they get those through voluntary contributions. So it is a matter of education rather than trying to get more and more groups involved in this area.

We know specifically what the American Red Cross and the Salvation Army and the Mennonite Disaster Service are going to do in a natural disaster.

Mr. GOLDWATER. What would be helpful in this area would be to put out a statement on an hourly or daily basis from the director of the disaster relief effort, even if it is the President of the United States, requesting people to send money to the volunteer organizations. There has to be one authority giving the instructions. That is the thing I have found. People were running around and they were having different orders. There was not a common denominator there flowing down. Different people had different ideas.

Mr. DUNNE. The law we are operating under provides for a Federal coordinating officer and his specific role is to coordinate the activities of all the Federal agencies working in consonance with the State and local governments and with the volunteer agencies. You now see in the disaster area a single Federal individual in charge, with all the coordination authorities that have been delegated to me.

I don't think you have seen in the more recent disasters, the Idaho disaster or the flood down in Houston last week, that we are not speaking with one voice. We have spent a great deal of time and effort and some money, under our preparedness activities, not only with the Federal agencies but also with the States so they know what to expect of us. We have gone to considerable effort to have the known volunteer agencies present at our preparedness sessions in each State as we have held them, and we have also had on a national basis, almost a day-to-day dialog with the large volunteer agencies. So we do have a much closer coordination than we have had in the past.

Mr. GOLDWATER. I don't want to be misleading. I have to recognize that a great deal has happened since 1971 in the organization of this whole effort. I was impressed with it in the Guatemala thing, but there was that one hole that hasn't been plugged and that is the proper handling of these unorganized uncoordinated Americans who want to help. You cannot ignore them because they are going to be there whether you want them or not. So you had better figure out a way of utilizing them. That is the one hole that I saw. Maybe you are right that it is more of a problem internationally than it is strictly a national problem here. I wanted to ask you about this earthquake business. Are you working at all with the National Bureau of Standards in your research?

Mr. DUNNE. I have a gentleman here from the policy development and research side of HUD which is the centralized research arm of the department and I think he could more specifically answer the question.

Mr. GOLDWATER. What is your name?

Mr. WERNER. I am William J. Werner, director of the building technology research staff in the Office of Policy Development and Research.

[A brief biographical sketch of Mr. William J. Werner is as follows:]

WILLIAM J. WERNER

Mr. William J. Werner was born in Brooklyn, New York, and received his degree in Civil Engineering from the Polytechnical Institute of New York. He has pursued graduate studies in structural engineering at George Washington University and Catholic University in Washington, D.C.

Mr. Werner came to the Department of Housing and Urban Development in 1969 as manager of "Operation Breakthrough" Housing System testing, evaluation, and quality control. He has been Acting Director of the Building Technology Research Staff, Office of Research and Policy Development, since 1973. Prior to his service with HUD he was employed by the U.S. Postal Service and as a structural engineer with several private firms.

Mr. Werner is a Registered Professional Engineer in Virginia and in the District of Columbia and a member of the American Society for Testing and Materials and the Federal Fire Council.

Mr. WERNER. We have had a many year relationship with NBS going back to at least 1969 that I am aware of across the board in housing technology. The projects that Mr. Dunne mentioned are not being done at the National Bureau of Standards. As the "client" we felt we wanted to go to where we thought we could get what we felt was the best for our research dollar. So the projects were all competitive procurements.

Mr. GOLDWATER. But you do talk with each other?

Mr. WERNER. Absolutely, yes. We are on many of the same joint committees as Dr. Wright mentioned.

Mr. GOLDWATER. How much money are you spending in this area of seismic resistance? Do you have a dollar figure?

Mr. WERNER. For fiscal 1976—and it includes approximately $250,000 in disaster housing systems designs for ruggedized mobile homes that can be reused as disaster housing or a cost effective disaster housing system—it is all lumped together in our budget category and it is approximately $800,000. We are proposing approximately $600,000 in fiscal 1977.

Mr. GOLDWATER. Do you work at all with the State and local governments involving the codes—I guess that is not an area of research, is it?

Mr. WERNER. One of the first things we do is determine the audience that we went our research to go to, and consequently in that regard we do work with the States. If the end product is to be something for a builder, we get involved with the National Association of Home Builders or building code officials or someone of that type.

Mr. GOLDWATER. But actually implementing what your R. & D. has come up with does not fall on your shoulders, does it?

Mr. WERNER. I don't quite follow.

Mr. GOLDWATER. You are in charge of research and development for HUD.

Mr. WERNER. Building technology research, right.

Mr. GOLDWATER. If you develop a specific technology, do you get involved in implementing it or seeking that it is implemented or trying to persuade its implementation at the local level?

Mr. WERNER. Yes, in two ways. First, to the extent we can try to work with the voluntary consensus standards writing organizations such as ASTM or American National Standards Institute or the National Conference of States on Building Codes and Standards. That is a moral persuasion type of effort. We also have the HUD Minimum Property Standards, which is our design document for properties insured under FHA mortgages. And, of course, if FHA adopts it in the Minimum Property Standards, then that has a spinoff.

Mr. GOLDWATER. Thank you.

Mr. BROWN. Mr. Dunne, am I correct in that there still remains a couple of other disaster agencies, the Federal Preparedness Agency and the Defense Civil Preparedness Agency? Are those still operating?

Mr. DUNNE. The Defense Civil Preparedness Agency in the Defense Department, of course, and the Federal Preparedness Agency, which was a spinoff from OEP, is now in GSA. Their main thrust is continuity of Government in case of a civil disorder or an attack.

Mr. BROWN. All of these agencies would presumably come into action in the event of a major national disaster I suppose?

Mr. DUNNE. The national disaster that is brought about by an attack on the civilian population, yes. Natural disasters, no. Natural disasters are highly localized. They are not national in scope. I could not conceive of a natural disaster that would shut down the whole country. I think we approach them in completely different ways.

Mr. BROWN. I apologize for my ignorance of the functions of the various agencies, but I am basically concerned with the degree to which the various agencies concerned with different types of disasters might have developed some degree of coordinated approach. There would obviously be certain commonality as to ways you would handle some of these things and I presume there is some degree of coordination between the three agencies.

Mr. DUNNE. I think the commonalities are overstated and the dissimilarities are understated. There is going to be a congressional hearing on this subject by the Joint Committee on Defense Production at which I have been invited to testify. I believe there are big conceptual differences that ought to be pointed out to the Congress. I know there are people who are trying to make various points in terms of the commonality of natural disaster and nuclear disaster preparedness but I would like to point out that there are an awful lot of dissimilarities. We ought to start focusing on the basic problem and not

just on breeding more agencies or trying to consolidate agencies. I have a disagreement philosophically, conceptually, and pragmatically with reorganization just to reorganize.

Mr. BROWN. Let me give one illustration of where there might be a commonality. One of the kinds of responses to an earthquake prediction might consist of the evacuation of a community which was under threat. That is the same sort of response you would take to an anticipated nuclear attack or any other kind of military situation, but basically I wanted to raise the question of whether in any of your research or planning to date you have gone as far as to contemplate the need for evacuation and what, if any, major efforts have been concerned.

Mr. DUNNE. That is something we are certainly looking at. I sent one of my senior regional directors and two outside consultants to Australia after it was hit by the cyclone in 1974 in which the Australian Government evacuated the major part of Darwin. We thought we could learn some lessons from that. It created more doubts in my mind about the feasibility of evacuation in the event of natural disaster. Of course, as Dr. McKelvey pointed out, we are not near a prediction capability and I set this as a hypothesis. If we reach the point where scientists can say with reliability that an earthquake will hit a year from now in the center of this particular metropolitan area and somebody, let us say the Governor, decides to evacuate the area, there are many policy considerations which suggest that maybe evacuation is not such a great idea, because what is going to happen to that community? For example, will the banks stop making loans and the insurance companies cancel insurance? And what will be the effect on local and State governments? There is a whole series of implications here. And so I am not willing to jump into this area of evacuation and say it is a great idea or a bad idea.

I think it has to be studied. And before we can get into an intensive study I think we have to wait until the scientific community comes up with a more reliable base for making predictions.

Mr. BROWN. This question was asked in connection with the prediction made by the Cal Tech research people with regard to the earthquake in Los Angeles. I am not, of course, espousing the immediate preparation of evacuation plans, but rather the point that you made that there is research on this. I presume your agency would be a primary agency in connection with any studies with regard to the desirability of evacuation in response to a disaster of this sort.

Mr. DUNNE. As part of our preparedness grant effort, the States are allowed to look into the question of evacuation. I think that decision will have to be made by the local officials and the Governor rather than the Federal Government.

Mr. BROWN. Mr. Dunne, I think that is probably as far as we want to go this morning with you and I will ask for your cooperation in the event we have missed any significant questions. Could we get a response in writing from you in that event?

Again, I apologize for keeping you this far into the noon hour. I do very much appreciate your cooperation with the committee and your excellent testimony. Thank you very much.

[Further written questions were submitted to Mr. Dunne. The questions and responses are as follows:]

Question 1. Please submit a statement of the dollar amounts obligated by HUD for earthquake work in fiscal years 1974, 1975, 1976, and 1977 (planned). The statement should be broken down into major categories and further into subcategories if this is informative. In-house work should be separated from work under grants, contracts, or interagency transfers.

In regard to your question on HUD funding for earthquake work, the data on external funding are as follows (there has been no in-house funding):

[In thousands of dollars]

Categories	Fiscal year—				
	Pre-1974 and 1974	1975	1976 [1]	Transition quarter [2]	1977 [2]
Disaster housing		298	809	360	600
Environmental planning and earthquake hazard reduction	[3] 467				300
Estimates of earthquake losses	407				
Total	874	298	809	360	900

[1] Preliminary.
[2] Estimated.
[3] Of this total about $250,000 was expended for earthquake hazard reduction.

Categories were discussed in my testimony. A breakdown into subcategories would serve no informational purpose.

Question 2. Please provide copies of the FDAA-funded studies of likely damage and casualties from earthquakes mentioned on page 2 of the testimony.

Copies were received and are available for inspection in the Committee offices.

[Whereupon, at 1:15 p.m., the subcommittee was recessed to reconvene at 9 a.m. on Wednesday, June 23, 1976.]

EARTHQUAKE

WEDNESDAY, JUNE 23, 1976

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, D.C.

The subcommittee met, pursuant to notice, at 12:10 p.m., in room 2318, Rayburn House Office Building, Hon. George E. Brown, Jr., of California, presiding.

Mr. BROWN. The subcommittee will come to order.

I want to apologize to the witnesses who have been inconvenienced as a result of the delay of the meeting of the subcommittee. I wish there were something we could do to make up for it, but unfortunately the nature of the business before the Democratic Caucus this morning was such as to make it impossible to proceed.

Our first witness this afternoon will be Mr. Frank Press. Dr. Press is the chairman of the department of Earth and planetary sciences at MIT and is one of the leading authorities on earthquake prediction in this country.

Mr. Press, will you come forward? We are very pleased that you could be here today and again I apologize for the inconvenience.

You may proceed with your statement. The full text will be included in the record at this point. You may extend or summarize it as you see fit.

[A brief biographical sketch of Dr. Frank Press and Dr. Press' prepared testimony follow:]

DR. FRANK PRESS

Frank Press is Professor of Geophysics and Chairman of the Department of Earth and Planetary Sciences at the Massachusetts Institute of Technology. He has held positions at Columbia University and the California Institute of Technology, where he was Director of the Seismological Laboratory from 1957 to 1965. Press was a member of the President's Science Advisory Committee from 1961–64, and served as a member of the National Science Board from 1970–76. He is President of the American Geophysical Union and is a member of the Council of the National Academy of Sciences. He is Chairman of the Committee on Scholarly Communication with the People's Republic of China.

Press received the Distinguished Service Award of the Department of the Interior in 1971, and the Distinguished Public Service Medal of NASA in 1973.

PREPARED TESTIMONY

Congressman Symington, members of the Subcommittee, let me begin by expressing my appreciation for the invitation to testify at these hearings dealing with possible legislation in the area of earthquake hazard reduction. The earthquake problem has many components. It includes the broad field of seismic engineering, which deals with the design of structures to withstand earthquakes, the study of soils and foundations and how they respond to violent ground shaking. Geological and geophysical hazards such as landslides and tsunami are

significant elements. Earthquake prediction is a major new element and the rapid progress in this field of research in recent years is a major scientific breakthrough. Seismic risk analysis dealing with the assignment of relative risk to different regions will impact upon local building codes and the siting of major structures such as nuclear power plants and dams. The social, economic, legal and public policy issues that arise from all of these elements must be considered in any comprehensive government policy in this area. I see by the list of witnesses that the Committee will receive testimony from experts in all of these areas, and I will concentrate on my own field of professional interest, earthquake prediction research.

The most advanced countries in earthquake prediction research are China, the Soviet Union, Japan and the United States. Most seismologists in these countries agree that precursory physical changes take place in the earth's crust prior to earthquakes and that these changes will eventually form the basis for an operating earthquake prediction system in many parts of the world. There may be some disagreement about which premonitory events will prove to be most effective, but the general opinion is that several indicators will prove to be significant. Although the Chinese state that their program is still in the developmental phase, they claim to have made several successful predictions. On February 4, 1975 the Chinese issued a warning five hours before a destructive earthquake of magnitude 7.3 in a densely populated area of Liaoning Province of northeast China. As a result, more than a million people were evacuated from their homes into the streets and fields, and tens of thousands of lives were probably saved when their homes collapsed. An American team is in China at this time at the invitation of the Chinese and is investigating the details of this event. Some information has already been released and I will give more details in Appendix I of this report.

Beginning in 1965, a number of studies commissioned by the Office of Science and Technology, the Federal Council for Science and Technology and the National Academy of Sciences have recommended that the government undertake a major research program with earthquake prediction as the goal. The seismologists engaged in these studies know that major earthquakes will recur in the United States in regions that have become densely populated since the last previous occurrence.

They were confident that progress could be made because of the rapid advances in the science of seismology and in the growing number of reports from the laboratory and the field that the physical properties of rocks subjected to stress change just prior to the time they fracture. In the past few years, qualified scientists in China, the Soviet Union and the United States have reported precursory changes prior to earthquakes in seismic velocities, well levels, tide gauge levels, surface deformation, electrical and magnetic fields, and radon content of well water. Despite all of the proposals and the obvious progress, the United States does not have at this moment an adequately funded research program which would achieve the goal of earthquake prediction even in limited areas over the next decade. The total budget for research directly related to the prediction goal is five or six million dollars per year. This includes government and university research. This budget is less than the Department of Defense was spending some ten years ago in seismological research connected with monitoring a nuclear test detection treaty (Project VELA). So far as the use of sophisticated methods of digital data transmission and recording systems, on-line monitoring of seismic events detected by large arrays using dedicated computers, the technology employed today in earthquake research is behind that of Project VELA ten years ago solely because of the support levels. Considering the potential that earthquake prediction holds out for saving large numbers of lives, it is difficult to rationalize the decisions made over the years not to embark on an adequately funded research program.

In the specific area of targeted research related to earthquake prediction, a national program is needed covering research not only in California and Alaska but also in other states and territories where earthquakes pose serious threats. My own estimate is that an earthquake prediction budget of some twenty to twenty-five million dollars per year is needed to achieve an operating prediction system in the most dangerous areas in a reasonable amount of time. Earthquake research represents one of those few situations where such a massive, immediate expansion of research can be justified in terms of reduced casualties, and accommodated by a wealth of under-utilized talent in the universities and in private industry. Some of the most outstanding earthquake scientists in the country, who

have much to contribute to earthquake prediction research, have been unable to get involved because of a lack of funds. Support at the level that I have indicated would allow for the installation of sensors on the major faults in the western states and Alaska, as well as develop an earthquake prediction strategy for the central and eastern states. It would allow for the development and installation of instruments to monitor the precursory phenomena that I have listed earlier. Digital data acquisition systems and dedicated computers could be used to monitor the physical state of the earth's crust. In order to accelerate the rate of data acquisition, research networks could be installed in seismically active areas abroad such as Turkey, Iran and the nations on the Pacific coast of South America.

This international aspect of earthquake prediction is important for many reasons. I have already mentioned the high level of effort in this field in China, Japan and the U.S.S.R. The exchange of information with China is just beginning. The cooperation with the Soviet Union and Japan is excellent and mutually advantageous. The earthquake hazards in some of the lesser-developed countries of the world are extreme. Cooperative efforts with these countries would pay off in that we could gather data more rapidly by working cooperatively with these countries than by pursuing research exclusively within our own country. From the standpoint of foreign aid, providing an earthquake prediction capability to countries like Guatemala, Peru and other lesser-developed nations would be an enormous benefit.

Congressman Symington has asked me to address several specific issues dealing with the Russian and Chinese experiences with earthquake prediction, the present status of earthquake modification, the likely future for earthquake prediction and modification in the United States, and what benefits may be expected if adequate resources were allocated.

The Russians and Chinese have ambitious programs in earthquake prediction. Cooperation is very close and we have a good idea of what is going on in the Soviet Union. The Russians were the first to report physical precursors connected with actual earthquakes. They discovered the velocity, deformation and radon anomalies preceding earthquakes and showed us their data in great detail.

It is my impression that the Soviets do not yet have an operating system but are still pushing ahead on the research front. In terms of geographic distribution and the number of people involved, the Chinese have the most ambitious research program in earthquake prediction in the world. Their strategy is a simple one which recognizes that because of their high density of population and the traditional methods of construction of peasant homes, an investment in earthquake prediction offers the greatest return. Rather than rebuilding the homes of hundreds of millions of people, the Chinese propose to predict earthquakes, evacuate people from their homes in the final few hours before the earthquake, and then rebuild properly after the earthquake has demolished homes and casualties have been minimized. The Chinese employ all of the modern methods that have been reported in scientific journals of the Soviet Union, Japan, and the United States. They also use traditional methods that have evolved over the centuries such as precursory, anomalous animal behavior. The unique feature of the Chinese program is the use of tens of thousands of paraprofessionals in earthquake prediction. These amateurs serve to educate their fellow citizens about earthquake hazards and safety procedures. They also construct simple seismographs and other devices which might detect precursory phenomena. In my opinion the use of such large numbers of paraprofessionals may be appropriate for the Chinese system but is probably not a transferable concept for this country. With television, radio, newspapers and schools providing access to the homes of Americans, amateurs serving to educate the public are unnecessary. The transmission of digital data over telemetry links that already exist for other purposes, the availability of both minicomputers and large computers to edit, digest and analyze this information obviate the use of large numbers of amateurs.

The data on induced earthquakes either by fluid injection or dam construction are quite persuasive that man can trigger earthquakes. In the near term, this approach will be particularly useful in understanding the earthquake mechanism and therefore make a positive contribution to earthquake prediction. The notion that induced earthquakes might lead to earthquake modification, that is, the defusing of earthquakes before they occur is something for future generations to think about, in my opinion. I do not see it as a high priority at this stage of our scientific development; however I do support studies connected with induced earthquakes because of their great importance in connection with dam safety and earthquake prediction research.

I have already mentioned what I think the level of effort should be for targeted earthquake prediction research. The recurrence of any one of the great (magnitude greater than 8) earthquakes in California today would constitute the greatest single catastrophe to strike this country in its history. We might take the case of Los Angeles as an example. Robert Williams, the Director of the Los Angeles Building Department, reports that 14,000 unreinforced brick and masonry buildings are presently occupied by 75,000 to 100,000 people in Los Angeles.

When one adds to this the possibilities of reservoir failures, soil liquefaction, landslides, blocked freeways, ruptured water and gas lines, fire, an unprepared populace and local, regional and federal government officials wondering who will do what in case of a major disaster, one has the elements of an unprecedented tragedy. A sudden loss potential amounting to tens of thousands of lives and tens of billions of dollars is a possibility. Under such circumstances I don't believe that the American public would accept simple cost benefit analyses as appropriate for evaluating the potential payoff of earthquake prediction research. What dollar value would one put on the lives saved? If we can achieve an operating earthquake prediction capability, one which could duplicate the Chinese achievement of last year in providing an alert many years in advance and a warning a few days to a few hours in advance, the benefits could be enormous. With a warning years in advance, weak structures could be strengthened, public education campaigns could be intensified, emergency plans could be carefully laid out and rehearsed, disaster relief could be planned and responsibilities assigned. In the final days or hours, nuclear power plants could be turned down, gas lines could be turned off, dam levels could be lowered, people could be evacuated from particularly hazardous sites, workers could be sent home, and food and medical resources could be distributed. Police and firefighting units could be deployed. It seems to me that casualties can be reduced enormously by these procedures and property damage reduced significantly.

With respect to the bills before the House of Representatives dealing with earthquake hazard mitigation, I would like to commend them all for recognizing that an adequate research program is needed and a government-wide organizational plan involving the many agencies that have responsibilities connected with earthquake hazards must be set up. I particularly like S–1174 because it emphasizes the necessity for a big push on the research front. It recognizes the existing research talent in the United States Geological Survey and the National Science Foundation as well as the relatively unused expertise in the universities and in private industry. It specifically spells out levels of research support for the first three years which are adequate to launch the program. H.R. 13845 spells out in great detail a government-wide organizational infrastructure for dealing with earthquake hazards but places insufficient emphasis on the research progress that is so urgently needed. The support levels specified in the bill are woefully inadequate. It seems to me that it is premature to freeze the government structure in such detail when we have no idea about the form or capabilities of an operating earthquake prediction system, and when studies are just getting underway dealing with the social, economic, legal, educational, and public policy issues connected with an earthquake prediction capability.

I thank the Committee for this opportunity to appear before it.

Appendix I

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Haicheng and Los Angeles: A Tale of Two Cities

Haicheng is a small town of 100,000 population in Liaoning Province of northeast China. It was totally destroyed in an earthquake of magnitude 7.3 which occurred on February 4, 1975. The epicentral region contained more than 1 million people. Not far from Haicheng, the southeast portion of the Liaotung Peninsula experienced an uplift of some 5 cm over the previous decade, with a corresponding subsidence of the northeast end.

The San Andreas fault cuts diagonally across the northeast corner of Los Angeles County. In a paper published in *Science* a few weeks ago, Robert Castle of the U.S. Geological Survey reports that an uplift of some 25 cm has occurred over a region of about 10,000 square km, mostly in Los Angeles County. The axis of the elliptically shaped uplift coincides with a 150-km stretch of the San

Andreas fault which broke in the last great earthquake in southern California, an event of magnitude 8 or larger, in 1857.

China experiences many great earthquakes and probably has suffered more earthquake losses than any other country in the world. However, the Haicheng shock may well be the most significant earthquake in history, because it was predicted within a few hours. As a result, more than a million people were evacuated from their homes, and tens of thousands of lives were probably saved. The sequence of events which led to this achievement are worth reviewing for the fascinating story that it makes and also to bring it to the attention of geophysicists as well as responsible government officials in Washington and California. The details were released by Chinese scientists at a Unesco conference in Paris in February of this year.

In 1970, Chinese authorities declared Liaoning Province to be an important region for earthquake monitoring based on its preceding earthquake history, its high density of population, and its concentration of industry. Teams of professional seismologists were organized to carry out premonitory observations and charged with the task of making predictions. Field investigations included studies of fault movements, leveling, gravity and magnetic observations, the observation of local crustal deformation, and the installation of temporary networks of seismographs to monitor seismic activity.

During the period 1970–1974, a preliminary estimate was made that southern Liaoning Province was in danger of suffering a strong earthquake. This intermediate term prediction was based on the obvious activity of the principal faults in the region, an apparent migration of strong earthquakes into the region, an increasing frequency of small earthquakes in the magnitude 3 to 4 range, and a slow increase in the rate of crustal deformation. The recommendation was made that all possible earthquake studies be further enhanced. Observations at fixed and mobile stations were strengthened, and thousands of amateur seismologists were alerted during the period July 1973 through October 1974. This more intensive investigation revealed that tilting across the Jinzhou fault had increased at a rate 20 times the normal one (2.5 mm across a 580-mm base line) in the period September 1973 to June 1974. Magnetic field anomalies were detected, and sea level rose on tidal stations of Liaotung Bay. The seismicity of the entire province increased in 1974.

In June 1974, acting on the basis of the intermediate term prediction of the possibility of an earthquake within 1 or 2 years, the Council of State of the Chinese government issued orders for the strengthening of professional and amateur seismological observations and for the implementation of precautionary measures against earthquake hazards. A preparedness campagin was launched with the following results: the local provincial government took over the leadership of the seismological work, including the observations of precursors and disaster preparedness measures. The number of professional seismologists was increased, and the observations were further strengthened. A public education campaign about the nature of earthquakes and disaster mitigation methods was implemented.

In November 1974 a regional seismological meeting was called to evaluate the new data that developed. It was found that the rate of crustal deformation and tilt was accelerating, and small earthquake activity south of Haicheng continued to increase. In December 1974 a great deal of unusual animal behavior was observed, and a number of water wells in the area became muddy and showed bubbling activity and level changes. The radon content of ground water also increased. A magnitude 4.8 earthquake occurred some 70 km north of Haicheng, which the Chinese interpreted as a signal of a forthcoming dangerous earthquake. Provincial officials were alerted, all reservoirs, mine shafts, industrial plants, and unsafe buildings were examined, and some were strengthened. 'Earthquake maneuvers' were practiced in some places, involving emergency measures in hospitals, evacuation of mines, movement of people, and reduction of shifts in steel mills to minimal levels.

The anomalous phenomena continued to build up following this shock. Of 81 wells being monitored in the region, 70 percent showed level changes, and 30 percent showed muddying and bubbling phenomena. In some places, water spurted out of the ground. The unusual animal behavior increased both in kinds of animals and extent of misbehavior. For example, snakes came above ground and froze to death—an unprecedented phenomenon. Tilt changes slowed, and other precursory phenomena reversed in direction, a sign of an impending earthquake. In mid-January of 1975, at a national seismological conference, the

prediction interval was narrowed to the first half of 1975, and a magnitude of 5.5 to 6.0 was specified. On January 28, an urgent regional meeting was called, where it was agreed to further strengthen prediction and precautionary measures. Psychological preparation of the public for an impending earthquake was undertaken.

On February 1 a series of small earthquakes began to show up in a previously aseismic region near the Yingkou seismological station. These small tremors increased from a few in number on February 1 to more than 500 on February 3. On the basis of these events and other anomalous precursory phenomena, regional officials notified all provincial centers that a large earthquake was imminent. Special precautionary measures were instituted, and the 'broad masses of the people' were notified to build simple outdoor shelters, to move patients from hospitals, and to make arrangements for old and weak people. Medical teams were organized, emergency rescue brigades were alerted, transportation vehicles were removed from garages and concentrated in specific areas, open air movies were shown to induce people to leave their homes, and militia men patrolled the streets to further persuade people to leave their houses. It should be noted that the temperature outdoors was —24 C. Special guards were placed at important office buildings and other structures. The final evacuation order was given at 1400 LT on February 4.

The earthquake occurred at 1936 LT on February 4. Its magnitude was 7.3. About 50 percent of the houses in the epicentral region were either badly damaged or destroyed. In some districts, 90 percent of the houses and structures collapsed. Perhaps 250 to 300 people were killed, a remarkably light figure compared to the tens of thousands of deaths that might have occurred.

Although not mentioned in the report, it seems as if there was a false alarm in the latter half of 1974.

The Chinese reached the following conclusions from their experience. A short-term earthquake prediction capability, within 24 hours of the event, is important. Prior to the earthquake, intensive mass education and mobilization together with strengthening of buildings, disaster relief planning, and, finally, evacuation of weak structures are the essence of reducing losses from earthquakes. Chinese society differs from ours, and their ideas and experience with disaster mitigation, though provocative, may not be directly transferable.

It is too soon to assess the American response to the worrisome uplift on the San Andreas fault. The region of concern is not very well instrumented with seismographs, tiltmeters, magnetometers, water well level indicators, radon monitors, or crustal deformation sensors. According to the *New York Times* of March 23, seismic researchers in southern California claim that their work is being slowed by insufficient budgets. A Los Angeles municipal building official warned that about 14,000 unreinforced masonry buildings did not meet the most up-to-date earthquake reinforcement standards and would be severely battered by a major earthquake. More than 75,000 people, many of them poor, live in these structures. The Director of the U.S. Geological Survey, Vincent E. McKelvey, flew to Sacramento to brief senior state officials about the new data. An official in the state's Office of Emergency Service is reported to have said, "We're regarding this as a good deal more significant than a scientific curiosity."

One would hope that these are beginning indications of an intensive effort to gather more data and to embark on a program of public education and disaster planning. Whether the bulge is a true precursor of a great disaster or not, these precautionary measures will not be in vain. The San Andreas fault will undoubtedly rupture again, and investments made today will reap dividends in the form of reduced casualties and losses whenever the earthquake occurs.

STATEMENT OF FRANK PRESS, CHAIRMAN, DEPARTMENT OF EARTH AND PLANETARY SCIENCES, MIT

Dr. PRESS. Let me summarize my remarks since you do have the full text and we can save time that way. In your letter of invitation you did indicate there were several specific questions you were particularly interested in, and let me dwell on those in my summary. First, let me say that the earthquake problem has many components and from your witness list I can see that you are covering all of them, those

dealing with engineering, with seismic risk analysis, with public policy questions and socioeconomic questions and so forth. And so I will concentrate on my own field of earthquake prediction.

The most advanced countries in earthquake prediction research are China, the Soviet Union, Japan, and the United States. Most seismologists in these countries agree that precursory physical changes take place in the Earth's crust prior to earthquakes and that these changes will eventually form the basis for an operating earthquake prediction system in many parts of the world. There may be some disagreement about which premonitory events will prove to be most effective, but the general opinion is that several indicators will prove to be significant.

Although the Chinese state that their program is still in the developmental phase, they claim to have several successful predictions. On February 4, 1975, the Chinese issued a warning 5 hours before a destructive earthquake of magnitude 7.3 in a densely populated area of Liaoning Province of northeast China. Our best estimate is that as a result of that prediction many tens of thousands of lives were saved because the people moved out of their houses before they were devastated.

Proposals to conduct earthquake prediction research in this country are more than 10 years old now, the first one going back to the Office of Science and Technology in 1965, a report triggered by the great Alaskan earthquake of the preceding year, and then subsequent reports of the FCST and the National Academy of Sciences. The experts have all agreed in these reports that we should embark on a major program in earthquake prediction. The need is great in terms of lives saved and the technology has advanced enough to embark productively on such a program.

At the present time the total budget is of the order of $5 million or $6 million per year in the specific area of earthquake prediction. It is interesting to me—I still fail to understand it—that 10 years ago the Defense Department was spending more on seismology connected with Project VELA, a project to detect nuclear explosions, than we are spending today in real dollars. And their technology, involving computers, digital telemetry systems, seismic arrays, on line analysis is more advanced than we can afford today with our present funding for earthquake prediction.

My own estimate is that an earthquake prediction budget of some $20 million to $25 million per year is needed to achieve an operating system in the most dangerous areas such as in California in a reasonable amount of time.

This kind of research is one of the few areas where I think the need is great in terms of reduction of casualties and also it is one of those few areas where there is a wealth of unutilized talent in industry and in universities that could make a tremendous contribution.

But these people are not now involved simply because of the inability of the U.S. Geological Survey and NSF to provide support for them. I can, if you wish, give you a breakdown of a reasonable budget. It is not a number out of the air, but one based on much thought by interested and knowledgeable people.

Mr. BROWN. I would appreciate your giving it if you can.

Dr. PRESS. Would you like me to do it now?

Mr. BROWN. Yes, if you can.
Dr. PRESS. Let me give you the budget items:

DEDICATED COMPUTER WITH NECESSARY TELEMETRY, $4 MILLION PER YEAR

At the present time the data acquisition system in the present earthquake prediction operation is absolutely primitive The data are analyzed based on photographic records primarily by individuals looking at each record. And I would say that 80 percent of the information is lost because this is an unproductive and inefficient way to analyze the data. The people who are doing this analysis know how to do it better. They can design a state-of-the-art system, but they cannot afford to do it at their present level of budgeting.

What we should have and what we had 10 years ago in Project VELA was a dedicated computer receiving digital information from thousands of sensors by modern telemetry techniques. The computer scans all of these sensors and makes instantaneous analyses of what is going on over an immense geographic area and can get out of the data 100 percent of its content rather than the inefficient 10 or 20 percent we are now getting.

INSTRUMENT DEVELOPMENT, $3 MILLION PER YEAR

Within industry, within the universities, we have ideas for improving the sensors that are now being used to monitor surface deformation of the ground, electromagnetic fields, tilt meters with long term stability which is important for forecasting the largest earthquakes, gravity meters designed to measure deformation of the Earth's surface and so on. The talent exists to undertake this kind of development immediately.

EXTENSION OF NETWORKS, $9 MILLION PER YEAR (CAPITAL AND OPERATING COSTS)

At the present time, for example, even in the State of California, our most intensively monitored State in terms of sensors in the ground, a good portion of this State is not monitored at all.

For example in the region of the Palmdale uplift which has been brought to our attention lately, until next year the density of instruments is embarrassingly small.

Alaska and Puerto Rico are two regions in great danger of earthquakes, but with a negligible monitoring capability. The area east of the Rocky Mountains, as you know by looking at the chart to my right, is an area that is subject to severe earthquakes, not as frequently as the western States, but dangerous ones nevertheless with extensive areas of damage. Essentially, except for a few spots, it is unmonitored in terms of viable earthquake prediction research. For extension of networks I propose for California $3 million, for Puerto Rico and Alaska $3 million and for States other than California and Alaska, $3 million.

FOREIGN DATA ACQUISITION, $5 MILLION

If we want to maximize the efficiency of our prediction program, we should be studying as many earthquakes as possible, as rapidly as

possible, to build up our experience and to build up the number of case histories of successful predictions.

There are other countries in the world, like Turkey, Japan, U.S.S.R., Iran, and China, which have even more severe earthquake problems than we do. These countries have more frequent earthquakes than the United States and by gathering data in cooperation with the rest of the world we can obtain data and gain experience more rapidly than by restricting our field research to our own territory.

And so I would propose that in this sense our research program be truly international. I am sure these countries would welcome our cooperation and would welcome anything we can do for them and at the same time helping ourselves.

BASIC RESEARCH $3.5 MILLION PER YEAR, INCLUDING $1 MILLION FOR LABORATORY STUDIES

Studies of why rocks fracture when they are stressed; $2 million for studies of the mechanism of earthquakes, induced earthquakes, man-made earthquakes, to learn more about the mechanism so we can predict them better; $0.5 million for numerical modeling.

If you add these figures up I think you would see that they are in the range I quoted in my report submitted earlier.

You ask me to comment on the level of prediction science in certain countries. The Russians have a major program and it is to their credit that the field discovery of major precursors like velocity changes and surface deformation were made by their scientists.

It is a measure of their interest in international cooperation that they shared their results fully with us. My impression is that the Russians do not yet have an operating system but they are actively pushing ahead with their research. Their research is different from ours, and perhaps stronger, in that they cover more geographic areas. We have concentrated on California, because of our present budget limitations. The Soviets have programs in central Asia, the Caucuses, and the Far East. In fact their main criticism is that we concentrate too much in one place, that is central California.

The Chinese have perhaps the most ambitious and the newest program of earthquake research in the world. The Chinese strategy is easy to understand. They are the one country in the world that probably could suffer 1 million people killed in a single earthquake. In fact, just about that many Chinese were killed in one great earthquake in the 16th century. The great population density and the traditional primitive, building practices combine to make the human loss potential very high.

The Chinese strategy is not to rebuild or strengthen all of the houses for their huge population. Rather they attempt to get the people out of the houses hours before the earthquake occurs, save all of these lives, and then rebuild with proper earthquake-resistant design.

You asked me to comment on the Chinese use of amateurs which is a rather unique thing we discovered when we visited China. The Chinese use tens of thousands of amateurs in their prediction program, in a number of different modes. Amateurs are used to educate the public by giving lectures in their urban and rural communities. Amateurs are used then to monitor instruments put in place by scientists, and have also developed their own instruments, reporting the results to the local scientific laboratory.

I don't believe that this aspect of the Chinese system is readily transferable to our society. I think in terms of public education, with television, radio, newspapers, and schools, that we have ample means for mass communication. So far as using amateurs to monitor instruments, I think it is much cheaper and more reliable with our electronic technology to do this by remote telemetry. It would be cheaper and more reliable.

Therefore, although the Chinese system of amateurs is a fascinating one, it works for them in a way that it might not work for us.

You have asked me to comment on induced earthquakes. Let me simply say that there is no question that man can actually trigger earthquakes by the injection of fluid in deep holes and by constructing dams on fracture systems and having the dams indirectly induce the earthquakes.

I think this kind of research should be supported for the reason that it will help us to understand earthquakes better. It will help us design dams with the possibility of triggering earthquakes in mind, but I am not sure that we are ready to talk about earthquake modification, that is defusing earthquakes and preventing them by releasing strain. That is something for future generations but I would say that research in this area is justified for the reasons I have given.

Let me conclude by saying that when I think in terms of the potential casualties of our most densely populated regions, and when I remember the statement by the director of the Los Angeles building department that he has 14,000 unreinforced brick and masonry buildings which would be seriously damaged if not devastated, and that these buildings are occupied by 75,000 to 100,000 people, most of them poor and old, when I add to this the possibility of reservoir failure, soil liquefaction, blocked freeways, ruptured water and gas lines, fire, unprepared populace, when I note that buildings supposedly designed according to the current earthquake building code were severely damaged in the San Fernando earthquake, when I take all of this into account, I conclude we have the potential for one of the major disasters in American history. I think we would not be living up to our responsibilities as citizens not to bring this great danger to your attention.

Mr. BROWN. Thank you very much, Dr. Press. I think your statement is an excellent contribution to our subcommittee's analysis of this legislation.

You have had the opportunity to be in close touch with the Chinese on this matter of earthquake prediction and resulting actions. And you have indicated in your statement some of the reasons for the Chinese handling of this. Could you elaborate a little bit more on the reasons why the Chinese have apparently made greater advances in this rather esoteric field than a highly developed scientific country like the United States? Are they depending upon folk knowledge to develop a theory of earthquake occurrence or how do you explain this great progress that they have made?

Dr. PRESS. It is a big country, it is a great country. It has a lot of people and for that reason it has an enormous potential. If they think a problem area is important they can deploy the needed resources and mount a major effort. The Chinese apparently have recognized the great danger of earthquakes and they have decided to give prediction research a very high priority. Chinese scientists scanned the

world literature and studied what was being done in Japan and the Soviet Union and in this country. They were conversant with the most recent advances that have been accomplished all over the world. And rather than starting from scratch, they simply built upon all of the discoveries made elsewhere.

As a result they have deployed networks of instruments, with strong resemblance to Soviet and American instruments. They have also made some developments on their own. Their program is as good as it is simply because of the level of effort and the number of people involved and the resources they have put into it.

The Chinese do not have computers in widespread use and that is very inhibiting to their program. They have many more earthquakes, perhaps, 10 times the number we do, and therefore can gather data 10 times more rapidly than we can. Three years of Chinese earthquake history might be equal to 30 years of American history in terms of gathering data. That is why I spoke in terms of international cooperation to enhance our program. To summarize, the Chinese may have had more experience with prediction of large earthquakes than we do simply because they have deployed instruments, and experience more earthquakes.

Mr. BROWN. What about the training of competent professionals? In certain areas we are familiar with, nuclear development and ICBM's, we know that they progressed because of being able to utilize Western trained scientists, some of them trained at Cal Tech and possibly MIT. Is there any indication that they have been able to train qualified professionals in this area to the level of competence that would be required or are they relying upon Western trained personnel here also?

Dr. PRESS. That is a fascinating question which I have thought long about. It is something that the China experts in this country are puzzling about. As you know during the cultural revolution, a period lasting some 6 years, university education was essentially closed down.

Mr. BROWN. These 6 years were the period of most rapid development in this field?

Dr. PRESS. The latter part of the period, yes. The Chinese embarked upon a system of training scientists, different from our system of graduate schools. There are no Ph. D.'s being produced in China. An apprentice system apparently is used in which a college graduate is assigned to a research laboratory and works with a more senior person, who directs his reading and research. It is the way, I suppose, we used to train lawyers in this country before we had law schools; namely, by apprenticing young students to law firms.

The world is watching the Chinese experiment to see whether it will work. In our visit to the laboratories of China I can simply tell you that we saw modern instruments which were being maintained properly. We saw geodetic laser devices of Chinese manufacture. They were working on modern telemetry systems to eventually bring seismic data directly into computers.

We saw a seismograph factory which was the biggest one I have ever seen, a huge place turning out large numbers of modern instruments. In the early fifties the Russians trained a number of Chinese geophysicists and geologists, providing a foundation on which to build. The Chinese read Western languages and have access to all of our publications.

So it is not as if they are operating in the dark. They can build upon our accomplishments and make their own advances as well.

Mr. BROWN. Do they have the kind of sophisticated measuring equipment and type meters that we seem to have here?

Dr. PRESS. In laboratory rock mechanics it was our impression that they were getting underway, using primitive equipment and methods. They were extremely interested in our experts in rock mechanics and wanted intimate details about laboratory methods in rock mechanics. We can surmise that they will move ahead strongly in the laboratory areas. In the kinds of instruments other than seismometers, it was my own impression that they were behind us. But again this is such a high-priority area that I am sure they will catch up.

Mr. BROWN. You mentioned one or two items of Chinese origin which seemed to be unique to the Chinese culture and that was their use of certain anomalies in the animal behavior and of course their monitoring of the behavior of water wells, which puzzles me a little—these are deep wells or relatively shallow wells? But the point is, however, does this combination of what seems to be unique to Chinese culture add up to a special contribution in this area which other countries or other cultures have not been using?

Dr. PRESS. I think the answer is "yes." The idea of using well level changes is modern technology. Modern theories of earthquake precursors predict that wells in the vicinity of a forthcoming earthquake will show level changes because the water level reflects changes in the permeability of crustal rocks, as microcracks develop prior to an earthquake.

Mr. BROWN. Would that also reflect changes in ground levels such as the Palmdale fault? Would that be reflected in a raising of the bottom of a well?

Dr. PRESS. They are both indirectly possibly related to the same physical changes in the crust prior to the actual earthquake. The Chinese use both dedicated wells which are somewhat deeper on the order of 100 or more meters that are drilled for scientific purposes, and they make extensive use of the large number of irrigation wells that they normally have drilled for agriculture.

It is a tricky business because when water is withdrawn from the ground for irrigation and if at the same time the well is supposed to monitor possible changes before an earthquake, interference may occur and spurious signals could be reported.

However, the Chinese, by averaging over a large number of wells—in one region they were averaging data from 75 wells in a limited area—might increase the signal compared to a noise of the agricultural fluctuations. It is a good idea, something we should try. I think the Chinese are monitoring hundreds of wells. I believe in this country, for the purpose of earthquake prediction, only one or two wells are being monitored.

Mr. BROWN. What about the animal anomalies?

Dr. PRESS. Again, this is a traditional Chinese tool that goes back a thousand or more years. The Chinese keep good chronicles of their history and you can find earthquake reports going back 2,500 years citing anomalous animal behavior. This is the question: Do animals sense a precursory chemical or physical change in the environment that our instruments have not detected? Let me tell you about the evolution of my own thinking.

At first, I was extremely suspicious. It was folk mythology. It was consistent with Maoist philosophy that the intellectual has much to learn from the innate wisdom of the peasant, that the peasant has something to tell the scientist and can teach him a great deal. And so it was consistent with their political philosophy to scientifically endorse anomalous animal behavior, a peasant method, as an earthquake precursor. But has it been tested under controlled conditions? How many times has animal misbehavior been recorded and not followed by an earthquake? Perhaps we only hear of the successful stories.

On the other hand, when one thinks about it, there could be a number of things happening that animals might be sensitive to that we are not even measuring. It may be that Chinese peasant wisdom may be able to teach us something.

I propose that we do look into animal behavior as a science research project and see if there is anything in it. We have an American delegation in China at this very moment looking at the methods the Chinese used to predict that great earthquake of 2 years ago and our people will look into the Chinese reports of anomalous animal behavior, which for this great earthquake are truly astounding.

For example, they reported that snakes came out of the ground prior to the February earthquake, with temperatures 20 degrees below zero, and froze to death on the ice. This had never been seen in the region.

Mr. BROWN. Everyone knows you can drive worms out of the ground by putting a stick in and vibrating it. Maybe the same thing happens here.

Dr. PRESS. It could be. Or the water table might go up and drive snakes out of the ground. The Russians and Chinese report that the appearance of radon in well water is associated with the future occurrence of earthquakes. Radon can ionize the atmosphere and produce ozone and animals are extremely sensitive to ozone. So one can think of a number of things that we are not measuring but that the animals might sense.

Mr. BROWN. Can you explain to me in simple terms this radon phenomenon? I am not sure I understand how the changes in radon level occur.

Dr. PRESS. This is a method that was discovered by the Russians and what they did was monitor changes in the radon activity in water, finding that prior to an earthquake, the radon content increases.

One theory to explain this is the following. As the stress builds up prior to the earthquake, cracks develop in the crustal rocks and it is the accumulation of these cracks and their localization below the fault which eventually results in the earthquake.

Now these cracks increase the access of water to the rock which is normally radioactive. So when you think of a rock that is uncracked or cracked relatively little, the water that flows through that rock sees very little of the internal surfaces of the rock. But once that rock develops large numbers of cracks, the water flowing through has access to more of the uranium naturally contained in the crust, one of whose radioactive decay products is radon. Thus, it is essentially the cracking of the rock which provides access of water to radon. This is just a theory, but I think it is a pretty good one.

Mr. BROWN. Mr. Goldwater, do you have any questions?

Mr. GOLDWATER. Yes, Mr. Chairman. Let me just make one observation which I hesitate to make but I think it needs to be made. Due to the Democratic caucus this morning, this has put me in a very difficult situation. I have a very keen interest in this legislation and the list of witnesses that are scheduled to be here. At 1 o'clock, I am scheduled for a conference in the Senate on another piece of legislation that the gentleman also has an interest in. And because of this mismanagement of our time due to the other party, I am in a situation where I will not be able to participate today in these hearings. I am deprived of listening to these fine witnesses for which I had prepared myself with dialog and knowledge. I had an opportunity to read Dr. Press's article and there were questions I wanted to raise. I think it is very unfortunate and untimely. I am hopeful we don't have to have this same kind of thing happen again.

Dr. Press, when we talk about cracks in the surface of the rocks, how big are these cracks?

Dr. PRESS. That is a good question and it is one of the things that we really would like to look into. These are cracks in rocks many kilometers below the surface so they are not directly accessible. I would say these cracks are very small, in fact some of them only visible through a microscope, but occur in huge numbers. As the stress builds up prior to the earthquake, some of these cracks might coalesce and grow in size and become quite large, in meters or even kilometers, in the process of forming a new fault.

Mr. GOLDWATER. Is the theory of plate tectonics fairly widely accepted by the community of geologists or experts, people who study earthquakes?

Dr. PRESS. I don't think we have ever taken a vote but I would be amazed if less than 90 percent of the geologists and geophysicists in this country did not accept it as the most important geological hypothesis of the century.

Mr. GOLDWATER. I notice in your article there was a graph or picture depicting all of the epicenters and they all seem to fall along the edges of these plates. Is there something in common about the surfaces or the edges of these plates that make them susceptible to creating this kind of resistance that eventually would create an earthquake?

Dr. PRESS. Yes. Just imagine these dozen or so plates over the world, all in continuous motion. The boundaries are where the plates are actually rubbing one against the other. The stress due to these motions tend to build up in time because of frictional effects, only to be released suddenly in a great earthquake when the frictional bond breaks.

There are many serious earthquakes, which occur within plates, although 90 percent or so of earthquakes happen at plate boundaries. I would say because of plate tectonics theory we have a better understanding of earthquakes in California which is a plate boundary, but we cannot as yet explain why earthquakes occur in the rest of the continental United States.

Mr. GOLDWATER. Does the San Andreas Fault represent a plate boundary?

Dr. PRESS. There are some people in California whose living rooms sit astride the boundary between the huge American plate and the huge Pacific plate. The San Andreas Fault is the plate boundary between two of the greatest plates on earth.

Mr. GOLDWATER. How do you explain the earthquakes that happen within a plate, or do you?

Dr. PRESS. I wish I knew. It would help me with an earthquake prediction strategy for the rest of the country if I understood that.

Mr. GOLDWATER. In your article you discussed the two principal models that you see being used and the question of which to use as a base line in this predictable earthquake effort. I don't quite understand the difference between those two models and why they are important.

Dr. PRESS. You are talking about the Soviet model and the American model? That paper was written 2 years ago and some American scientists are beginning to look at the Soviet model as more fitting of the data, so I am not sure I would call it a Soviet and American model. Let us call it model 1 and model 2. Both models deal with the dilatancy in rocks, that is the internal cracks which develop in rock just prior to rupture. That is something you can measure in the laboratory. When you squeeze a rock, it expands in size because of all the little cracks that open up.

In model 1 (which used to be the American model), when these cracks develop and dilatancy occurs, the rocks have an enhanced ability to hold more fluid because there are more voids and so the rocks become more fluid because there are more voids and so the rocks become seimsaturated. And because of the dryness, the frictional contact between the walls of the cracks is increased, actually strengthening the rock.

When that happens, water flows in gradually over a period of time from distant regions and fills these newly expanded cracks. The rock is now weaker, triggering the earthquake. Model 2 does not depend on the flow of fluids into the dilatant region. Instead, the number of cracks build up, gradually at first and then more rapidly as the earthquake approaches. Finally, an avalanche of cracking develops in the crust until the cracks all become coalesced along the fault, which gives way and triggers the earthquake.

These are the two models, both involving dilatancy. Model 1 suggests that fluids play an important role; model 2 implies that it is the continued increase in cracking that is important.

Mr. GOLDWATER. When you talk about the two models that have been proposed, do you propose that we study these two models? You call them models so I would interpret that to mean something that you are going to create as a baseline or at least a fundamental starting point in our using it as a base to make predictions on.

Dr. PRESS. One can proceed in a number of ways. I think the Chinese attitude toward this is that they don't think in terms of theories or explanations. They are looking for precursors. Whatever works, works. They will try lots of things and build up statistical validity by having a lot of cases.

It is our attitude that it is not enough to proceed empirically. If we really want to have confidence in what we are doing we should have models or theories to check out. If we embrace empiricism, just trying what works, without a real understanding of what works, we will each have confidence that what we are doing is right.

We have these two models or working hypotheses, and you can be sure that in our prediction research we will be testing each of them to see which is right. It may be that on the San Andreas Fault, neither

will be applicable whereas in central Asia one would work very well. So I think in our own program we would like to look for things that work but also try to understand why they work by checking them out against theories, the ones mentioned and others which will come along.

Mr. GOLDWATER. Are we anywhere close to having these models in place?

Dr. PRESS. You mean validating one model with the other? I don't think so. I can think of a number of experiments that can be designed to test the models, for example studying well levels on the San Andreas Fault.

Mr. GOLDWATER. Thank you, Mr. Chairman.

Mr. BROWN. Thank you, Mr. Goldwater, and may I say that I share your chagrin about the disturbance in our schedule. I recognize the unsatisfactory nature of these proceedings.

Mr. GOLDWATER. It is unfortunate Mr. Chairman that I will have to go to the other conference. Aren't you a conferee on that also?

Mr. BROWN. Yes, I am a conferee also. The chairman of the subcommittee expects to be here as quickly as he can and I thought I would continue the hearing.

Mr. GOLDWATER. I apologize to the witnesses. I had really looked forward to listening. I will read your statements.

Mr. BROWN. Dr. Press, just another question or two. You gave us a tentative budget for a 1-year period. May I assume that you anticipate that a similar level of expenditures over a multiyear period would be in order and that costs, say, for the initial capital costs of computers, telemetry and the network systems would then be replaced by operating costs after the systems are deployed?

Dr. PRESS. I should have specified that. I am sorry. I agree with what you have just said.

Mr. BROWN. You mentioned that project VELA had been budgeted at a larger amount than the current amount we are spending on earthquake research and prediction. Of course there is an ongoing program within ERDA and possibly Defense Department to monitor underground nuclear explosions and to develop more sophisticated technologies in this area. Is that type of technology substantially transferable to some of the purposes of earthquake monitoring?

And secondly, as far as you know, is the basic instrumentation monitoring and so forth in these areas open literature so that it would be available for research in the earthquake field?

Dr. PRESS. To take the last question first, I think it is available. I think the whole American seismological community owes its present technical capabilities to Project VELA. This project did support a lot of work, much of which has been finished and I would say successfully finished. In terms of instruments, I think the biggest thing we can learn from Project VELA is what I alluded to earlier, the idea of telemetry and the idea of online computers scanning large numbers of sensors automatically, detecting earthquakes, getting their magnitudes and locations, determining changes in crustal velocities, looking for changes in spectra of different events or repeated events in an area, doing all of this online, automatically. Tilt meter data, well level data, could be incorporated. We know how to do this. It is a matter of giving this program sufficient priority so that it can be undertaken.

Mr. BROWN. It seems to me that in principle this is not much different from our monitoring network for the space program. We are

here using remote telemetry and large-scale computers as, for example, we use to monitor the present Mars program and even more extensivly probably on the lunar programs.

Dr. PRESS. I think what I am describing is something that is being done in a number of different fields. It is being done in the space program where many instruments are being monitored. The idea of large computers dedicated to a project is in widespread use. The Weather Bureau's use of computers is a familiar example.

It has several large dedicated computers.

Mr. BROWN. Dr. Press, I very much appreciate your testimony. I understand you have certain time requirements also. I am sure there would be other questions we would like to ask but with your permission we will submit them to you in writing. We will look forward to further contact with you on this subject. I want to thank you again very much for your consideration in remaining here despite the delay and interruption in schedule.

Dr. PRESS. I appreciate the invitation and this opportunity to be here.

[Further questions in written form were forwarded to Dr. Press. The questions and responses follow:]

EARTHQUAKE QUESTIONS FOR DR. FRANK PRESS

Question 1. Have you drawn up a budget of how the $20–25 million per year you suggest for earthquake prediction should be used? If so, please provide the Subcommittee with a copy. If not, how did you arrive at the figure?

Answer. This question was asked by Congressman Brown, and I replied to him orally and will not repeat the answer here.

Question 2. From your knowledge as a member of the NSF advisory committee and the "Ramo Committee" would you comment on the NSF-USGS research plan and any other plans the Executive branch may have for earthquake work.

Answer. In my opinion, the research plans of the NSF and USGS for the years 1973 through 1977 have been inadequate when measured against the national need and the new opportunities for rapid progress. For the years 1973 through 1976, the USGS budget in earthquake hazard mitigation has been constant. For 1977, the budget request was down from $11.3 to $10.5 million. A special add-on of $2.4 million for the Palmdale uplift places the agency $1.6 million ahead of its fiscal year 76 level, even though more than $2 million is needed to instrument and analyze the data from the Palmdale uplift. This means the USGS will have to cut earthquake studies in other parts of California in order to properly instrument the Palmdale uplift. Playing musical chairs on the San Andreas fault is not my idea of adequate planning. I hasten to add that at the working level, the scientists of the USGS have planned more ambitious programs, have incorporated advice from university and industrial scientists, and regret the lack of support for their program exceedingly. The inadequate plan and the lack of far-sightedness is the responsibility of senior officials in the Department of Interior.

Question 3. On page 8 of your testimony you refer to "federal officials wondering who will do what in case of a major disaster." Are you familiar with work of the Federal Disaster Assistance Administration, the Federal Preparedness Agency, and the Defense Civil Preparedness Agency? How does your knowledge of those agencies square with the implication just quoted that federal preparations would be inadequate?

Answer. A government-wide organization plan for earthquake hazard mitigation, of the kind referred to in the Mosher bill, should have been forthcoming from HUD and FDAA, but no action has been taken by the agencies which have responsibilities in this area. There is no visible research program in the areas of earthquake hazard mitigation by HUD or FDAA. HUD is directly or indirectly responsible for tens of billions of dollars of annual construction, but seems singularly unconcerned with earthquake hazard mitigation. The enabling legislation for FDAA provides for research programs in hazard mitigation, but this agency refuses to participate in prediction research.

Question 4. At what stage of reliability should official earthquake predictions, in your mind, first be made? What are the pros and cons of a) risking a false

alarm and b) failing to make a prediction of an earthquake that occurs (assuming there are precursory signs)?

Answer. The social, economic and public policy implications of earthquake prediction technology are as important for researching as is earthquake prediction itself. An adequate hazard mitigation research program must include such questions as those addressed here. It seems to me that field surveys of individuals, corporate managers, and public officials ascertaining their response to predictions of varying reliability and false alarms could be carried out so that proper answers can be given to these questions. The feasibility and the value of public education campaigns could be analyzed. The economic implications of low and high reliability predictions and false alarms could be studied in parallel with earthquake prediction research. The legal and public policy questions could be looked into. The understanding and experience that would flow from such research would enable us to provide adequate answers to this question.

Mr. BROWN. Our next witness this afternoon is Dr. Clarence Allen of the Department of Geology and Geophysics, California Institute of Technology.

Dr. Allen, I extend to you the same apologies that I made to Dr. Press.

[A brief biographical sketch of Dr. Clarence Allen and Dr. Allen's prepared testimony follow:]

DR. CLARENCE R[ODERIC] ALLEN

Born 15 February 1925, Palo Alto, California.

Public schools, Claremont, Calif.; B.A. (Physics), Reed College, 1949; M.S. (Geophysics), Calif. Inst. Technology, 1951; Ph.D. (Structural Geology and Geophysics), Calif. Inst. Technology, 1954.

1st Lt., USAAF, 1943–46 (B–29 Navigator, Far East); Asst. Prof. of Geology, Univ. of Minn., 1954–55; Asst. Prof. of Geology, Calif. Inst. Technology, 1955–59; Assoc. Prof., 1959–64; Prof. of Geology and Geophysics, 1964– ; Interim Director, Seismological Lab., 1965–67; Acting Chmn., Div. of Geological Sciences, 1967–68; Chmn. of the Faculty, 1970–71.

Member: Am. Assoc. for the Advancement of Science; Am. Assoc. of Petroleum Geologists; Am. Assoc. of University Professors; Am. Geophysical Union (Fellow); Assoc. of Engineering Geologists; Earthquake Engineering Research Inst. (Fellow); Geological Soc. of America (Fellow); Phi Beta Kappa; Seismological Soc. of Am.; Soc. of Exploration Geophysicists; Structural Engineers Assoc. of Southern California.

Registered Geologist, Certified Engineering Geologist, and Registered Geophysicist, State of California.

Consulting Board for Earthquake Analysis, Calif. Dept. Water Resources, 1963– (Chmn., 1965–74); Earthquake studies Advisory Panel, U. S. Geological Survey, 1965–75; Nat. Science Foundation, Earth Sciences Advisory Panel, 1965–68 (Chmn., 1967–68); Geological Soc. of Am. (Counselor, 1969–71; Vice President, 1972–73; President, 1973–74); Calif. State Mining and Geology Board, 1969–75 (Chmn., 1975); Seismological Soc. Am. (Board of Directors, 1970–76; Vice President, 1974–75; President, 1975–76); Nat. Science Foundation, Advisory Com. for Environmental Sciences, 1970–72 (Chmn., 1971–72); Los Angeles County Earthquake Commission, 1971–72; [Calif.] Governor's Earthquake Council, 1972–75; U.S. Nat. Com. on Geology, 1973– ; Nat, Acad. Sciences, Panel on Earthquake Prediction (Chmn.), 1973–76; Am. Seismology Delegation to the People's Republic of China (Vice Chmn.), 1974; Calif. Earthquake Prediction Evaluation Council, 1975– .

1st G. K. Gilbert Award in Seismic Geology (Carnegie Inst, Washington), 1960. Elected Fellow, Am. Acad. of Arts and Sciences, 1974. Elected Member, Nat. Acad. of Engineering, 1976. Elected Member, Nat. Acad, of Sciences, 1976.

Primary research interests and fields of publication: Geophysical and structural studies of glaciers (field work in Alaska, Alberta, Norway, Washington); Physiography of active faults; Relationships between seismicity and geologic structure; Tectonics of regional fault systems (field work in Alaska, Mexico, California, Venezuela, Chile, New Zealand, Philippines, Taiwan, Japan, Turkey, Pakistan); Earthquake mechanisms and micro-earthquakes; Geologic hazards and governmental policy; Earthquake prediction.

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STATEMENT OF DR. CLARENCE R. ALLEN

Congressman Symington and members of the Subcommittee, I am honored to be invited to appear as a witness before your committee today. My name is Clarence R. Allen, and I am Professor of Geology and Geophysics at the Seismological Laboratory of the California Institute of Technology in Pasadena. I am also Chairman of the National Academy of Science's Panel on Earthquake Prediction, whose report has been essentially completed for some time now. However, I regret that—at least as of yesterday afternoon—our report had not as yet been finally cleared by the Academy's report-review committee, although it presumably will be within a very few days. Under the circumstances, my testimony today necessarily represents only my own opinions, and I cannot officially speak for the Academy or for its Panel on Earthquake Prediction. Nevertheless, over the past several years I have talked at length with many of my scientific colleagues concerning problems of earthquake prediction, and I am confident that my views are reasonably representative of those of many scientists in the field.

Although I will be speaking today primarily about earthquake prediction, I recognize that prediction represents only one facet of the total earthquake-hazard-reduction effort, and I recognize that the various legislative bills under consideration by your Subcommittee are concerned with the larger problem, including that of societal response. Nevertheless, I am fully convinced that earthquake prediction can and should play a leading and vitally important role in the hazard-reduction effort, and it represents one area where exciting and significant scientific advances are being made right now, and will almost certainly continue to be made in the next few years if we are able to obtain continuing encouragement and support. Early this year, more than 23,000 lives were lost in a major earthquake in Guatemala, mostly resulting from the collapse of non-earthquake-resistant dwellings. A timely warning of the impending earthquake, advising residents to go out-of-doors, would undoubtedly have saved the lives of most of those killed and prevented tens of thousands of injuries. The stakes in earthquake prediction are exceedingly high; most seismologists feel that now is the time to make a national commitment to a long-term program aimed at developing a reliable and effective operational earthquake-prediction capability.

Let me try to respond to your Chairman's specific questions.

What is the present status of earthquake prediction?

There is no question but that earthquake prediction is still in the research phase, and although a few earthquake predictions have already been successful in a scientifically meaningful way, tremendous amounts of basic and applied research must be carried out before we can develop a system that permits socially meaningful predictions on a routine basis. Most, but not all, seismologists agree, however, that this is an attainable goal.

How do you believe earthquake prediction will develop in the next few years?

Given adequate funding, it is my guess that we will be successful in predicting an earthquake in the magnitude 5 range in California within the next five years. However, my own estimate is that we are at least 10 years away from the time when we shall be in a position to implement a system of routine earthquake predictions with an acceptably low false-alarm and failure rate. In my opinion, the apparent public impression that routine prediction of earthquakes is imminent is not warranted by the present level of scientific understanding. We have a long ways to go, particularly in areas involving very basic research, before an effective earthquake-prediction system will be operative or even capable of being planned.

What resources should be devoted to earthquake prediction?

It appears that the federal effort in earthquake prediction at the present time amounts to an annual expenditure of 10 to 11 million dollars, although this encompasses work involving a rather broad definition of "earthquake prediction." Of this total, some 5 million is budgeted by the U.S. Geological Survey, 4.2 million by the National Science Foundation, 1.3 million by the National Aeronautics and Space Administration, and .09 million by the Nuclear Regulatory Commission. It is my opinion that a truly effective earthquake-prediction pro-

gram will require an annual expenditure of at least two to three times that at present, amounting to at least $25,000,000 per year for the next ten years. This judgment is based on my estimate of the scope of the research work that must be done, as well as upon the manpower that is realistically available to carry out the effort. It might be noted, for example, that during the first year of its external research grants program (FY 1975), the Geological Survey received proposals from universities, private industry, and state agencies for more than 13 million dollars, more than half of which were judged to be of very substantial potential value. Yet budgetary restrictions allowed research proposals for only 2 million dollars to be funded.

What should be the roles of Federal laboratories and academic institutions?

Certainly a team effort on the part of many groups, including private industry as well as federal and academic institutions, will be necessary to achieve the goal of effective earthquake prediction. In terms of the manpower available, however, it is my belief that non-federal groups are going to have to play a far more important relative role in the expanded program than has been the case thus far. I feel that there are definite dangers in the abrupt expansion of federal agencies to meet specific and temporary problems, particularly when a large part of the talent and the resources to solve the problems exists outside of those agencies. In the specific case of earthquake prediction, it is clear that when we are finally in a position to implement a routine prediction program, a federal agency such as the Geological Survey will obviously have to play the leading role, but the attainment of the prediction capability is still so far in the future that we must take advantage of every possible resource, both inside and outside of government, in carrying out the necessary research and development.

What are the expected benefits?

There is not the slightest question but that lives can be saved by effective earthquake predictions, and this has already been amply demonstrated in China. While I emphasize again that earthquake prediction is only one facet of a total program in earthquake-hazard reduction, the cost benefit ratio—especially in terms of human lives—is exceedingly favorable by almost any calculation. It has been estimated, for example, that in the absence of an effective prediction, a loss of life measured in the tens of thousands is likely in a major California earthquake. In the City of Los Angeles alone, some 75,000 to 100,000 people—mainly poor and elderly—live in pre-1933 unreinforced masonry buildings that will almost certainly fail in a major local earthquake, but which could be evacuated given adequate warning. Engineers have correctly pointed out that a prediction will certainly not keep an unsafe building from collapsing, but it might well allow the saving of human lives by a timely evacuation of the structure.

It has been estimated that knowledge of an impending great earthquake, a year or more in advance, could result in a reduction in annualized losses from earthquakes of $250 million per year. The savings would result from measures taken to strengthen buildings and their contents, reduce the fire hazard, increase dam safety, enhance nuclear power-plant safety, and the like. For still-shorter-term predictions (e.g., one week), substantial savings of lives would result from temporary measures such as the evacuation of dangerous buildings and the mobilization of emergency forces.

Finally, I would like to comment on some of the specific legislation that has been proposed in the Congress for earthquake-hazard mitigation. Senate Bill 1174, the so-called Cranston Bill, seems to me to be realistic in that it recognizes the necessity for extensive basic studies before an effective earthquake-prediction system can be designed, and it recognizes the gross inadequacy of present funding in this area. It also represents a commendable balance of effort between the engineering and prediction efforts, as well as those involving societal response. My principal reservations concerning the Cranston Bill involves its assignment of responsibility to specific government agencies. Many of us engaged in basic scientific research are a bit surprised to find that the primary engineering effort has been assigned to the National Science Foundation, whereas the principal scientific research effort has been assigned to an operating government agency—the U.S. Geological Survey. Many of us in the academic research community are somewhat uneasy to find that the National Science Foundation's traditional and very effective role in the support of basic research in the universities seems to have been undercut, and we are uneasy about the prospects of applying for basic research funds to an agency with which we are in direct competition—albeit a healthy and desirable competition. I fully recognize the

need for the Geological Survey to contract with outside groups for certain of its mission-oriented tasks, and I applaud its efforts in this direction, but I am uneasy about the assignment to the Survey of the support of non-Federal basic research in seismology and earthquake prediction—a role that I would sooner see given to the National Science Foundation. I suggest that the Cranston Bill be modified to recognize the present and future role of the National Science Foundation in the support of non-Federal research in seismology, tectonics, and geology that are relevant to earthquake prediction, and that the relative funding of the National Science Foundation and U.S. Geological Survey in the Bill be adjusted to take this modification into account. I should emphasize that I do not question the assignment to the Geological Survey of the principal Federal in-house earthquake-prediction effort; it is a remarkable organization with abundant scientific talent and a long tradition of eminent scientific accomplishments. Already, the Geological Survey's contributions to earthquake prediction and hazard reduction are known world-wide.

House Bill 13845, introduced by Congressman Mosher, seems to me to be attacking a somewhat different aspect of the earthquake-hazard-reduction problem, and I would not like to see it considered a substitute for the Cranston Bill. The Mosher Bill is apparently responding to recommendations of the National Academy of Science's report on Earthquake Prediction and Public Policy, but I would emphasize that we as yet have no routine earthquake-prediction capability, and it seems to me that the setting up of such an elaborate and expensive management infra-structure is a bit premature. Furthermore, the absence of any specific recommendations for increased funding of the necessary engineering and scientific research programs seems to imply that the present budgetary process is working effectively, which I do not consider to be the case. I am not convinced that the Mosher Bill imparts the necessary sense of urgency to the problem, and in this sense I prefer the approach of Senator Cranston.

In conclusion, let me simply state that now is the logical time to make a national commitment to an effective earthquake prediction and response program, and to allocate the necessary resources to achieve the task.

STATEMENT OF CLARENCE ALLEN, DIVISION OF GEOLOGICAL AND PLANETARY SCIENCES, CALIFORNIA INSTITUTE OF TECHNOLOGY

Dr. ALLEN. Congressman Brown, I am honored to be invited to appear as a witness before your committee today.

My name is Clarence R. Allen, and I am professor of geology and geophysics at the Seismological Laboratory of the California Institute of Technology in Pasadena. I am also chairman of the National Academy of Science's Panel on Earthquake Prediction, whose report has been essentially completed for some time now.

In contrast with what is stated in the prepared testimony before you, that report has now been finally approved within the last few hours by the National Academy's Report and Review Committee, and following the summary of my own personal viewpoints I would like to put into the record, if I may, the summary of recommendations of the National Academy report.

Mr. BROWN. You say it has been approved this morning?

Dr. ALLEN. Yes; at 8:50. I finally got word.

Mr. BROWN. We are delighted to know that and without objection the material will be included in the record.

Dr. ALLEN. First of all I would like to summarize some of my own viewpoints although you will see in many parts that they agree with the National Academy report.

Although I will be speaking today primarily about earthquake prediction, I recognize that prediction represents only one facet of the total earthquake-hazard-reduction effort, and I recognize that the various legislative bills under consideration by your subcommittee

are concerned with the larger problem, including that of societal response.

Nevertheless, I am fully convinced that earthquake prediction can and should play a leading and vitally important role in the hazard-reduction effort, and it represents one area where exicting and significant scientific advances are being made right now, and will almost certainly continue to be made in the next few years if we are able to obtain continuing encouragement and support.

Early this year, more than 23,000 lives were lost in a major earthquake in Guatemala, mostly resulting from the collapse of non-earthquake-resistant dwellings. A timely warning of the impending earthquake, advising residents to go out of doors, would undoubtedly have saved the lives of most of those killed and prevented tens of thousands of injuries.

The stakes in earthquake prediction are exceedingly high; most seismologists feel that now is the time to make a national commitment to a long-term program aimed at developing a reliable and effective operational earthquake-prediction capability.

Let me try to respond to your chairman's specific questions. "What is the present status of earthquake predictions?" There is no question but that earthquake prediction is still in the research phase, and although a few earthquake predictions have already been successful in a scientifically meaningful way, tremendous amounts of basic and applied research must be carried out before we can develop a system that permits socially meaningful predictions on a routine basis. Most, but not all, seismologists agree, however, that this is an attainable goal.

"How do you believe earthquake prediction will develop in the next few years?" Given adequate funding, it is my guess that we will be successful in predicting an earthquake in the magnitude 5 range in California within the next 5 years.

However, my own estimate is that we are at least 10 years away from the time when we shall be in a position to implement a system of routine earthquake predictions with an acceptably low false-alarm and failure rate.

In my opinion, the apparent public impression that routine prediction of earthquakes is imminent is not warranted by the present level of scientific understanding. We have a long ways to go, particularly in areas involving very basic research, before an effective earthquake-perdiction system will be operative or even capable of being planned in detail.

"What resources should be devoted to earthquake prediction?" It appears that the Federal effort in earthquake prediction at the present time amounts to an annual expenditure of $10 to $11 million, although this encompasses work involving a rather broad definition of "earthquake prediction," and for that reason is somewhat larger than the number named by Dr. Press. This includes a good deal of work in hazard evaluation which is peripherally related to earthquake prediction.

Of this total, some $15 million is budgeted by the U.S. Geological Survey, $4.2 million by the National Science Foundation, $1.3 million by the National Aeronautics and Space Administration, and $0.09 million by the Nuclear Regulatory Commission.

It is my opinion that a truly effective earthquake-prediction program will require an annual expenditure of at least two to three times that at present, amounting to at least $25 million per year for the next 10 years.

This judgment is based on my estimate of the scope of the research work that must be done, as well as upon the manpower that is realistically available to carry out the effort.

It might be noted, for example, that during the first year of its external research grants program, fiscal year 1975, the Geological Survey received proposals from universities, private industry, and State agencies for more than $13 million, more than half of which were judged to be of very substantial potential value. Yet budgetary restrictions allowed research proposals for only $2 million to be funded.

Mr. BROWN. May I interrupt and ask if you differ or concur with the rough breakdown offered by Dr. Press with regard to the distribution of that amount of money? Your figures are essentially the same, the total figures.

Dr. ALLEN. I agree with the kinds of things he emphasized, particularly the development of better computerized facilities. Yes, I think we are speaking of the same kind of breakdown.

"What should be the roles of Federal laboratories and academic institutions?" Certainly a team effort on the part of many groups, including private industry as well as Federal and academic institutions, will be necessary to achieve the goal of effective earthquake prediction.

In terms of manpower available, however, it is my belief that non-Federal groups are going to have to play a far more important relative role in the expanded program than has been the case thus far. I feel that there are definite dangers in the abrupt expansion of Federal agencies to meet specific and temporary problems, particularly when a large part of the talent and the resources to solve the problems exists outside of those agencies.

In the specific case of earthquake prediction, it is clear that when we are finally in a position to implement a routine prediction program, a Federal agency such as the Geological Survey will obviously have to play the leading role, but the attainment of the prediction capability is still so far in the future that we must take advantage of every possible resource, both inside and outside of Government, in carrying out the necessary research and development.

"What are the expected benefits?" There is not the slightest question but that lives can be saved by effective earthquake predicitons, and this has already been amply demonstrated in China. While I emphasize again that earthquake prediction is only one facet of a total program in earthquake-hazard reduction, the cost-benefit ratio—especially in terms of human lives—is exceedingly favorable by almost any calculation.

It has been estimated, for example, that in the absence of an effective prediction, a loss of life measured in the tens of thousands is likely in a major California earthquake. In the city of Los Angeles alone, some 75,000 to 100,000 people—mainly poor and elderly—live in pre-1933 unreinforced masonry buildings that will almost certainly fail in a major local earthquake, but which could be evacuated given adequate warning.

Engineers have correctly pointed out that a prediction will certainly not keep an unsafe building from collapsing, but it might well allow the saving of human lives by a timely evacuation of the structure.

It has been estimated that knowledge of an impending great earthquake, a year or more in advance, could result in a reduction in annualized losses from earthquakes of $250 million per year. The savings would result from measures taken to strengthen buildings and their contents, reduce the fire hazard, increase dam safety, enhance nuclear powerplant safety, and the like. For still shorter term predictions, for example 1 week, substantial savings or lives would result from temporary measures such as the evacuation of dangerous buildings and the mobilization of emergency forces.

Mr. BROWN. May I interrupt again at that point? I was struck by Dr. Press' comment about the Chinese strategy which seems to forgo any structural rebuilding or strengthening of structures prior to an earthquake and depend upon evacuation and then plan to rebuild, presumably in a safer fashion, the properties which are destroyed. Your view seems to be that we could engage in an alternate strategy of actually strengthening some of the marginal buildings if we were given sufficient leadtime in doing that and that that would be economically justifiable under the circumstances. Is that your view?

Dr. ALLEN. It is, particularly inasmuch as I don't think within the next 10 years we will have a routine earthquake prediction capability. We will certainly be having earthquakes within the next 10 years, and it behooves us to try to do what we can in that period to keep lives from being lost in those buildings which are sure to fail. The Chinese situation, it seems to me, is quite different from ours in that most people have been killed in their own houses. Most of our houses are basically pretty safe places—our single-family dwellings—but we still have this problem of the major unreinforced brick buildings which unfortunately house a large number of elderly and poor people in the downtown areas of our large cities.

Mr. BROWN. Would the normal consequence of either building or rebuilding to more stringent earthquake standards be to extend the lives of those buildings? In other words, are we constructing a longer lived building than our normal construction practices would lead us to do?

Dr. ALLEN. I don't fully understand the question.

Mr. BROWN. If we were to build to the highest earthquake standards, are those buildings likely to last longer or have a longer lifetime than if we did not build to such standards? In other words, what is the impact of building earthquake protection into the life of a building?

Dr. ALLEN. I am not an engineer and perhaps Mr. Steinbrugge could comment on this better. My own feeling is that if we design it to be earthquake resistant and if it is in an area like California, yes.

Mr. BROWN. If an earthquake occurred it would last longer but in the absence of an earthquake would it be longer lasting?

Dr. ALLEN. I am not sure I am able to answer that.

Mr. BROWN. It may be an inconsequential question.

Dr. ALLEN. Finally, I would like to comment on some of the specific legislation that has been proposed in the Congress for earthquake-hazard mitigation. Senate bill 1174, the so-called Cranston bill, seems to me to be realistic in that it recognizes the necessity for extensive basic studies before an effective earthquake-prediction system can be designed, and it recognizes the gross inadequacy of present funding

in this area. It also represents a commendable balance of effort between the engineering and prediction efforts, as well as those involving societal response.

My principal reservations concerning the Cranston bill involve its assignment of responsibility to specific Government agencies. Many of us engaged in basic scientific research are a bit surprised to find that the primary engineering effort has been assigned to the National Science Foundation, whereas the principal scientific research effort has been assigned to an operating Government agency—the U.S. Geological Survey.

Many of us in the academic research community are somewhat uneasy to find that the National Science Foundation's traditional and very effective role in the support of basic research in the universities seems to have been undercut, and we are uneasy about the prospects of applying for basic research funds to an agency with which we are in direct competition—albeit a healthy and desirable competition.

I fully recognize the need for the Geological Survey to contract with outside groups for certain of its mission-oriented tasks, and I applaud its efforts in this direction, but I am uneasy about the assignment to the Survey of the support of non-Federal basic research in seismology and earthquake prediction—a role that I would sooner see given to the National Science Foundation.

I suggest that the Cranston bill be modified to recognize the present and future role of the National Science Foundation in the support of non-Federal research in seismology, tectonics, and geology that are relevant to earthquake prediction, and that the relative funding of the National Science Foundation and U.S. Geological Survey in the bill be adjusted to take this modification into account.

I should emphasize that I do not question the assignment of the Geological Survey of the principal Federal in-house earthquake-prediction effort. It is a remarkable organization with abundant scientific talent and a long tradition of eminent scientific accomplishments. Already, the Geological Survey's contributions to earthquake prediction and hazard reduction are known worldwide.

House bill 13845, introduced by Congressman Mosher, seems to me to be attacking a somewhat different aspect of the earthquake-hazard-reduction problem, and I would not like to see it considered a substitute for the Cranston bill.

The Mosher bill is apparently responding to recommendations of the National Academy of Science's report on earthquake prediction and public policy, but I would emphasize that we as yet have no routine earthquake-prediction capability, and it seems to me that the setting up of such an elaborate and expensive management infrastructure is a bit premature.

Furthermore, the absence of any specific recommendations for increased funding of the necessary engineering and scientific research programs seems to imply that the present budgetary process is working effectively, which I do not consider to be the case. I am not convinced that the Mosher bill imparts the necessary sense of urgency to the problem, and in this sense I prefer the approach of Senator Cranston.

In conclusion, let me simply state that now is the logical time to make a national commitment to an effective earthquake prediction and response program, and to allocate the necessary resources to achieve the task.

That completes my own personal testimony and if I might I would just like to summarize, with your permission, the National Academy's report.

The summary involves some 14 points and let me just read them to you.

The members of the Panel on Earthquake Prediction have reviewed the major research efforts in earthquake prediction by investigators of all countries. The following statements summarize the Panel's views.

1. Earthquake prediction holds great potential for saving lives, reducing property damage, enhancing the safety of critical facilities, and helping make possible more rapid restoration of normal living after an earthquake.

2. Anomalous physical phenomena precursory to some earthquakes have been clearly identified.

3. The physical nature of precursory phenomena is complex, and current models to explain them are crude; improvement of these models will require considerable effort in the field and laboratory, as well as in theoretical studies.

4. Some small earthquakes have been predicted in a scientifically credible way, and most researchers are optimistic that we will eventually be successful in predicting larger earthquakes as well.

5. Of the types of recognizable phenomena thought to be precursory to earthquakes, some may, in fact, be due to other causes and yield false alarms. Successful routine prediction will probably require the use of several techniques.

6. At present, the ability to detect and locate an impending earthquake requires a dense distribution of instruments in the quake area. Improved observational networks in areas of high earthquake probability are mandatory if we are to gain the fundamental knowledge on which to build an effective earthquake-prediction program.

7. Predictions of earthquakes should specify time, magnitude, place, and probability. However, even a statement that does not specify time or magnitude, or a statement that an earthquake will not occur in a particular place or at a particular time, would be meaningful.

8. Neither the present state of the art nor the present distribution of instrumentation can permit socially meaningful predictions on a routine basis. Therefore, at this time, an expression such as "area of intensive study," as used in Japan, might reflect more accurately the confidence level of interpretations of the observed phenomena in some areas than would an actual prediction.

9. A successful scientific prediction within the next 5 years will probably be made for an earthquake of magnitude 5 or greater in California. With appropriate commitment, the routine announcement of reliable predictions may be possible within 10 years, although large earthquakes may present a particularly difficult problem. The apparent public impression that routine prediction of earthquakes is imminent is not warranted by the present level of scientific understanding.

10. Until formal procedures for issuing predictions have been established, predictions made by responsible scientists should be accom-

panied by sufficient backup data for full evaluation by the scientific community.

11. During the development of an earthquake-prediction and warning capability, there will be unavoidable errors and false alarms. The public must be made aware of this prospect, and the development of any procedure to issue warnings must accommodate it. Even the ultimate system will probably not be infallible.

12. The rate of development of a reliable earthquake-prediction capability operating on a routine basis will depend to a large extent on the amount, rate, and deployment of funding. Progress in improving the state of the art in the early growth period will be particularly sensitive to the level of support. The Panel believes that an effective program will require a 10-year commitment of effort, and that a large increase to several times the curent annual Federal expenditures would be cost effective and would be in the national interest.

13. The scientific and technical aspects of earthquake prediction have advanced to the point at which the development of systems for associated societal response should be addressed promptly in a formal manner. A prediction capability will be of little value if societal response procedures are not formulated concurrently.

14. If the earthquake-hazard problem is to be attacked realistically, the development of an earthquake-engineering design and construction are complimentary and equally necessary, and should be carried on at the same time.

The primary purpose of this report, as stated in the preface, is to review the state of the art and the future outlook of earthquake prediction. The Panel had no initial intention to make specific recommendations, and in particular to make recommendations with respect to funding. When the study was completed, however, it was apparent to the Panel that four areas are of sufficient urgency that such recommendations are needed and should be acted on without delay. They are:

1. The United States should now make a national commitment to a long-term program aimed at developing a reliable and effective operational earthquake-prediction capability.

Based on an assessment of worldwide observations and findings over the past few years it is the Panel's unanimous opinion that the development of an effective earthquake-prediction capability is an achievable goal. In recent years, several isolated earthquakes have been successfully predicted by scientific criteria. These results and other studies indicate that with appropriate commitment and level of effort, the routine announcement of reliable predictions may be possible within 10 years in well-instrumented areas, although very large earthquakes may present a particularly difficult problem. A truly effective national program will require a significant increase to several times the current annual expenditures for prediction research. If the 10-year research effort is successful, subsequent implementation of the resulting earthquake-prediction capability, for all seismic areas of the United States and on a continuing basis, will require a comparable national commitment.

2. A representative group of competent scientists should be formed now to advise the Federal Government at the highest levels on the progress and needs of its earthquake-prediction program.

United States research in earthquake prediction now looks so promising, and its social consequences are so profound, that an advisory unit should be established to provide advice about the progress and needs of the effort to the highest levels in the Federal Government, preferable directly to the Executive Office of the President, that is, to the Director of the Office of Science and Technology Policy. Such as a group of nongovernmental scientists would report periodically on the status of the total U.S. earthquake prediction effort, identify gaps and overlaps in the national research program, advise on the establishment of an earthquake warning procedure, and maintain a broad overview of the program's needs and funding.

3. A formal procedure should now be established for evaluation of earthquake predictions and for advising relevant agencies and groups concerning their validity.

Predictions are now being put forth by various groups—formally or informally—and responsible public officials and agencies are becoming concerned as to how to evaluate these predictions and react to them. The Panel feels that the time has come for a formal body to be created to evaluate all such earthquake predictions. The purpose of such a body should not be to censor or restrict individuals and organizations in the making of responsible predictions, or to make predictions itself, but to serve as the filter between those who issue predictions and those who are obliged to react to them. Such a procedure would encourage responsibility among predictionmakers since all predictions would be subject to thorough and systematic scrutiny by their scientific colleagues.

In view of the tremendous responsibilities of such a body and the profound potential impact of its judgments, it should have representation from a wide spectrum of the seismological community. Representatives of concerned public agencies should be encouraged to attend its meetings as observers. An evaluation group of this type, made up of scientists from a variety of institutions and agencies, has already been established in the State of California.

4. Research, planning, and development both of the integrated operational prediction capability and of an effective social response capability should be carried out concurrently and in coordination.

The solution of social-response problems should be given priority comparable to that of developing prediction technology. If this is not done, we may learn how to predict earthquakes before we know what to do with the predictions when we get them. To avoid this unacceptable outcome, we must mount a research and planning effort of major scope, closely integrated with the scientific and technical development of prediction capability. The effort must be problem oriented and highly interdisciplinary: many issues require the attention of sociologists, social psychologists, lawyers, political scientists, organization theorists, experts on command and control, and experts from other disciplines. In the final operational earthquake-warning-and-response system, an authoritative scientific and technical prediction capability and an effective social response capability will be equally important.

That completes my statement.

Mr. Brown. Thank you very much. It is an excellent statement by the Academy. If I didn't know better, I might think you had contributed. [Laughter.]

Dr. ALLEN. I should emphasize this is only the summary and conclusions. The main body of the report follows.

Mr. BROWN. Mrs. Lloyd, do you have any questions?

Mrs. LLOYD. Thank you very much. I certainly appreciate your testimony, Dr. Allen. I am sorry I had to come in late but I will take it with me and review it later.

It is alarming that we do not have any plans for an earthquake warning system. At what stage of viability—you were talking about stages of development—should official earthquake predictions be made? What is the danger of a false alarm? Would you equate this with a system such as an air raid alert—maybe I am getting ahead of myself.

Dr. ALLEN. It seems to me that particularly during the next 10 years, as we develop an earthquake prediction capability, we will have predictions being offered by numerous individuals and groups with various degrees of reliability. It seems to me that we cannot specify at what level those will be made public and at what level they will not be made public. I think the idea of keeping anything secret is out of the question. Not only is it impossible at the present time, but it is probably undesirable as well. I think the important thing is that the public be aware of the fact that there are various levels of reliability.

That is, just because the chances of rain are less than 50 percent tomorrow doesn't mean that the weather bureau doesn't make that prediction. They still try, but they may fail—just as we may fail sometimes. But I think at this point to say that there is a level of reliability above which we will announce would not be an appropriate measure.

Admittedly, I think we must achieve a certain degree of success and reliability before we are convinced that we have an effective system that can go into operation and warrant public response. Hopefully, if we are right 75 percent of the time, we will have an effective system in terms of social response, but I foresee that particularly over the next 10 years, we are going to be having predictions offered with a great variety of reliabilities.

Mrs. LLOYD. To whom should this authority be given?

Dr. ALLEN. At the moment, I don't think, as stated in the Academy report, that we can censor these kinds of predictions. I think anybody has the right to make a prediction. Nevertheless, I think it is true that the agencies that are obligated to respond must have some filtering mechanisms so that they do not themselves try to evaluate every prediction made by various people, including scientists as well as complete amateurs.

In the State of California there is a group established which performs that evaluation and advises the agency as to their evaluation of a prediction. I think at the Federal level such a group will also have to be formed, but exactly under what aegis I am not sure at the moment.

Mrs. LLOYD. Our chairman was discussing the construction of buildings that would not be prone to earthquake damage. Have we devised any form of shelter where people would go in case of an earthquake? Has this been considered?

Dr. ALLEN. Of course, if one is in a building which is not safe and if one knows an earthquake is coming, the obvious thing is to go out-

side. In this sense, I don't think we have to visualize shelters of the same type you speak about with regard to tornadoes.

Mrs. LLOYD. I am totally ignorant of earthquakes. I am asking some of these things for my own information.

Dr. ALLEN. Following a major earthquake, aftershocks may occur. I think the recommendation is that people simply stay outside, away from possible falling objects, until such time it appears relatively safe to go back into the structures.

Mrs. LLOYD. We were speaking of the time and money needed in this program. Do we have the capacity for training of our scientists and the instruments? Are we lacking facilities for training?

Dr. ALLEN. I do not think so. As a matter of fact, one of our reasons for feeling that the level of efforts could be several times larger than that at present is that there exists a large qualified group of people whose attention could be turned to this problem right now, given sufficient funding and direction.

It is true that many of our universities and schools right now could use more funds for supporting graduate students and for training in this direction. That certainly would be one of the results of increased funding in this field.

Mrs. LLOYD. Is there any correlation whatsoever with any earthquakes in densely populated areas? Are densely populated areas more prone to earthquake?

Dr. ALLEN. Not in general, no. Earthquakes occur of course for geological reasons. It does so happen that many cities are in areas with these geological attributes, but taken as a whole, I don't think there is any major correlation between densely populated areas and earthquakes.

Of course one of the things that makes California an attractive place to live is the coastal mountains and the coastal valleys, and the reasons we have them is because of the San Andreas Fault. So there is—in a sense—a relationship.

But if you look at the map of the earthquake epicenters in California, it is not coincident with the population centers.

Mrs. LLOYD. Thank you very much.

Mr. BROWN. You have had some experience in your own institution with some earthquake predictions recently. Were those evaluated as to level of credibility prior to the time the predictions were made? Or was there any mechanism or thought given to the effects of making such a prediction prior to the time it was actually made?

Dr. ALLEN. Yes; considerable thought was given to the level of reliability of the hypothesis test, as I think Dr. Whitcomb prefers to call it. He is going to testify tomorrow, and I would prefer not to speak for him.

Likewise the State evaluating committee tried in its judgment to give a feeling for its sense of confidence in the prediction.

Mr. BROWN. As a followup to that prediction, you noted, I am sure, the rather immediate and strident response on the part of some people in the local area. Was there any thought given to the analysis of this response as part of an ongoing study of the problems involved in earthquake prediction?

Dr. ALLEN. Many people have been looking very carefully at what happened in Los Angeles and Dr. White, who I believe is testifying

tomorrow, will testify specifically on that problem, because his group was involved in a study of what happened.

I might say that, all in all, my reaction was that the response was very encouraging. We thought the news media—in general—treated this thing in a very level-headed way. The public response, with a few exceptions, we thought, was very encouraging.

I think, all in all, this sort of dress rehearsal gives us some hope and encouragement that earthquake prediction really can be beneficial in terms of public response.

Mr. BROWN. The thrust of my question was primarily to determine if we were taking advantage of this experience as a part of our total analysis of the problem. I thought it was a rather interesting experiment, myself.

Dr. ALLEN. Very, very interesting, and yes, I can assure you, social scientists have been looking very carefully at what happened in the Los Angeles area, not only with respect to the so-called hypothesis test of Dr. Whitcomb, but also with regard to the reaction to the announcement of the Palmdale bulge.

Mr. BROWN. Dr. Allen, your concluding statement indicates that you feel this is the right time to do something in this field. Of course, your statement indicates some of the reasons for that. Your reasons as to thinking the timing is appropriate do not necessarily coincide with the reasons of Members of Congress who are voting for legislation and I wonder if we can strengthen this a little bit.

We have a situation of severe budgetary constraints upon Federal programs and in order to justify any legislation we have to make a strong case for the logic and timing of a particular program because generally it is going to mean that some other program will have to be cut back. Would it be your view that we could make a strong case for dollars spent in this program as having a greater cost-effectiveness than some other dollars which you don't need to specify at the present time?

Dr. ALLEN. It is really difficult for me to compare this with other programs and say that this particular program is more worthwhile or has a more favorable cost-benefit ratio than other scientific programs. All I can say is if we look at the possible effects of earthquakes and try to evaluate the tragedies that will result, we see tremendous benefits coming from increased efforts in this area, and also we see tremendous excitement in terms of the possibility of doing something about this.

I would emphasize that when our panel on earthquake prediction first met some 2 to 3 years ago, I think the feeling was one of general skepticism, that it was not really feasible.

I think during these past 2 or 3 years, our committee has swung around to a relatively optimistic viewpoint, and I think this is true throughout the seismological community in general.

So in essence we see here the unique opportunity to take advantage of a scientific breakthrough. It looks as though something has really happened here to allow us to realize significant social benefits from an exciting scientific venture.

Mr. BROWN. We welcome the return of the chairman at this time.

Mr. Chairman, I think we have just about concluded questioning of Dr. Allen unless you have some further questions.

Mr. SYMINGTON. I am sorry to have missed this opportunity. I am sure that Congressman Brown covered some valuable ground.

Dr. Allen, I will certainly be studying the record in due course. We had some conflicts today, as you know, due to the caucus and certain other items of business. We are very grateful to you and the other witnesses for your patience and your consideration of the committee's problems.

If there are no further questions, we will excuse the witness.

Thank you very much, sir.

[Further questions in written form were forwarded to Dr. Allen. The questions and responses follow:]

Question 1. Have you drawn up a budget of how the $25 million per year you suggest for earthquake prediction should be used? If so, please provide the Subcommittee with a copy. If not, how did you arrive at the figure?

Answer. Our National Academy of Sciences' Panel did not present a detailed budgetary breakdown because it was felt that this went beyond the charge to the Panel. Nevertheless, there was agreement that a level of effort some two to three times that at present (about $10 million per year) was necessary to achieve the goal of effective earthquake prediction in a reasonable time. This judgment was based on our evaluation of the various current efforts and how they should be expanded or improved, a comparison with programs in other countries, and our estimate of the available qualified personnel to do the work. A detailed budget is now being prepared by the National Science Foundation's Advisory Group on Earthquake Prediction and Hazard Mitigation, of which I am also a member; this Group's report should be available presently.

Question 2. At what stage of reliability should official earthquake predictions, in your mind, first be made? What are the pros and cons of (a) risking a false alarm and (b) failing to make a prediction of an earthquake that occurs (assuming there are precursory signs)?

Answer. As stated in my testimony before the Subcommittee, I feel that essentially all reasonable earthquake predictions—even those of low reliability—must be made public; secrecy is impossible in any event. However, it is important that the author's estimate of reliability (i.e., his confidence in the success of the prediction) be included with the other announced data, so that public officials and others can choose whether and how to react—much as they do with the Weather Bureau's forecasts based on a percentage probability. Inevitably, there will be both false alarms and failures, especially during the development stage of achieving a prediction capability. If there are too many failures and false alarms, the program will obviously loose public support and credibility. But this is a risk that must be taken. I am optimistic that—in the long run—we can achieve an acceptably low failure and false alarm rate, and that the social benefits from successful predictions will far outweigh both the costs of development and the hazards of occasional failures and false alarms. But I am under no illusions; we are in for some trying times during the development of our prediction capability over the next ten years or so.

We will now call on Dr. Otto Nuttli, who hails from St. Louis, Mo.

We are very grateful to you, Dr. Nuttli, for being with us this afternoon and again I must convey a personal apology to you on behalf of the committee for the inconvenience that this day has imposed upon us all.

[A brief biographical sketch of Dr. Otto W. Nuttli and Dr. Nuttli's prepared testimony follow:]

DR. OTTO W. NUTTLI

Date of Birth: December 11, 1926.

Education: B.S. (1948), M.S. (1950) and Ph.D. (1953) in geophysics from Saint Louis University.

PROFESSIONAL EXPERIENCE

On faculty of Saint Louis University since 1952, professor of geophysics since 1962. Visiting research scientist at University of Michigan (summer 1962). Visit-

ing research scientist at University of California at Berkeley (summers 1964, 1967). Consultant to Federal government agencies and to industry.

PRESENT PROFESSIONAL POSITIONS AND APPOINTMENTS

President of Seismological Society of America (1976–1977).
Member, U.S. National Committee on Geology (1975–1979).
Member, Committee on Seismology of National Research Council (1976–1979).
Member, Advisory Group on Earthquake Prediction and Hazard Mitigation (1976).
Member of Board of Governors of American Geological Institute (1976–1977).

PROFESSIONAL SOCIETY MEMBERSHIPS

Seismological Society of America (editor, 1971–1975; vice-president, 1975–1976; president, 1976–1977).
American Geophysical Union (fellow).
Royal Astronomical Society.
Society of Exploration Geophysicists.
American Association for the Advancement of Science.

RESEARCH INTERESTS

Seismicity and tectonics of central United States.
Earthquake ground motion studies, particularly for the central and eastern United States.
Source mechanics of earthquakes.

STATEMENT BY OTTO W. NUTTLI

At the request of the Honorable James W. Symington, Chairman of the Subcommittee on Science, Research and Technology, my discussion will concern earthquakes in the eastern and midwestern United States, in particular how they differ from earthquakes in the West and how this presents some unique problems with regard to prediction and hazard mitigation.

Although large earthquakes occur relatively infrequently east of the Rocky Mountains, no state is free from suffering some effects of earthquakes. This is in part a consequence of the fact that the perceptible and damage areas of eastern earthquakes are as much as one hundred times larger than those of their western counterparts of the same magnitude. Instead of areas the size of a county being badly damaged, as in the West, a large midwestern or eastern earthquake will result in major damage to areas the size of a state or states. Indirect consequences of the earthquake can affect the entire eastern half of the country.

Concerning the problems of earthquake prediction and hazard reduction, there are three principal ways in which the eastern problems differ from the western ones. In many other ways, of course, they are similar, as I shall discuss later. The differences result from: (1) the fact that in the East we cannot easily identify the faults that are responsible for the earthquakes (2) the fact that the frequency of occurrence of earthquakes is less in the East than in the West (3) the fact that larger damage areas result from eastern and mid-western earthquakes.

In California and Nevada one can, from the ground or from an airplane, actually see the San Andreas fault or the faults along the Sierra Nevada front where the major earthquakes occur. They are readily accessible, so that one knows where to place instruments such as seismographs, tiltmeters and other devices to make the kinds of measurements that are required for earthquake prediction. In the East, on the other hand, we cannot so readily identify the active faults. Some are covered by hundreds to thousands of feet of alluvial or glacial sediments, which obscure their presence. They can be seen only indirectly, either by locating and mapping the numerous microearthquakes that are continuously occurring along them or by geophysical methods, such as seismic reflection techniques, which enable us to map the deep underground strata. Only after the earthquake-active regions of the East have been identified and accurately located, which is what we call seismicity studies, can we get on to the problems of earthquake prediction. Some of the information gained from seis-

micity studies will also be data that can be directly applied to earthquake prediction studies.

From historic data we know of a number of places where future large earthquakes are most likely to occur. Proceeding from west to east, these include: the Wichita Mountain-Ouachita Mountain front of northern Texas, south central Oklahoma, central Arkansas and northern Mississippi, the Nemaha uplift of central Oklahoma, eastern Kansas and eastern Nebraska, the New Madrid seismic zone of southeast Missouri, northeast Arkansas, western Tennessee, western Kentucky and southern Illinois, the Wabash valley seismic zone of southeastern Illinois and western Indiana, a seismic region of western Ohio, a seismic region of western New York, a seismic region of indefinite extent that includes the Boston area, eastern New York and states to the northeast, a seismic zone of eastern Tennessee, eastern Kentucky, Virginia and West Virginia and a seismic zone including Charleston, South Carolina. All of these are places where damaging earthquakes have occurred in the past and where they will occur in the future. We should do as much as we can to delineate these seismic zones, both so that we can make reliable estimates of earthquakes ground motions, in order to construct safe buildings at no greater cost than is necessary, and so that we can begin to get about the business of earthquake prediction. The technology is available. If we are provided the resources necessary for such research, we can achieve these objectives of delineating active fault zones and of establishing the ground motions that will result from earthquakes occurring in them. Let me speak, for example, of a case with which I am most familiar. In recent years Saint Louis University has received support from the U.S. Geological Survey and the National Science Foundation for just such studies in the New Madrid seismic zone of the central Mississippi valley. In historic times this seismic zone has been the most active of any in the eastern United States.

In the early history of our country it produced some truly major earthquakes. As an aside, I might mention that the first scientific publication concerning these earthquakes was written by the late Honorable Samuel Mitchill, a congressman from New York. And the first Federal Disaster Relief Act was passed in 1815 to give citizens title to new land, to replace the land that was ravaged and made unproductive by the earthquakes. To return to my example, as a consequence of the research support given to Saint Louis University we have been able to narrow down the breadth of what was at one time thought to be a diffuse zone of earthquakes, and now recognize it as having the characteristics of a true fault zone, at least 125 miles long, with an offset near its northern end. We have been able to accomplish this in spite of the fact that the fault is covered by thousands of feet of river sediment, and that there is absolutely no surface indication of faulting. We also have been able to establish that beneath the presently most active part of the fault zone there is a region of lower-than-normal wave velocities in the crust and upper mantle of the Earth, a condition which possibly is indicative of the dilatancy that precedes earthquakes. But before we can make any predictions we must examine the behavior of this region of anomalous velocity over a period of time, to see if it is changing and, if so, by what amount. In the meantime we also are beginning to acquire an understanding of the source mechanics of the New Madrid earthquakes, which is important information if we are to predict the earthquake ground motion.

As I pointed out earlier, earthquakes in the East occur relatively infrequently. As a consequence we do not have a sufficient historic record to tell us the size of the maximum possible earthquake that can occur in each of the long list of earthquake regions mentioned earlier. If we do not know how large an earthquake can be, we either have to overdesign structures to make them capable of withstanding the largest earthquake that has occurred anywhere in the world, or we must accept a certain amount of risk in their design. Information that could be obtained by microearthquake studies would provide us with knowledge of the length of the active fault segments, which is related to the maximum possible earthquake that can be associated with the fault.

The third point of difference between eastern and western earthquakes is the size of the areas of damage and perceptibility, which is as much as one-hundred times greater for eastern earthquakes. One obvious consequence is that eastern earthquakes, when they occur, affect many more people. Another one, if we decide to emphasize earthquake prediction for the large metropolitan areas, is that we

must look at a much larger region of potential earthquake sources that could affect a given metropolitan area.

The importance of the low attenuation of earthquake ground motion in the eastern United States cannot be overemphasized. Returning to the New Madrid earthquakes of the winter of 1811–1812 as an example, the major ones cracked stone walls and knocked down chimneys in St. Louis at a distance of 200 miles, knocked down chimneys in Louisville at a distance of 300 miles and damaged chimneys in Cincinnati at a distance of 400 miles. In 1811 there wasn't much in the way of man-made structures to be destroyed. Now there are, in addition to the buildings that people live and work in, structures such as gas and oil pipe lines, dams and bridges whose damage and disruption would affect the lives of millions of people.

An earthquake, no matter where it occurs, is caused by basically the same physical processes operating within the Earth. Therefore the methods and tools of prediction will be essentially the same in the East as in the West. Most or nearly all of the research and experience gained in predicting and reducing the hazard of western earthquakes will be applicable to eastern ones. Because large earthquakes occur more frequently in the West and because a much greater research effort is being devoted to predicting earthquakes in that region, it is likely that the first successful prediction of a major earthquake will occur in the West.

Success in prediction can be measured in more ways than the obvious one of an individual or organization correctly forecasting the place, time and magnitude of an earthquake. Is an earthquake that occurs that was not forecast as great or greater a failure in prediction as an event that was forecast but failed to materialize? This will depend on the goals of the prediction program, whether they are to predict major earthquakes occuring only in certain specified places (for which large research efforts and expenditures of funds will be made) or whether they are to predict all major earthquakes. If the latter is the case, then much more effort than is presently being expended will be required to identify all the seismic zones in the United States which have the potential for producing a destructive earthquake.

Nearly all the prediction tools that have been proposed make use of observations of changes in various physical properties of the Earth. In order to determine these changes, we must know what the normal values are. Since for large earthquakes some of these changes in properties take place over months or years of time, we require at least a number of years of observations to obtain the necessary data.

I was asked to comment upon the outlook for success of earthquake prediction in the East. Basically, I think that it is as promising as it is for the West, with the qualification that it is going to require more time than is needed in the West and a greater amount of research effort than is presently being carried on. In a few places, most notably the New Madrid region, New York State and Charleston, South Carolina, we have or soon can be expected to have some of the basic data on earth properties and on active fault identification that are needed for earthquake prediction. But even in these areas we do not have the density of coverage and all the types of instruments that are necessary, nor the resources to add to our staffs the number of scientists who would be needed to interpret the data. In the remainder of the eastern United States, which includes most of it, we are lacking basic seismicity data. Not only can we not make earthquake predictions without these data, we cannot even rationally design structures without such information.

In summary, the prospects of successfully predicting earthquakes in the West at the present time are greater than in the East because most of the active faults are readily identifiable and because the theory of plate tectonics aids one in knowing where to look for earthquakes. In the East, where plate tectonics theory gives no clue as to the location of the active faults, we will have to make use of detailed seismicity studies to obtain the necessary information. This is a major undertaking, but considering the density of population in the East and the widespread areas of damage that accompany such earthquakes, it is both a reasonable and a necessary thing to do. After the active faults have been delineated and after we acquire sufficient data so that we can distinguish between normal and anomalous physical properties of the Earth, I believe that our prospects for successful prediction of eastern earthquakes will be as good as for western ones.

STATEMENT OF OTTO W. NUTTLI, PROFESSOR OF GEOPHYSICS, ST. LOUIS UNIVERSITY

Dr. NUTTLI. I appreciate your invitation to be here.

At your request, I shall discuss earthquakes in the Eastern and the Midwestern United States, and in particular how they differ from earthquakes in the West and how this presents some peculiar problems with regard to prediction and hazard mitigation.

Although large earthquakes occur relatively infrequently east of the Rocky Mountains, no State is free from suffering some effects of earthquakes. This is in part a consequence of the fact that the perceptible and damage areas of eastern earthquakes are so much as 100 times larger than those of their western counterparts of the same magnitude. Instead of areas the size of a county being badly damaged, as in the west, a large midwestern or eastern earthquake will result in major damage to areas the size of a State or States. Indirect consequence of the earthquake can affect the entire eastern half of the country.

Concerning the problems of earthquake prediction and hazard reduction, there are three principal ways in which the eastern problems differ from the western ones. In many other ways, of course, they are similar, as I shall discuss later. The differences result from, one, the fact that in the east we cannot easily identify the faults that are responsible for the earthquakes, two, the fact that the frequency of occurrence of earthquakes is less in the East than in the West, and, three, the fact that larger damage areas result from eastern and midwestern earthquakes.

In California and Nevada one can, from the ground or from an airplane, actually see the San Andreas fault or the faults along the Sierra Nevada front where the major earthquakes occur. They are readily accessible, so that one knows where to place instruments such as seismographs, tiltmeters and other devices to make the kinds of measurements that are required for earthquake prediction.

In the East, on the other hand, we cannot so readily identify the active faults. Some are covered by hundreds to thousands of feet of alluvial or glacial sediments, which obscure their presence. They can be seen only indirectly, either by locating and mapping the numerous microearthquakes that are continuously occurring along them or by geophysical methods, such as seismic reflection techniques, which enable us to map the deep underground strata.

Only after the earthquake-active regions of the East have been identified and accurately located, which is what we call seismicity studies, can we get on to the problems of earthquake prediction. Some of the information gained from seismicity studies will also be data that can be directly applied to earthquake prediction studies.

I will not recite the large number of places where earthquakes have occurred in the past or might occur in the future in the East and Midwest. It covers most of the Eastern half of the United States.

We should do as much as we can to delineate these seismic zones, both so that we can make reliable estimates of earthquake ground motions, in order to construct safe buildings at no greater cost than is necessary, and so that we can begin to get about the business of earthquake prediction.

The technology is available. If we are provided the resources necessary for such research, we can achieve these objectives of delineating

active fault zones and of establishing the ground motions that will result from earthquakes occurring in them.

Let me speak, for example, of a case with which I am most familiar. In recent years St. Louis University has received support from the U.S. Geological Survey and the National Science Foundation for just such studies in the New Madrid seismic zone of the central Mississippi valley.

In historic times this seismic zone has been the most active of any in the Eastern United States. In the early history of our country it produced some truly major earthquakes.

As an aside, I might mention that the first scientific publication concerning these earthquakes was written by the late Honorable Samuel Mitchill, a Congressman from New York. And the first Federal Disaster Relief Act was passed in 1815 to give citizens title to new land, to replace the land that was ravaged and made unproductive by the earthquakes.

To return to my example, as a consequence of the research support given to St. Louis University we have been able to narrow down the breadth of what was at one time thought to be a diffuse zone of earthquakes, and now recognize it as having the characteristics of a true fault zone, at least 125 miles long, with an offset near its northern end.

We have been able to accomplish this in spite of the fact that the fault is covered by thousands of feet of river sediment, and that there is absolutely no surface indication of faulting.

We have also been able to establish that beneath the presently most active part of the fault zone there is a region of lower than normal wave velocities in the crust and upper mantle of the Earth, a condition which possibly is indicative of the dilatancy that precedes earthquakes.

But before we can make any predictions we must examine the behavior of this region of anomalous velocity over a period of time, to see if it is changing and, if so, by what amount.

In the meantime we also are beginning to acquire an understanding of the source mechanics of the New Madrid earthquakes, which is important information if we are to predict the earthquake ground motion.

As I pointed out earlier, earthquakes in the East occur relatively infrequent. As a consequence we do not have a sufficient historic record to tell us the size of the maximum possible earthquake that can occur in each of the long list of earthquake regions mentioned earlier.

If we do not know how large an earthquake can be, we either have to overdesign structures to make them capable of withstanding the largest earthquake that has occurred anywhere in the world, or we must accept a certain amount of risk in their design.

Information that could be obtained by microearthquake studies would provide us with knowledge of the length of the active fault segments, which is related to the maximum possible earthquake that can be associated with the fault.

The third point of difference between eastern and western earthquakes is the size of the areas of damage and perceptibility, which is as much as 100 times greater for eastern earthquakes.

One obvious consequence is that eastern earthquakes, when they occur, affect many more people.

Another one, if we decide to emphasize earthquake prediction for the large metropolitan areas, is that we must look at a much larger

region of potential earthquake sources that could affect a given metropolitan area.

An earthquake can affect a region as much as 300 or 400 miles away.

The importance of low attenuation of earthquake ground motion in the Eastern United States cannot be overemphasized.

Returning to the New Madrid earthquakes of the winter of 1911–12 as an example, the major ones cracked stone walls and knocked down chimneys in St. Louis at a distance of 200 miles, knocked down chimneys in Louisville at a distance of 300 miles, and damaged chimneys in Cincinnati at a distance of 400 miles.

In 1811 there wasn't much in the way of man-made structures to be destroyed. Now there are, in addition to the buildings that people live and work in, structures such as gas and oil pipe lines, dams and bridges whose damage and disruption would affect the lives of millions of people.

An earthquake, no matter where it occurs, is caused by basically the same physical processes operating within the Earth. Therefore the methods and tools of prediction will be essentially the same in the East as in the West. Most or nearly all of the research and experience gained in or predicting and reducing the hazard of western earthquakes will be applicable to eastern ones.

Because large earthquakes occur more frequently in the West and because a much greater research effort is being devoted to predicting earthquakes in that region, it is likely that the first successful prediction of a major earthquake will occur in the West.

Success in prediction can be measured in more ways than the obvious one of an individual or organization correctly forecasting the place, time, and magnitude of an earthquake. For example, suppose we don't predict an earthquake that occurs somewhere, is that a prediction failure? Is that as great a failure as predicting one that does not occur. This will depend on the goals of the prediction program, whether they are to predict major earthquakes occurring only in certain specified places, for which large research efforts and expenditures of funds will be made, or whether they are to predict all major earthquakes.

If the latter is the case, then much more effort than is presently being expended will be required to identify all the seismic zones in the United States which have the potential for producing a destruction earthquake.

Nearly all the prediction tools that have been proposed make use of observations of changes in various physical properties of the Earth. In order to determine these changes, we must know what the normal values are. Since for large earthquakes some of these changes in properties take place over months or years of time, we require at least a number of years of observations to obtain the necessary data.

I was asked to comment upon the outlook for success of earthquake prediction in the East. Basically, I think that it is as promising as it is for the West, with the qualification that it is going to require more time than is needed in the West and a greater amount of research effort than is presently being carried on.

In a few places, most notably the New Madrid region, New York State and Charleston, S.C., we have or soon can be expected to have some of the basic data on earth properties and on active fault identification that are needed for earthquake prediction.

But even in these areas we do not have the density of coverage and all the types of instruments that are necessary, nor the resources to add to our staffs the number of scientists who would be needed to interpret the data.

In the remainder of the eastern United States, which includes most of it, we are lacking basic seismicity data. Not only can we not make earthquake predictions without these data, we cannot even rationally design structures without such information.

In summary, the prospects of successfully predicting earthquakes in the West at the present time are greater than in the East because most of the active faults are readily identifiable and because the theory of plate tectonics aids one in knowing where to look for earthquakes.

In the East, where plate tectonics theory gives no clue as to the location of the active faults, we will have to make use of detailed seismicity studies to obtain the necessary information. This is a major undertaking, but considering the density of population in the East and the widespread areas of damage that accompany such earthquakes, it is both a reasonable and a necessary thing to do.

After the active faults have been delineated and after we acquire sufficient data so that we can distinguish between normal and anomalous physical properties of the Earth, I believe that our prospects for successful prediction of Eastern earthquakes will be as good as for Western ones.

Mr. SYMINGTON. Thank you, Dr. Nuttli, for a very fine presentation.

Mr. Brown, do you have questions?

Mr. BROWN. Dr. Nuttli, do you have any hypotheses or theories that would explain the seismicity of the earthquakes in the Eastern and central part of the country in the absence of a plate boundary? Is it possible that the plates themselves are not really, shall we say, integral and that they might have cracks in them and they are subject to flexing?

Dr. NUTTLI. The plates are probably in a state of stress. They are being pushed apart, say in the Atlantic Ocean, and they meet some resistance at the Pacific boundaries. So they are in a state of stress and anything that tends to modify a state of stress could be responsible for the earthquakes themselves. We would like to test this hypothesis with the seismicity studies.

Mr. BROWN. From your standpoint, the same kind of monitoring data and instrumentation and so forth would be as applicable to the kind of data that you need as it would be in the Western United States?

Dr. NUTTLI. We would need to make the same kind of measurements that are made in the West with the addition that we first of all would have to outline the active faults.

We would first have to hunt them out and then we could go ahead with the other kinds of measurement leading to earthquake prediction.

Mr. BROWN. In other words, fault structure is not necessarily identified with plate boundaries?

Dr. NUTTLI. Right. There are many faults throughout the Eastern and Western parts of the country.

Mr. BROWN. In your description of the large earthquakes in the 1811 period and the data you gave us on those, how was that data obtained?

Dr. NUTTLI. It is newspaper accounts primarily and the one item I just mentioned in passing by Congressman Mitchill from the State of New York written back in the early 1800's.

Mr. BROWN. I'm glad you put it in because at these times it is good to know that Congressmen at least in the past were capable of doing something useful.

You heard the testimony of the two earlier witnesses. Would you have any major differences with them with regard to the level of resources and the application of funding in this field? Does it seem roughly reasonable?

Dr. NUTTLI. They seem like very reasonable numbers, yes. I am in basic agreement.

Mr. BROWN. It is your view that we have reached a point in the development of knowledge in this field that it would be timely to move with considerably more effort and with a higher priority than we have in the past?

Dr. NUTTLI. I feel that we have the people to do it and we have the technology.

Mr. BROWN. Thank you very much.

Mr. SYMINGTON. Thank you, Mr. Brown.

We had some testimony yesterday from the U.S. Geological Survey witness, I think it was, who said that he had recommended a certain figure—I cannot remember what it was—to the Department of Interior and they had recommended a certain figure, he did not remember what that was, to the Office of Management and Budget, and they had recommended a certain figure which of course appeared, and he could not remember—$10 million, I think, for 1977, or thereabouts.

And then I asked the witness if he thought they could use more, given the existing technology, to hasten the day in which we might be able to make more accurate predictions and perhaps intelligent provisions for the possibility of an earthquake.

He said, yes, he could use more, but he was reluctant to say how much more. Do you have any idea from your experience as an individual involved in this work and perhaps familiar with the budgeting involved, what we could do with that budget, without a bill at all, but simply to increase our effort of today?

Dr. NUTTLI. We have been speaking this afternoon of about $20 million in funding for the earthquake prediction part itself. I believe Dr. Press had broken the $20 million into subelements. I could repeat them for you, if you wish.

Mr. SYMINGTON. Oh, no. I missed that testimony but I will go over it. I am glad it has been covered.

Can you tell me a little bit more about the southeast Missouri earthquake? What occurred there?

Dr. NUTTLI. It was a whole series of earthquakes starting December 16, 1811. It was one of the first major earthquakes. It was so strong that it changed the course of the Mississippi River. It completely ravaged the lands in southeast Missouri and northeastern Arkansas so that they were impassable even on horseback. There were large rifts in the area, 10 feet wide, and many feet deep. The earthquake knocked down everything in the neighboring settlements. There were not many, only about 5,000 people in the territory of Arkansas and the southern part of what we now call Missouri and 5,000 people in the St. Louis area at that time.

The earthquake did major damage in St. Louis. It did damage as far away as Cincinnati where it cracked chimneys. People ran out of their houses in the middle of night in Pittsburgh in severe fright. In Washington, D.C. it was strongly felt also and it was felt as far away as 2,000 miles, in Canada.

There were also thousands of smaller earthquakes and on February 7 the biggest earthquake of all happened. People describe the earthquake and its aftershocks as such that the earth did not settle down for a day.

It is hard to predict how people would behave now. It will happen sometime in the future. There were big earthquakes after that in 1843 and 1895 which did a fair amount of damage.

Mr. SYMINGTON. That sounds like 40-year intervals.

Dr. NUTTLI. Yes, but there have been no earthquakes since 1895 of a comparable size. Recently in March 1976 there was one in southwestern Arkansas, 40 miles northwest of Memphis, and it cracked plaster in Memphis.

Mr. BROWN. Could I interject, Mr. Chairman? Was it to your knowledge the most severe earthquake that has occurred?

Dr. NUTTLI. There are different ways of measuring the size and severity of an earthquake. One is the magnitude of the earthquake. The magnitude of the San Francisco 1906 earthquake was 8.3. I would estimate the magnitude of this earthquake, the February 7, 1812 one, as 8.2, almost of comparable size.

In terms of the area of land being devasted, the earthquakes of 1811 and 1812 affected much bigger areas.

Mr. BROWN. You have a sentence in your statement which says the length of the active fault segment is related to the maximum possible earthquake that can be associated with a fault. Am I to assume from this that earthquakes are not unlimited in their size and force and depending upon the fault there is some maximum limit which we can conceive of in some reasonable way?

Dr. NUTTLI. Correct.

Mr. BROWN. I say this because in the minds of the uninformed, in which I classify myself, there is sometimes the feeling that an earthquake can be of an unlimited structure and it might result in California dropping off into the ocean or something of that sort. And it is frightening and the sense of it being unlimited increases the frightening aspects of earthquake. That is not the case, though?

Dr. NUTTLI. As far as we know, there is a certain thereshold for the size of the earthquake depending upon the strength of the rock which makes up the Earth itself. That would probably correspond to the biggest earthquake that occurred anywhere in the world of about magnitude 8.7. In theory there is no upper limit but in practice there appears to be one.

Mr. SYMINGTON. In that connection, yesterday there was testimony about the most up-to-date methods of reinforcing structures, et cetera, and there were various estimates of 10 percent of the otherwise lost life and property. That is kind of a depressingly low percent for a return on what, as I take it would be a considerable investment. Must we content ourselves with such a small return? Or can something be done to get the people psyched up to go into this kind of work?

Dr. NUTTLI. I am not an earthquake engineer and I am really not qualified to comment on the 10 percent.

Mr. BROWN. I think that referred to structural damage and not lives.

Dr. NUTTLI. Ten percent of several billions of dollars is still a lot of money.

Mr. SYMINGTON. Are you familiar with the Earth resources satellite observations and are they relevant now to this study?

Dr. NUTTLI. I don't know of anything firsthand but I read about them. I am not doing any research along those lines. Perhaps Dr. Whitcomb tomorrow will discuss this.

Mr. SYMINGTON. We want to be sure that we don't overlook any vehicles and instruments for helping us along. Of course, that program is financed in part from other sources. So it is sort of a lateral diffusion of help. I understand they can spot faults and things like that.

Dr. NUTTLI. Yes, that is my understanding.

Mr. SYMINGTON. We will recess for a few minutes and then return. I have one or two questions for you, Dr. Nuttli, when we return, if you could indulge the committee.

[Brief recess taken.]

Mr. SYMINGTON. We will come back to order.

Dr. Nuttli, you described some fundamental differences between the East and West with respect to earthquake likelihood and scope. What would the implications for a national earthquake hazard reduction policy be which would flow from these perceived differences?

Dr. NUTTLI. We know that earthquakes are going to occur in the East. We know that from past experience. Someone has made an estimate that if we take the total area affected by earthquakes over a long enough period of time that the East will be affected equally as well as the West.

This is a very long-term average of possibly 1,000 years or more. So I do think we should be getting about the problem of studying these Eastern earthquakes. There are some parts of the East where we do not even record earthquakes that are strong enough to cause some minor damage. It is just because of a lack of funding and a lack of people taking part in these studies. But I think there are no fundamental differences in doing earthquake prediction in the East or in the West.

Mr. SYMINGTON. Is it your thought that we may arrive at a point where we will have the science and technology to predict the onslaught of an earthquake, say, a year in advance, or 6 months, or 5 years?

Dr. NUTTLI. We don't have it at the present time. I think if the kind of research activities that are being discussed this afternoon are actually carried out, that with enough effort—we are speaking of long-term effort of perhaps 10 years or more—that we might develop that capability in that time but we cannot do it at present.

Mr. SYMINGTON. Do you think we will have it within 10 years?

Dr. NUTTLI. I am not certain. It depends upon how much effort is put into earthquake prediction and having the basic research and efforts and just what the accomplishments are. But in the New Madrid area we do know where the faults are and so we are up to the point where we are in the west, so far as monitoring the fault zones themselves.

Mr. SYMINGTON. I missed the earlier testimony. I don't know whether there was any to the effect that some kind of human intervention is possible through, I suspect, the use of nuclear power.

Dr. NUTTLI. This was touched upon only very, very briefly. I think Dr. Allen mentioned that——

Dr. ALLEN. I think it was Dr. Press.

Dr. NUTTLI. It was very far down the line, if at all practical. I am skeptical of it myself.

Mr. SYMINGTON. I tend to be also. I guess if you had something sufficently large to alter that kind of a disruptive force it would be more than you would want to use in any event. So you say we are going to have these?

Dr. NUTTLI. Yes; and we should do all we can to protect people when they occur.

Mr. SYMINGTON. You think if we invest sufficiently in existing and likely science which will come on line within the 10-year time frame, you mentioned that we will be much more likely in 10 years to be able to make this kind of prediction in time to do something about it?

Dr. NUTTLI. I think that is certainly a correct statement.

Mr. SYMINGTON. So in your view the budget is about 50 percent for 1977 of what it ought to be to take full advantage of the talents and skills which could be addressed to this problem?

Dr. NUTTLI. Right. We do have the people and we have the technology as well to do these further studies.

Mr. SYMINGTON. This is hypothetical but if we were planning for something as apocalyptic as World War III and you knew it was coming in a certain number of years but could be forestalled with proper investment in a decade, there should be very little difficulty in getting the Government to ask and the Congress to give. But it is more difficult in this instance.

Dr. NUTTLI. Well, we do know that earthquakes will happen in the future. We are convinced of that. We cannot tell you when, at least at the present time.

Mr. SYMINGTON. I guess it is difficult to get Congress to vote funds in budget-tight periods for something that might occur 150 years in the future. It might cause a lot of people to think it is not their problem.

Dr. NUTTLI. But even though we have these very large earthquakes at long intervals apart, we do have smaller ones which are still quite damaging. They do occur more frequently. We should not use that as an argument for doing something.

Mr. SYMINGTON. Or for not doing enough.

Dr. NUTTLI. Right.

Mr. SYMINGTON. Certainly $20 million which could save at the moment of truth hundreds of millions is not a bad investment.

Dr. NUTTLI. And lives as well.

Mr. SYMINGTON. Well, I thank you very much.

Dr. NUTTLI. Thank you, Mr. Chairman.

Mr. SYMINGTON. I would enjoy going on with this but I think we owe it to our other witness to terminate here. I hope that if we have questions to submit in writing, you would be willing to give us your answers?

Dr. NUTTLI. I would be pleased to do so.

Mr. SYMINGTON. Thank you very much, for being with us today.

We will now have our fourth and final witness, Dr. Karl Steinbrugge, of the Department of Environmental Design, University of California at Berkeley.

We are pleased to have you with us and thank you for your patience. We welcome your testimony.

[A brief biographical sketch of Dr. Karl V. Steinbrugge follows:]

DR. KARL V. STEINBRUGGE

Professor of Structural Design, University of California, Berkeley. Consultant to Federal Agencies: NSF, FDAA, and USGS. Manager, Earthquake Department, Insurance Services Office, Pacific Region, San Francisco.

Chairman: California Seismic Safety Commission. Earthquake Engineering Research Institute: Past president. State Mining and Geology Board (California): Former member. In 1970, Chairman of the Task Force on Earthquake Hazard Reduction, Office of Science and Technology, Executive Office of the President, Washington, D.C.

Graduate, Oregon State University, 1941, with B.S. in Civil Engineering. Publications: 23 major papers, plus many minor papers. Licensed civil and structural engineer, California.

PROFESSIONAL AND SCIENTIFIC ACTIVITIES

1. Past president (1967–68), Seismological Society of America: also past secretary (1960–64) and director. Has served on numerous committees.
2. Past president (1968–70), Earthquake Engineering Research Institute: also past director and secretary. Has served on many committees, such as chairman of a committee which translated and published Russian earthquake engineering publications (financed by the National Science Foundation).
3. United States Delegate to the International Association for Earthquake Engineering, 1969–73, and he is a member of their Executive Committee, 1969–75.
4. Chairman, United States National Committee on Earthquake Engineering, 1969–75. Member, 1975 to —.
5. Past director (1964–65), Structural Engineers Association of Northern California: served on numerous scientific and professional committees; he is currently on a committee which is restudying lateral force code provisions.
6. Honorary member, Construction Inspectors Association. (One of the principal organizers of this association.)
7. Member, United States National Committee on Geology, 1967–71.
8. Fellow, American Society of Civil Engineers: has served on numerous committees such as on a committee to evaluate papers to be given at national meetings held in San Francisco in 1963.
9. Member, American Concrete Institute: has reviewed scientific papers for publication.
10. Member, American Geophysical Union.
11. Has served as member or chairman of about 6 NAS/NAE Committee/Panels.

SPECIAL SERVICES TO GOVERNMENTAL AGENCIES

Federal agencies

1. Office of Science and Technology, Executive Office of the President, Washington, D.C.: Chairman, Task Force on Earthquake Hazard Reduction, 1970.
2. Advisory Committee on Reactor Safeguards (ACRS), Consultant, 1964–date. (The ACRS is an agency established by Act of Congress.) The work concerns itself with the siting of nuclear reactors and other safeguards with respect to the earthquake hazard.
3. Department of Commerce and Department of Housing and Urban Development: (a) A substantial portion of "Studies in Seismicity and Earthquake Damage Statistics", submitted in 1967. (b) "Studies in Seismicity and Earthquake Damage Statistics, 1969", Appendix A, submitted in 1969.
4. ESSA of Department of Commerce: studies of numerous earthquakes, including the 1964 Alaskan earthquake, 1969 Santa Rosa, California, earthquake, 1971 San Fernando, California, earthquake among others.
5. Department of State, AID Program: a special study of the earthquake hazard in Caracas after the 1967 Venezuelan earthquake.
6. Office of Emergency Preparedness: served on their Evaluation Board with respect to their 1967 study of earthquake hazard in San Francisco. A similar study for Seattle, Washington was evaluated at a later date.

7. Department of State and Department of Commerce: chairman of a team of scientists and engineers which was sent to USSR in 1969 to investigate their state of the art of earthquake engineering and engineering seismology.
8. U.S. Geological Survey: Member of a team which went to USSR to meet with Soviet counterparts on earthquake prediction problems. (1973).
9. U.S. Geological Survey: Member, Earthquake Studies Advisory Panel, 1973 to —.

State and local agencies

1. San Francisco Bay Conservation and Development Commission: Chairman of Board of Consultants on Safety of Fills, 1970–71. Member, 1971–72.
2. Tri-Cities Study on Earthquake Hazards, member of Advisory Board, 1973.
3. (State of California) Governor's Earthquake Council, member, 1972–74.
4. Legislative Joint Committee on Seismic Safety (California): Chairman of Advisory Group on Engineering Considerations and Earthquake Sciences, 1969 to 1972. Chairman of Advisory Groups' Executive Committee, 1969–74.
5. California State Strong Motion Instrumentation Program Advisory Board, member, 1972 to —.
6. California State Mines and Geology Board, member, 1969 to —.
7. Seismic Safety Commission of State of California, Chairman, 1975 to—.

STATEMENT OF KARL STEINBRUGGE, DEPARTMENT OF ENVIRONMENTAL DESIGN, UNIVERSITY OF CALIFORNIA AT BERKELEY

Professor STEINBRUGGE. I thank you for this opportunity to testify before the Subcommittee on Science, Research, and Technology. In my capacity as chairman of the California Seismic Safety Commission, I have been asked to speak on the function and viewpoints of this commission on earthquake hazard reduction problems with respect to possible actions by the Federal Government.

California is currently the principal testing ground for earthquake prediction research and earthquake haz[illegible] mitigation efforts. These activities have placed the State in a guinea pig arena, with many of the problems that this connotation may imply. As a result, the California Seismic Safety Commission is significantly involved with a number of State and Federal agencies.

The commission's origin stems from the Joint Legislative Committee on Seismic Safety established by the California Legislature in 1969 under the chairmanship of Senator Alfred E. Alquist. Its objective was to "develop seismic safety plans and policies and recommend to the legislature any needed legislation to minimize the catastrophic effects upon the people, property, and operation of our economy should a major earthquake strike any portion of California."

A total of 70 advisers under my chairmanship worked for the Alquist committee, producing after 4 years of study the report "Meeting the Earthquake Challenge." This study is public policy oriented, and includes relationships between State and Federal Governments. Copies of this California effort are being given to your subcommittee.

Although the primary effort was directed toward the preparation of the final statewide seismic safety plan, a number of items of legislation—considered too important to be delayed—were enacted.

The final piece of legislation from the joint committee was that which established the Seismic Safety Commission. This commission has been in existence for about 1 year and is the continuing body on seismic safety problems.

Clearly, the State of California has shown substantial interest in seismic problems. It has brought about significant public policy results

in land-use planning in fault zones, hospital safety, disaster preparedness planning, among others.

But it has also become evident to the commission that the continuing problems have ramifications which involve many Federal agencies. For example, California simply does not have the medical, financial, and other resources necessary to cope with the expected losses after a major earthquake. Over 10,000 deaths could be expected in the San Francisco area; over 12,000 deaths in the Los Angeles area. Property losses will be in terms of tens of billions of dollars. Current research studies on earthquake prediction indicate that a substantial life saving will result from a successful prediction, but that the overall financial impact could be worse.

As a result from the State's point of view, a reliable earthquake prediction capability may have some of the aspects of a mixed blessing.

Whenever a high confidence prediction is made for a major catastrophe, State and local government responses can be drastic and expensive. For one State and local governmental action, hundreds of thousands of people may be removed from homes, hospitals, factories, offices, and the like, thereby resulting in loss of income, costs for temporary housing, and other social, economic, and political problems which could cost billions. The State does not have these resources. For one example, the Chinese-American population in San Francisco's Chinatown are in a hazardous building area which, for historic-cultural reasons, the public wants to preserve. Evacuation of this minority population would be mandatory in the event of a prediction, with the added need to keep together the removed population for linguistic and cultural reasons. Costs of these secondary effects will be expensive, and not eliminate the reconstruction costs after the event.

Turning next to the proposed legislation before this subcommittee, I find the general objectives expressed on all of them to be satisfactory. However, all bills could be improved by increasing the emphasis on the understanding and implementation of the engineering-socio-economic-political ramifications of an emerging prediction capability.

Specifically with respect to the details of the bills:

One: A strong multiagency national program is necessary, with its administration being physically located in the Executive Office of the President so that realistic Federal agency response can be expected.

Two: The National Science Foundation and the U.S. Geological Survey should be colead agencies for all pure and most applied research responsibilities.

Three: There is a need for Federal predisaster assistance in order to mitigate potential adverse effects from a predicted earthquake; this would be in addition to the postdisaster efforts by the Federal Disaster Assistance Administration. Alternately, the benefit/cost of earthquake prediction may be a negative factor in a monetary and social sense.

In summary and conclusion, it would seem best to amend the Cranston bill, incorporating the relevant sections of the Mosher and Bell bills insofar as they relate to the items discussed above. Next, the levels of funding listed in the Cranston bill should be augmented to broaden the base of research. Finally, may I give you copies of the report "Earthquake Hazard Reduction" which is a viewpoint on priorities and potential benefits.

I would like to add at this point that I would agree with what the previous speakers have said regarding the level of funding with respect to earthquake prediction capabilities.

When we are talking about the broad approach to mitigate some of these problems, we will need additional funds.

Mr. SYMINGTON. Thank you very much. I appreciate the succinct and helpful statement.

You have heard the other witnesses and you are familiar with the fact, I suspect, that the Government witnesses opposed these bills on the ground that there is an existing competence and jurisdiction and scope under the disaster relief clause which is available to the Government today without any further legislation.

You seem to support a variation of the Cranston bill. Why is it that you do not agree with the Government witnesses that there is enough scope in today's legislation to deal with this problem?

Professor STEINBRUGGE. There may well be and I believe I should perhaps state that there undoubtedly is this capability and competence. But there is a difference between capability and competence and the use of them. Therefore I feel that to implement something like this is not a matter of agencies getting together and talking about competences and leaving the matter at that.

It is for this reason I believe the administration of the enacted legislation should be in the Executive Office of the President so heads can be pounded together and get action. At present there are only two agencies of the many who are truly doing something about hazard reduction; namely, the Geological Survey and the National Science Foundation.

Mr. SYMINGTON. HUD, I think, has some disaster relief obligations.

Professor STEINBRUGGE. Yes, they do, and I have also been involved, but they appear to be taking a lessening interest. I think many agencies may feel some of the financial implications of the prediction itself.

Mr. SYMINGTON. Is there some psychological moment at which the public will be told of the prediction? If so, what degree of certainty on the Richter scale prediction should be the criterion for telling them at that particular point or should it be like tornado warnings that one may be in the area and the time passes and it is predicted to hit in a certain place at a certain time? Do you anticipate sort of phased warnings? I suspect that is inevitable.

Professor STEINBRUGGE. With respect to earthquake predictions, I would agree with the statement made by Dr. Clarence Allen; namely, that all prediction information must be made public immediately. The degree of action to be taken is something that our Commission is heavily involved with because a false prediction may be very costly—let us take the case of moving all of the people out of San Francisco's Chinatown or all of the poor people out of the Tenderloin and the State not having the funds to take care of this problem. This will cause political ramifications as well as economic problems.

We have not yet come up with a solution.

Alternately, to hide prediction information from the public, is probably the worse thing we could do because the news media could justifiably grab on that and result in an overalarmed public. I think we have to "tell it like it is."

Mr. SYMINGTON. Of course, the testimony that we have heard before this committee in the past couple of days, in one sense, has constituted an absolute prediction that there will be an earthquake within a certain recognizable time frame in the eastern part of the country. The first warning has already gone out.

Professor STEINBRUGGE. It is not "if we are going to have an earthquake." It is when. And under those circumstances we must look at prediction a little differently.

I might add that while I am speaking here from the California point of view, I have also had the opportunity to look at these problems from the national point of view. It is my personal point of view that the single greatest disaster to strike the United States, from the point of view of earthquake, will not be in California. It will be in the east of the Rocky Mountains. Larger life loss and property damage will occur in the area where there is no preparedness at all. And it will be catastrophic, far greater here in the East, than it will be in the West. It is a national problem.

Mr. SYMINGTON. Does that also take into account the possibility of a tidal wave in the West?

Professor STEINBRUGGE. I don't expect that a seismic sea wave having its origin off of Alaska, Chile, or Japan doing significant damage in California compared to a great California earthquake.

Second, the west coast warning systems are ideal in that they may give lead times in terms of hours. This means that one can evacuate people. The inundation areas are well known and well defined. Indeed, in Hawaii, the phone book shows the hazardous areas; we are trying to do something like that in California.

Mr. SYMINGTON. Who funds your commission?

Professor STEINBRUGGE. The State of California.

Mr. SYMINGTON. What is the budget?

Professor STEINBRUGGE. About $125,000. We do not want more money.

Mr. SYMINGTON. That's nice. What do you do with that money?

Professor STEINBRUGGE. Our job, as we view it, is policy and oversight. We do not engage in research. We do not maintain any operational capabilities. As such, we work with all agencies within the State and often can speak for their proposals or against them as the case might be.

We have direct access to the legislature through the two legislators on the Commission. We also are directly accountable to the Governor and are a little unusual in this joint responsibility.

The Commission examines a number of unusual and complex problems. For example, as engineers and scientists learn new things about earthquakes and incorporate the findings into the building code—as we are doing now in California and others will be doing in many parts of the United States—this will result in a number of the buildings constructed today "unsafe" a year from now. This means that today's construction is legally safe but an identical building constructed in a year or two may be legally unsafe. If we want "perfect" safety, we will tear down all of California's buildings every time there is a new building code. That, of course, is not acceptable. Practically, then, the Commission must concern itself on how unsafe a structure has to be before something is done about it.

Mr. SYMINGTON. I remember not long ago in St. Louis, in the West End, they were planning some housing with HUD and they were told

that they were in a certain zone where the requirements for the structures would increase the cost of the project by 20 percent or so. This was all based on the southeast Missouri earthquake, I guess over 100 years earlier. So it seems to me that these awarenesses are already cranked into bureaucratic initiatives.

Professor STEINBRUGGE. The numbers pertaining to the cost of earthquake bracing are often bandied about and they are difficult to review without knowing more about them. It all depends upon the base one starts from and where one goes from there.

For example, I teach structural engineers and architects. Some students come from the St. Louis area and they ask what I would do if I were in the area and earthquake bracing costs were 20 percent more of the total. First, I would question the 20 percent as being generally too great. Next, if one decides to build a building that is a—"look, ma, no hands" type of architecture—then costs could increase by perhaps 20 percent. Alternately, if the design concept starts with a reinforced concrete building and if the percentage of wall openings is small, the result could be a fortress for no increase in cost. Thus no firm rule on costs can be established.

One could argue that for a high rise building, earthquake bracing might substantially increase costs. But the question could be asked—Why not build a low rise at no increase in cost?

Earthquake bracing for wood frame houses costs very little. It mostly depends on foundation type and anchorage to these foundations.

Mr. SYMINGTON. You probably have to be consulted on things like this in California quite a lot for both insurance purposes and public. Why not build a low rise at no increase in cost?

Professor STEINBRUGGE. Yes.

Mr. SYMINGTON. I imagine there are certain zoning and construction requirements for people who are building in the San Francisco area, for example along the San Andreas Fault. Do you help them establish what those are?

Professor STEINBRUGGE. Only partially. By and large, the building standards, be they for insurance or normal construction, follow the recommendations of the Uniform Building Code which is the primary building code in that area.

After the 1957 San Francisco earthquake, I believe that Federal agencies increased their requirements for wood frame houses, mainly from nonreinforced concrete foundations to reinforced concrete foundations. I would guess that increased costs ran around $100 per house. Surely that is cheap insurance.

The proximity to the fault is not necessarily the overriding hazard, provided the structure is not on the fault trace. Clearly, in California, the farther away you are from the fault during an earthquake, the better off you are. But the farther away you get from one fault, the closer you are to another. So we do not, in general, differentiate with respect to distance from the fault.

Mr. SYMINGTON. There was a discussion between two farmers in Missouri where one asked the other where he would like to be during the Third World War and the other replied. I want to be where my friends are. And he says, well, where is that? That is where a lot of people would like to be in an earthquake.

Professor STEINBRUGGE. I think one sometimes has to put your money where your mouth is. In my case, I knowingly bought a house within a quarter of a mile of the earthquake active Hayward Fault. I feel safe and my house is paid for.

Mr. SYMINGTON. I think that covers pretty well what we hoped to get today. I am very grateful to you for this today.

[Further questions in written form were submitted to Dr. Steinbrugge. The questions and responses follow:]

Question 1. You say that the financial impact of an earthquake will be worse if it is predicted (towards the bottom of page 2). Could you explain in more detail why you believe this.

Answer. The extent of the negative financial impacts of an earthquake prediction is a function of the lead time (i.e. the time between the announcement of the prediction and the expected occurrence of the event) and a function of the prediction's window of time (i.e. length of time during which the predicted earthquake is expected). Many scenarios are possible, and the extent of the negative financial impacts will vary. For one of many possible scenarios and potential problem areas, consider a 3-month lead time followed by a 3-month window of time for a prediction in San Francisco or Los Angeles. Complete evacuation is most unlikely—there are no housing facilities for 5 to 10 million people, and selective evacuation is the probable solution. There will be tens of thousands of older structures which will be "slightly" unsafe and warrant temporary bracing. This temporary bracing will cost thousands of dollars in apartment houses (hazardous ceilings, parapets, chimneys, facings, water heaters, etc.) and most of this money will *not* be recoverable since temporary structural repairs do not usually adapt to permanent repairs. Obviously, a 9-month lead time rather than 3 months will allow many permanent repairs to be done.

Another kind of problem arises in the outlying regions where lesser intensities are expected. A conservative bureaucracy fearing personal as well as departmental liabilities from instances of earthquake induced injuries or deaths will in these fringe areas undoubtedly also require strengthening of partially unsafe buildings.

Multiplying the number of potentially temporarily strengthened buildings by the estimated cost of non-salvageable repairs runs into hundreds of millions.

I have cited building strengthening as one kind of negative financial example, and other kinds can also be cited.

Question 2. At what stage of reliability should official earthquake predictions, in your mind, first be made? What are the pros and cons of (a) risking a false alarm and (b) failing to make a prediction of an earthquake that occurs (assuming there are precursory signs)?

Answer. In my capacity as Chairman of California's Seismic Safety Commission, I wish that there were a simple answer to your question. The subject is under most active and intense study and, I suspect, the answers will remain very soft for some time. At present, each prediction (or non-prediction) is treated on its own merits.

I thank you, all of the witnesses. Because of the conflicts we have had and the number of members who could not be here there may be questions that we will submit in writing to the witnesses and I hope it will be possible for you to answer.

We are all extremely interested in the subject and we are quite anxious to take constructive steps. We are not at all sure what those steps should be. We draft legislation and the Government responds that we don't need it and then it turns out that some people think the Government is not doing enough and we feel that one way or another we need to make some progress. The American people certainly hold the Congress accountable. That is why we value your testimony so much and your help.

The committee will then recess until tomorrow in this room at 9 o'clock.

[Whereupon, at 2:30 p.m., the subcommittee was recessed to reconvene at 9 a.m. on Thursday, June 24, 1976.]

EARTHQUAKE

THURSDAY, JUNE 24, 1976

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9 a.m., in room 2318, Rayburn House Office Building, Hon. James W. Symington, chairman of the subcommittee, presiding.

Mr. SYMINGTON. We will go on the record.

We are particularly pleased and honored this morning by the presence of Senator Frank Moss of Utah. Senator, we are grateful to you for taking your time to be with us this morning to give us some of your impressions about the current state of the art in this country about dealing with prediction and hazard reduction, knowing that there are some bills before us submitted by your colleague, Senator Cranston, and knowing, too, that the administration witnesses feel that they have enough laws to go on, which may or may not be the case.

In any event, we were very anxious to stimulate governmental initiatives that could reduce the tragic consequences of oncoming earthquakes.

So we are extremely grateful to you for your testimony this morning and we look forward to it.

[A brief biographical sketch of Senator Frank E. Moss follows:]

Frank Edward Moss, Democratic Senator, of Salt Lake City, Utah; born in Holladay, Utah, September 23, 1911, son of James E. and Maud Moss; attended the public schools and Granite High School; graduated from the University of Utah with B.A. (magna cum laude) in 1933 and from George Washington University Law School with J.D. (cum laude) in 1937; Distinguished Alumni Award, George Washington University, 1963, doctor of laws (honoris causa), University of Utah, 1973; attorney for the Securities and Exchange Commission, Washington, D.C., from 1937 to 1939; elected Salt Lake City judge in 1940 and reelected in 1945; elected Salt Lake County attorney in 1950 and reelected in 1954; served 4 years during World War II as Judge Advocate in the European theater with the Air Corps; holds commission of colonel, United States Air Force Reserve, retired; member: Church of Jesus Christ of Latter-day Saints, Order of the Coif, the American Legion, Veterans of Foreign Wars, and Lions Club; served as president of the Utah State Association of County Officials and two terms as president of the National Association of District Attorneys; married Phyllis Hart in 1934 and they have four children; elected to the United States Senate on November 4, 1958; reelected November 3, 1964, and again on November 3, 1970.

STATEMENT OF HON. FRANK E. MOSS, SENATOR FROM THE STATE OF UTAH

Mr. MOSS. Thank you, Mr. Chairman.

I certainly appreciate this opportunity to appear before your committee to say a few words about the bills that are before you which include S. 1174 and H.R. 13845.

There are other bills which you are taking cognizance of at this time because there is a growing and considerable concern that we be prepared as best we can for any earthquake emergency.

There is also a great concern that we improve upon techiques we now have for observation and the various means of surveillance which will allow us to predict with some degree of accuracy and timeliness where an earthquake is likely to occur.

In coming into the room, I noticed the map on the wall with all the red dots on it. That is quite a startling thing, to think that earthquakes have been recorded in all those places at some time or another in fairly recent times.

As you know, there is a line going down to the middle of my State, Utah. It is what is known as the Wasatch Fault and it slips once in a while. We have not had a major or serious slippage but we recognize that it is entirely possible. Should the Wasatch Fault slip in any appreciable amount, it passes right through the Salt Lake Valley, the most heavily populated area of Utah and the resulting damage could be catastrophic. Consequently we should be prepared.

I, of course, do not have the technical background or information to be able to discuss in any depth the methodology to be used and what we have available. I do know however, from hearings we have held on the Senate side and from conversing with people, that we are now able to observe earth movements much better.

One of the advantages of the surveillance-type satellites that we now have circling the globe, like Landsat and LAGEOS, is that they can give us imagery and data to show us in a long overall pattern, the movements of the plates, the fracture areas, and where there are anomalies on the surface of the Earth, this again shows the improved tools we have for detecting where earthquakes might happen.

I also brought with me simply for the committee to examine, newspaper clippings from the Salt Lake Tribune. One is the 18th of June. The other is the 21st of June, in which considerable discussion is given to possible hazards that might arise from earthquakes.

I might say, it is an interesting thing that when the Teton Dam broke and the flood came in Idaho, just north of us, one of the first rumors was that an earthquake had caused that break. That, of course, turned out to be false. They found no seismic disturbance had happened. The fact that was an immediate rumor gives a clue to the sensitivity that we feel out there to possible earthquakes.

Should an earthquake happen in Utah or elsewhere with the number of water storage facilities we have, a flood would be a likely result. We also are concerned with our buried gas lines that might rupture in which event we could have an explosion or a fire.

All of these are threats and I would point out that almost the whole first page of the second section on Monday, June 21, of the Salt Lake Tribune, is devoted to stories about what might happen in the case of earthquakes. I join in the concern of my community about it.

I have prepared a statement, Mr. Chairman, that really just points out the areas where I think the hazard is known to be more acute than others and I point out that we have now gone far beyond the point where we could simply say, well, we just have to live and hope that it never happens.

There is something we can do about it and certainly we owe it to our people to establish a coordinated program first for improved observation and then for perhaps building codes or directions of sorts to be prepared to offset damage that would come if we have slippage.

I think by channeling and focusing our attention we will be able to avert or minimize a great deal of the damage that comes from earthquakes. We all know that in the great San Francisco earthquake the real loss of life and damage came not so much from the movement of the earth and the buildings but from the fire that broke out and the loss of water when the mains were broken.

This is something we need to do. I strongly urge your committee to delve into this and help us get underway as soon as we can.

I would ask permission that my statement be printed in the record in full.

Mr. SYMINGTON. It certainly will be.

Mr. MOSS. Thank you.

[The statement follows:]

STATEMENT OF SENATOR FRANK E. MOSS (D.-UTAH)

Mr. Chairman, I would like to express my appreciation for the opportunity to appear before you this morning to testify on H.R. 13845 and S. 1174. These are two very important bills in which I have agreat personal interest and I was fortunate to be able to open the hearings on S. 1174 in the Senate.

As a Senator from Utah I have been interested in reducing the potential dangers of earthquake since long before I was elected to the Senate. Utah has been fortunate in years past because earthquakes occurred in less populated areas. However, the extensive growth of population in Utah as well as in the United States in recent years, which will surely increase in the future, means that we can no longer ignore protection against earthquakes. Just as we have recognized the need for protection against disasters of flood and abnormal weather, we must recognize the need for mitigation of earthquake damage. The worst natural disaster this nation has suffered was hurricane Agnes. Many lives were lost in that disaster and damage exceeded $4 billion—that certainly gives me cause for thought when I consider that in just one minute a major earthquake in Boston, Charleston, Salt Lake City, or St. Louis could cause the loss of untold numbers of lives and property damage which would exceed that caused by hurricane Agnes.

Mr. Chairman, since April of last year I have had six different occasions to comment on the need for legislation which would help mitigate the consequences of earthquake. As I reviewed those statements in preparation for this testimony I was struck by a strange coincidence—on each occasion I was able, in the statement, to comment on an earthquake which had occurred some place in the world since I had made the preceding statement. Six statements means, of course, that in the last 14 months there has been throughout the world at least six major earthquakes in that period of time. Today's testimony is no exception to that rule. Once again earthquakes have occurred. This time in Italy, only a few weeks ago and in the U.S.S.R. The loss of life and damage was, as always, extensive.

We cannot continue to disregard this cause of disaster. We have been fortunate in the United States. The loss of life has been relatively small and the property damage relatively insignificant. When I say relatively, I mean relative to the loss which has occurred in other countries. We may not continue to be so fortunate. I do not have to be a prophetsayer to predict that an earthquake will at some time occur in a major urban area in the United States. Because we know it will happen we have spent a part of our research effort in attempting to predict earthquake. Prediction of a quake might help—but not enough. Even with a full year of advance knowledge that a severe earthquake would occur in Los Angeles or St. Louis, there would not be a lot we could do. I don't believe we could evacuate these two cities in time. Our attention must be turned to proper construction, education, and over prevention. The legislation which you are considering today will do precisely that. Earthquake itself is not the only major cause for concern.

There are usually other major problems which occur as a result of an earthquake. In the San Francisco earthquake, 80 percent of the loss was the result of fire which could not be controlled because the quake had broken the water lines. In my home state loss of water could be a problem, but more likely we would be inundated with water. The recent dam burst in Idaho makes a very poignant point with those of us who must store our water in reservoirs in the mountains. An earthquake of any severity could cause dams to burst. With the bursting of those dams, what the earthquake had left undamaged the floods would certainly finish off. A recent USGS report makes a significant point of this problem.

These are alarming topics to speak of, but the failure to act to protect our national interest gives me cause for speaking with alarm. More than 70 million people in the United States live in areas of high seismic risk. For too many years we have done little to counter the damage which can be caused by earthquake. Our inaction has probably been caused by lack of recognition—our failure to recognize two facts: One, that earthquakes can and will occur in densely populated areas—we need only look to Guatemala for the most recent evidence of that fact, and two, that modern technology can minimize the dangers of earthquakes both to life and property.

We would be grossly negligent if we waited until a disaster has occurred in Los Angeles, Boston, or Seattle before we take action to mitigate the potential dangers of earthquake. There are many preventive measures which can be taken by those communities which are susceptible to earthquake and damage, and H.R. 13845 and S. 1174 make provision for the initial steps in that direction.

Mr. Chairman, the time has come when we no longer need to view earthquakes as simply a natural phenomena—one that can cause losses in life, injury, destruction of property, and economic and social disruption. Earthquakes are an inevitability in our future but our ability as humans to minimize these losses is changing. This capability, along with the measures called for in S. 1174 could significantly change future losses. To ignore this capability at this time would be irresponsible. We need to move ahead now with the appropriate resources, and that means money and people dedicated to reducing hazards from earthquakes.

As I view S. 1174 and H.R. 13845 introduced by Congressman Mosher, I see an immediate opportunity to move ahead with this needed legislation. While the Senate bill emphasizes a national program in earthquake hazard reduction with certain objectives, and provides necessary funds to implement such a program, the House bill focuses attention on the need for organization. An effective institutional intrastructure to carry forth a national program that involves so many agencies is critical. The two bills are thus very complementary. While one authorizes absolutely needed resources, the other attempts to put our institutional machinery together. Each is necessary, and neither is sufficient without the other. Let us move together on such an important national issue.

For too long we have neglected this need. I have sponsored legislation in every Congress since the 92d which would help in our efforts to mitigate the catastrophe which can result from earthquake. The bills which you are now considering are a real opportunity to begin to correct past deficiencies.

Finally, Mr. Chairman, I wish to thank you again for having these hearings. I urge that favorable action be taken during this session. Though the executive has been doing some work on various aspects of earthquakes, we in the Congress can no longer wait and be satisfied with its failure to establish proper priorities and continued decreased funding. The time is now to move ahead on such a pressing problem.

Mr. SYMINGTON. The non-Federal witnesses have commended S. 1174 to us. Some of them have suggested that it might be required for us to have some formal group to be set up for the evaluation of earthquake predictions which would be a broad-based scientific group. Do you think that might be helpful?

Mr. Moss. I think it might be a better way to do it instead of the usual advisory committee which is made up of officeholders. It might be better to place responsibility in a full-time professional group. I think that would be improvement.

Mr. SYMINGTON. Federal witnesses seemed to take a well-coordinated position that there was no need for legislation in this area and that there was sufficient authority under the disaster relief act, and so forth,

within the Government, to take advantage of the existing skills, talents, and abilities. How do you feel about that?

Mr. Moss. Well, I think the legislation is necessary and desirable because I think this is something we need to focus on. We cannot just leave it—there is some observation, some commentary being made—but I think there is a feeling among our people that very little is being done.

As I was pointing out—all of the members weren't here then—in my State, there is a great deal of discussion going on in the press as to what would happen in the case of an earthquake and what are we doing to be prepared for it and how could we offset the damage, anything of that sort. We ought to have a designated agency or grouping required to study it and publish periodically a report or something of the sort so we would know what they are doing.

Mr. SYMINGTON. We are inclined to agree with that and in response to our questions we heard that the budget in the Government for 1977 was about $10 million for earthquake research of various kinds. We asked the private sector witnesses of the scientific community what they thought about this and the general feeling was that that could well be doubled to take maximum advantage of the current skills in formulating prediction capability. And we certainly think that the Government ought to increase its investment here.

If we were talking about World War III coming along, we would beef up our defense. This situation could have similar consequences.

Mr. Moss. I agree. It is a threat to life and property as would be a military engagement. They are very different of course but it is a threat. As long as the threat is there, we should be prepared as best we can to avert it or minimize the damage and loss of lives that would come.

Mr. SYMINGTON. Thank you. Mr. Brown, do you have any questions?

Mr. BROWN. Senator, I am sure you are aware we have particular concerns in California about earthquakes because of the relatively large number we have experienced there. My own area of southern California is no exception. I have grown up with the experience of earthquakes and up to the relatively recent past have always felt that there are nothing that could be done about the acts of God. We would hope that we would be spared but we could not depend upon it.

The question I have now is, do you think the political community—I am thinking specifically of the Members of the House and Senate—are ready to accept the fact that we have experienced a change, a relatively significant change in our capability to do something about earthquakes and this justifies an expanded, higher priority, more focused public program? The scientific witnesses seem to agree to that but the question we have, of course, in negotiating legislation, is whether our own colleagues sense that and whether there is sufficient emphasis therefore to warrant the passage of a bill and taking it to the President for his signature. Would you comment on that briefly?

Mr. Moss. Yes, I recognize that the principal problem in moving forward with this bill or whatever bill this committee might want to report, is overcoming a sense of apathy or a sort of fatalism, as you said. Many people, never having experienced earthquake, just feel: "Well, why try to do anything, it is an act of God. If it comes, we will just have to live with it."

But I think there is a growing awareness and I particularly think that the Congress should be alerted and educated to the problem enough that they can overcome this degree of apathy.

One of the things that strikes the eye in coming into this hearing room is that map with those red dots on it. That alone ought to awaken the interest of almost everyone. I see very few States that have not acquired at least one dot. Your State of California and my State of Utah both have a good number of dots where there have been earthquakes.

The other part—and the reason I think the scientific witnesses are more in favor of the bill than others—is that there now has been considerable advance in the state of the art in being able to observe phenomena that are predictive of where movement might occur.

We have also developed a technique for building waterlines, gas mains, and other things; they can be constructed in a way which will resist or become compatible with movement so that in the event of an earthquake we do not get the added hazard of fire or flood or whatever else comes.

I explained to Mr. Symington earlier that when the Teton Dam broke the first rumor that went through my part of the country was that there had been an earthquake. That is how sensitive people are. That turned out to be false and there was no evidence that there was any earthquake involved but that is what can happen.

Mr. BROWN. That is particularly true in Los Angeles. The earthquakes we have had there have come very close to precipitating major floods just from our own reservoirs within the Los Angeles basin. They are not comparable in size to the ones that you probably have in your area but they could cause tremendous damage and rupture.

Mr. Moss Indeed, they could.

Mr. BROWN. I am particularly appreciative of your concern for this because I did not want to think that only the California Representatives and the California Senator were concerned about this. It would not bode well for the ultimate enactment of the legislation. I appreciate your testimony.

Mr. SYMINGTON. Thank you, Mr. Brown.

Mr. Mosher?

Mr. MOSHER. Mr. Chairman, I always have a high regard for the good advice of Senator Moss but I have not seen his testimony so I cannot ask really pertinent questions concerning the testimony. Maybe that makes it apropos for me to just as the Senator to reiterate now in summary what emphasis, what particular emphasis, you think there should be in any legislation that we adopt. You have said that you think there is need for legislation and I agree with you. Where do you think the emphasis should lie in the legislation we should consider?

Mr. Moss. The emphasis, I think, should lie—first of all, I am aware of the fine bill you have introduced and I think it contains some provisions that certainly would be complementary to the Senate bill, which is number 1174, and especially the formal organization idea, rather than have it simply be a committee looking at it—but I think the emphasis ought to be twofold.

First, I think we need to improve and add to as rapidly as we can the surveillance element of determining areas of likely movement and being able to observe in advance where we should be prepared. Now that goes all the way from satellite surveillance which now can show

us fractures and things of that sort and will undoubtedly continue to improve as it gets more sophisticated and more accurate with seismographs and other things that we have so that we know more and more.

We have learned a great deal but there is much more we need to know in detecting where earth movement is likely to come.

The second thing that needs emphasis is long-range preparation to avert damage or disaster that would come out of an earthquake and that is what I was discussing with Mr. Brown. One thing would be the rupture of dams and reservoirs and floods because in the arid part of this country we have to impound all water and hold it behind dams in order to get through the dry part of our season. If we do not have them we cannot live and yet we ought to build them in places and under the best techniques we know how to avert a rupture and a flood in the event of an earthquake.

It is the same for gaslines and waterlines where they cross faults or where they are in areas of suspected movement, they can be built either with a redundant bypass or flexibility or whatever the state-of-the-art would represent to try to avert a rupture there. A gas rupture, of course, is explosive and brings on fire. Building codes ought to be much more rigid where they are in the proximity of a fault area or likely movement so that there would not be a collapse of buildings and loss of lives.

Earthquakes, unfortunately, seem to come in the middle of the night a lot of times. Building structures can be improved, either no highrise buildings at all along the fault or at least built in such a way that they would withstand considerable movement and not collapse. All that needs to be done and of course we need a rather broad educational program among our people both as to how to react and to let them know that we can avert or mitigate loss and damage by earthquake. I think we could guarantee the savings of a lot of lives and damage in that way.

Unfortunately, you get a little nervousness even talking about it but I think if done in the right way people could come to think of that just like having a fire drill, knowing how to get out of the building if it gets on fire.

Mr. MOSHER. These things you emphasize certainly are crucial and I think there are some others you haven't mentioned but we all recognize that the responsibility of the Federal Government is rather fragmented. I judge from what you say that you do believe that we should consider a coordinated effort to effect a mechanism to achieve these goals.

Mr. Moss. I think so, Mr. Mosher. I think if it is just left as an extra duty for, say, the Science Foundation, or some other organization, it doesn't get the concentrated attention that it deserves, nor is the awareness of the public aroused that we are doing something about it and my constituents want something done.

Mr. SYMINGTON. Senator, we thank you very much for your testimony and for the courtesy of being with us this morning. We will certainly see what we can do to alert the Utah community on time.

Mr. Moss. Thank you very much. I do appreciate the opportunity to be here.

Mr. SYMINGTON. I think the next witness is Gilbert White, director of the Institute of Behavioral Science of the University of Colorado.

Dr. White, we welcome you to the witness table and we look forward to your testimony.

Mr. MOSHER. Mr. Chairman, maybe I should add one comment in anticipation of Dr. White's testimony. As you undoubtedly know, he is a very distinguished member of the Council of Advisors to the Board of the Office of Technology Assessment.

Mr. SYMINGTON. Glad to know that.

[A brief biographical sketch of Dr. Gilbert F. White and Dr. White's prepared testimony follows:]

CURRICULUM VITA

September, 1975

Name: Gilbert F. White

Date of Birth: November 26, 1911

Education: S.B., S.M., Ph.D., University of Chicago

Positions Held:

Geographer with the Mississippi Valley Committee, National Resources Committee, and National Resources Planning Board, 1934-1940
Bureau of the Budget, Executive Office of the President, 1940-1942
American Friends Service Committee, 1942-1946
President, Haverford College, 1946-1955
Professor of Geography, University of Chicago, 1956-1969
Visiting Professor, University of Oxford, 1962-1963
Professor of Geography and Director, Institute of Behavioral Science, University of Colorado, 1970-

Honors:

Distinguished Service Award, Association of American Geographers, 1955, 1974
Daly Medal, American Geographical Society, 1971
Eben Award, American Water Resources Association, 1972
Thomas Jefferson Award, University of Colorado, 1973
National Academy of Sciences

Activities:

Member, Hoover Commission Task Force on Natural Resources, 1948
Vice Chairman, President's Water Resources Policy Commission, 1950
Member, UNESCO Advisory Committee on Arid Zone Research, 1953-1956
Chairman, United Nations Panel on Integrated River Development, 1957-1958
President, Association of American Geographers, 1961-1962
Consultant, Lower Mekong Coordinating Committee, Cambodia, Laos, Thailand, and Vietnam, 1961-1962, 1970
Chairman, American Friends Service Committee, 1963-1969
Member, Special NSF Commission on Weather Modification, 1964-1965
Chairman, Bureau of Budget Task Force on Federal Flood Policy, 1965-1966
Chairman, Committee on Water, National Academy of Sciences/National Research Council, 1964-1968
Chairman, Steering Committee for High School Geography Project, 1964-1970

Activities (continued)

Member, UNESCO Advisory Committee on Natural Resources Research, 1967-1971
Member, Advisory Committee on Environmental Sciences, NSF, 1968-1971
Scientific Adviser to Administrator of United Nations Development Programme on Man-made Lakes, 1966-1971
Chairman, Commission on Man and Environment, International Geographical Union, 1969-76
Member, Scientific Committee on Problems of the Environment, International Council of Scientific Unions, 1970-
Chairman, Advisory Board, Energy Policy Project, 1972-1974
Chairman, International Environmental Programs Committee, National Research Council, 1972-76
Chairman, Environmental Studies Board, National Research Council, 1975-
Member, Technology Assessment Advisory Council, U.S. Congress, 1973-75
Trustee, Resources for the Future, 1967- (Chairman, 1974-)
Member, Earthquake Studies Advisory Panel, U.S. Department of the Interior, 1973-

Selected Publications

Human Adjustment to Floods, Chicago: University of Chicago Department of Geography Research Papers, No. 29, 1942
(Editor), The Future of Arid Lands, Washington, D.C.: American Association for the Advancement of Science, 1956
Science and the Future of Arid Lands, Paris: United Nations Educational, Scientific and Cultural Organization, 1960
(With Egbert de Vries, Harold B. Dunkerley, and John V. Krutilla), Economic and Social Aspects of Lower Mekong Development: A Report to the Committee for Coordination of Investigations of the Lower Mekong Basin, January, 1962, (English and French)
Social and Economic Aspects of Natural Resources: A Report to the Committee on Natural Resources, Washington: National Academy of Sciences, Publication 1000-G, 1962
Choice of Adjustment to Floods, Chicago: University of Chicago Department of Geography Research Paper, No. 93, 1964
(Joint Author), A Unified National Program for Managing Flood Losses: A Report by the Task Force on Federal Flood Control Policy, Washington: 89th Congress, second session, House Document 465, 1966
Strategies of American Water Management, Ann Arbor: University of Michigan Press, 1969

Selected Publications (continued)

(Editor), Water, Health and Society: Selected Writings of Abel Wolman, Bloomington: Indiana University Press, 1969

(With David J. Bradley and Anne U. White), Drawers of Water: Domestic Water Use in East Africa, Chicago: University of Chicago Press, 1972

(Joint Editor), Man-Made Lakes: Their Problems and Environmental Effects, Washington: American Geophysical Union, 1973

(Editor), Natural Hazards: Local, National and Global, New York: Oxford University Press, 1974

(With J. Eugene Haas), Assessment of Research on Natural Hazards, Cambridge: MIT Press, 1975

(With others), Flood Hazard in the United States: A Research Assessment, Boulder: Institute of Behavioral Science, 1975

Testimony By

Gilbert F. White
Institute of Behavioral Science
University of Colorado

To The

U.S. House of Representatives
Committee on Science and Technology
Subcommittee on Science, Research and Technology

Earthquake Hearings
June 24, 1976

Washington, D.C.

Mr. Chairman. The threat of earthquakes to national well being and the current status of research on earthquakes have been described thoroughly by previous witnesses. I shall not attempt to discuss either topic. However, there are two directions in which the Subcommittee inquiry may be extended with possible benefit. The first direction relates to lessons which may be drawn from national experience with other extreme natural events. The second direction relates to the characteristics of a genuinely balanced program of research on earthquake hazard.

These remarks are drawn from an analysis of the status of public response to natural hazards in the United States and from a review of research needs supported by a grant from the National Science Foundation. The results of the assessment of research needs have been summarized in a report published by the MIT Press (White and Haas, Assessment of Research on Natural Hazards, MIT Press, 1975) as well as in a series of monographs published at the University of Colorado. One of the monographs deals explicitly with problems of earthquake and tsunami occurence and the adjustments which the nation makes to them (Ayre, Earthquake and Tsunami Hazard in the United States: A Research Assessment, University of Colorado, 1975).

It is important to examine earthquake problems in the broad context of natural hazards in the United States because there is much in the record of public activity with regard to other hazards that has a bearing on the strategy which the Federal government pursues with respect to earthquakes. Consider two examples.

The policy and programs of the Federal government in coping with floods has much to teach us about the wisdom of suggested strategies with regard to earthquakes. In the early days of this century the government

concentrated chiefly on issuing warnings with respect to floods and on control of the Lower Mississippi River. In 1936 it initiated a national program of public support for construction of dams, storage reservoirs, detention reservoirs, levees, floodwells, channel improvements, and floodways as a means of curbing floods and reducing damages from their occurrence. After more than 30 years of activity under this program and after an expenditure of more than 9 billion dollars on engineering works, observers noted that while the investments in flood control works were generally efficacious from an engineering standpoint and resulted in reduction of flood losses in many areas they were accompanied by an enlargement in the total damages suffered in the United States from floods. This situation is summarized succinctly in House Document 465 (A Unified National Program for Managing Flood Losses) which was transmitted to the Congress by President Johnson in 1966. At that time the Federal government moved toward a broader policy in dealing with floods. This included flood warnings, flood control, flood plain delineation, flood insurance, and a variety of efforts at land management.

In the case of floods the strategy of concentrating on technological means of predicting and controlling the extreme event failed to provide vigorous support for other measures: well-intentioned efforts to support both research and technological development were counterproductive.

Let us take a second and more simple example. As a result of Federal support of research and operations concerning hurricanes, the capacity to predict the time and place of the landfall of tropical cyclones has improved over recent decades. Loss of life has on the average been reduced. However, at the same time the vulnerability of the nation to property

damage from hurricanes has mounted, and the likelihood of catastrophic events has also increased. At the same time the Federal effort was greatly expanded to reduce suffering from disasters when they occur.

Three lessons from the experience with flood, hurricane and other hazards are relevant to a consideration of earthquake research.

1. Concentration upon means of predicting the event, improving the design of buildings, and providing emergency relief may fail to reduce the national toll of losses unless accompanied by equally careful efforts to deal with community preparedness and land use management.

2. Many of the unsolved problems of mitigating disaster are common to several hazards and must be examined in a broader framework if effective public measures are to be designed. This is true of problems of warnings, emergency services, building design, insurance, and land use management.

3. It is extremely difficult to achieve a genuine coordination of Federal, state and local activities in hazard response and mitigation. This has not yet succeeded for either floods and hurricanes. Strong and unified Congressional directives are necessary to offset the independent and segmented efforts of the many agencies involved.

After a deliberate review of the present situation, the conclusion of the University of Colorado study was that a research program along new lines would be required. This is described in the following text from our 1975 report (pp. 324-336).

Public investment in research related to earthquakes and tsunamis has been focused primarily on geophysical, seismological, and engineering research. Only nominal amounts have been invested in research on insurance and community preparedness.

An analysis of significant research needs suggests that the emphasis should be shifted if economic loss and social disruption are to be reduced.

Land use management - Of all the potential mechanisms to cope with earthquakes, the simplest and most direct would be the avoidance of high-risk areas wherever economically practicable. However, San Francisco cannot be relocated, and undeveloped high-risk areas may be potentially very valuable, (as in some parts of the San Francisco Bay Area). The degree of risk is not always obvious. Several courses of action are indicated: 1. risk zoning of critical parts of the already developed areas to turn them into park land or other nonhazardous use as opportunity arises; 2. risk zoning of high-risk undeveloped areas to prevent future hazardous development; and 3. development of systematic techniques for collection and evaluation of data for use in microzoning (zoning of comparatively small areas), and the establishment of criteria for microzone levels of risk.

Research should be done on microzoning procedures with some detailed case studies, collection of local seismicity data and local fault mapping as needed, and the identification of especially hazardous areas, including potential landslides and soil liquefaction. Expenditures to support 200 person years of effort over ten years are required.

A research effort designed to point out ways in which restriction of building in fault zones might be encouraged and adopted would have considerable payoff. This restriction of building could begin in actual fault zones and other areas of high hazard such as those in which the soil is known to be subject to liquefaction, and could be extended to other areas as microrisk zones are assessed.

The study would analyze the question of how such zoning could be adopted, especially for structures and facilities of vital importance. Social, political, and economic constraints to land use management would be assessed, as well as its consequences. The study of zoning adoption for the earthquake hazard may be similar to such studies for other hazards such as flood plain management.

Research on zoning and subdivision regulation could be combined, in certain instances at least, with experimental research on building code adoption. Undeveloped areas subject to high seismic activity could be used for certain economically feasible purposes if improved building codes were first adopted and used as a basis for seismic-resistant design.

An adequate investigation would run for a period of five years at a cost of 40 person years.

Similar studies on a much smaller scale are needed for coastlines where tsunami hazard is large or where invasion by urban development is rapid. Two person years should be spent on problems of local provision for tsunamis in land use management, and ten person years should be given to risk zoning.

Earthquake-proofing - Few structures can be made completely earthquake-proof, especially against the shaking produced by giant earthquakes. Figure 11-13 provides an estimation of physical damage to buildings located in the Los Angeles area

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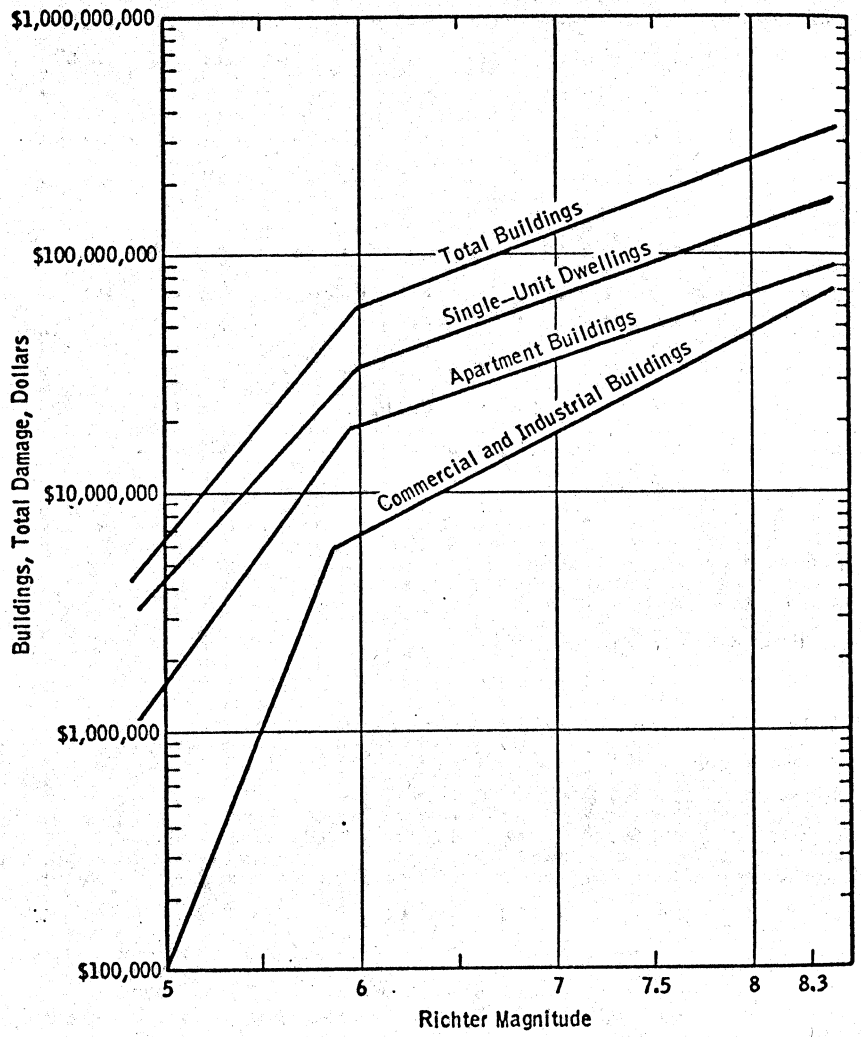

FIGURE 11-13

TOTAL DAMAGE TO BUILDINGS IN LOS ANGELES, 1970, FROM SIMULATED HISTORICAL EARTHQUAKES

in 1970 if potentially damaging earthquakes of which there was record after 1769 were to recur. This is based on a simulation which estimates earthquake characteristics, the building inventory, and building design and construction. Public structures were not included. The damage suffered by single-family dwellings is the largest category.

Most buildings could be designed and constructed to resist significant structural damage, the possibility of total collapse. Loss of life and injury could be greatly reduced.

Most of the research attention to date, the largest single program in the natural hazards field, has been applied to the more spectacular and analytically interesting types of structures, for example, many-storied buildings, large dams, nuclear power plants, and storage tanks. Relatively little attention has been paid to lesser structures, including the ordinary single-family dwelling. While this approach has produced positive results, it has neglected several important problems: 1. potential weaknesses in certain methods (lift-slab construction, prefabricated construction, and other methods which may result in lack of adequate structural continuity) have not been investigated sufficiently; 2. low structures, with the exception of school buildings in California, generally have not been given attention commensurate with their property value and the human risks involved; 3. many-storied buildings that have been adequately designed and constructed to withstand the motion of major earthquakes without serious structural damage are not necessarily safe for human occupancy if the elevator system fails or if fire breaks out; and 4. a dam and the valley below it, which seemed safe at the time of construction of the dam, may later prove to be unsafe due to increased density of human population in the valley, deterioration of the dam and its foundation, or the occurrence of a greater-than-expected earthquake.

Engineering research is needed on: 1. development of continuity in structural systems; 2. earthquake resistance of low buildings; 3. overall safety of multistoried buildings, including structural integrity, safe evacuation routes, and fire resistance; and 4. overall safety of dams and the valley below, and restrictions on land use in areas subject to flooding. Research is also needed for greater understanding of foundation conditions.

Additional funding of about 200 person years over the next ten years would be appropriate. The movement toward improving earthquake-resistant construction has been generally successful, with some exceptions, and needs further support.

The upgrading of building codes should be studied in light of the fact that estimates of increased costs to *new* construction rarely exceed 6% of the total cost of the structure. Building codes for all classes and structures and the political, social, and economic constraints to their adoption and enforcement should be considered.

Some high-risk cities appear to be significantly more progressive in the upgrading of building codes than other cities. If this is true, a series of comparative case studies would provide answers on how this upgrading takes place, and what the secondary consequences are. Experimental efforts should be made to provide incentives to the local powers who could influence building code upgrading. For example, communities could be identified where the mortgage lenders are somewhat progressive. A small team of professionals (economists, structural engineers) could carry out a careful effort to demonstrate to the lenders why supporting an improved building code would be in their own best interest. Other approaches could be tried in other cities to see which approach was most effective in producing the desired change. It is suggested that

such a study should run for a period of five years at a cost of 25 person years.

Old buildings probably present the most difficult problem of all. They may be lucrative rental property or tax write-offs for the owners, homes and community foci for a great number of persons who cannot or will not live anywhere else, and may also be potential death traps due to the danger of collapse or fire. The two general classes of problems concern the physical condition of the structures and the social and economic constraints on doing anything about the conditions.

Research into ways of strengthening old buildings could scarcely be expected to lead to general procedures because of the great differences in construction and conditions. However, it might be possible to arrive at suggested procedures for particular classes of buildings.

Both types of research--survey and evaluation, and procedures for strengthening--might well be carried out in connection with programs of demolition for urban renewal and community conservation or other purposes if arrangements can be made well in advance of the start of demolition. Funding of about 100 person years over ten years would support a useful program of investigation.

Research is needed which will contribute to quicker adoption of policies that will sharply reduce the risk from old buildings. Economic constraints to the phasing out of dangerous structures include not only costs to the individual owner, community, state, or Federal subsidies, but also shifts in the tax base. Social costs include the disruption of established neighborhoods, a possible rise in social instability associated with urban renewal, and the problems inherent in the relocation of families and businesses. Long Beach, California, has undertaken a program designed to specify the seismic risk

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for each structure and the social costs and benefits of regulating future use or rehabilitation of each structure. Such a program could provide the basis for a valuable case study carried on by an interdisciplinary team.

It is difficult to estimate how dangerous a threat older buildings pose to lives and property. Study is needed to determine the risk they present, as well as how this risk might be lessened. Such work might start by determining how many old buildings exist in hazardous areas, as well as their conditions and use patterns. Of those that are dwelling units, knowledge of their inhabitant density would clarify the degree of risk they present. Research could be designed to determine how the risk might be reduced. Determination of their natural rate of abandonment could be followed by an investigation of how that rate might be affected and what would be the cost of remodeling appropriate structures to some level of acceptable safety. All alternatives should be examined. In addition to alternatives for reducing the risk, the research should address the social, economic, and political constraints to the adoption of each alternative.

The research would vary in time and cost with the size and density of the areas selected for analysis. However, a study costing on the order of 30 person years over five years should provide a good basis for action.

In addition, the analysis of tsunami-resistant structures with a view to improving design and code provisions should be undertaken. Costs of seven person years are warranted.

Earthquake prediction and warning - Specific forecasts of damaging earthquakes may be available in less than a decade, and possibly next year, but it is not clear whether the forecasts will be more of a blessing or a curse. Empirically

based research on the social, economic, political, and legal consequences of earthquake forecasts and warnings must be given a high priority, and it currently is under review by a panel of the National Research Council.

Specific forecasts of damaging earthquakes will have lead times on the order of a few months to ten years, and will be relatively specific as to location and magnitude. Such forecasts are qualitatively different from those used in other hazard warning systems.

A reliable method of reasonably precise prediction, with a low false alarm rate, could significantly reduce earthquake casualties and might reduce property losses. It seems very likely that earthquake prediction will have additional and perhaps large-scale impacts, some of which will probably be positive and others negative.

There may be two types of forecasts and therefore the possibility of two types of "false alarms." The first is a forecast that an earthquake *will* take place, the second is a forecast that an earthquake will *not* occur. Furthermore, the very existence of an earthquake prediction and warning system may to some extent generate a false sense of security and a tendency on the part of the public to infer that *no* warning means that *no* damaging earthquakes will occur.

The public's response to earthquake prediction is exceedingly difficult to estimate. There are no good parallels to use as a basis for estimating the response. If, in advance of credible forecasts for damaging earthquakes, responsible public agencies and private interest groups develop plans and policies which are based on realistic assumptions about the actions of other organizations and people, the whole situation will be less volatile and less likely to produce adverse economic effects, unnecessary social disruption, or political upheaval.

There are no existing social mechanisms to assist responsible officials and organizations in arriving at plausible and realistic estimates of responses to the forecasts. If the results of careful research on the probable response of organizations and the public are reported to all responsible officials, they will have adequate, realistic knowledge upon which to develop their plans.

Negative consequences could also be enormous during the extended period following forecast of a damaging earthquake. Insurance companies might decide to stop selling or renewing earthquake insurance coverage. As a result, investment agencies might drastically reduce their commitments to construction and development in the area, an action which could trigger an extended slowdown in the local economy. Many people might move away from the area. Others might converge on it.

Because of the potential for very large-scale negative consequences, it is imperative to learn how to cope with earthquake prediction as early as possible. Support for at least 50 person years over five years is required.

The Pacific-wide Tsunami Warning System detects tsunamis rapidly and effectively. Where lead time is sufficient, dissemination of relevant information to the threatened communities is generally adequate. The actual forecast is handicapped by difficulties in estimating the flood depth or "run up", and in calculating the generation of waves from seismic data. Preparedness at the local level to disseminate needed information for prompt evacuation appears to be lacking in most cases. This may be due in part to the rarity of a tsunami warning in any given community. It is not known what incentives are required to insure that vulnerable communities maintain adequate local warning-response capability. Information on that question could be gathered by a research effort on the order of