S. HRG. 109–93

U.S. TSUNAMI WARNING SYSTEM AND S. 50, "THE TSUNAMI PREPAREDNESS ACT OF 2005"

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED NINTH CONGRESS

FIRST SESSION

FEBRUARY 2, 2005

Printed for the use of the Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE

22–845 PDF WASHINGTON : 2005

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2250 Mail: Stop SSOP, Washington, DC 20402–0001

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED NINTH CONGRESS

FIRST SESSION

TED STEVENS, Alaska, *Chairman*

JOHN McCAIN, Arizona
CONRAD BURNS, Montana
TRENT LOTT, Mississippi
KAY BAILEY HUTCHISON, Texas
OLYMPIA J. SNOWE, Maine
GORDON H. SMITH, Oregon
JOHN ENSIGN, Nevada
GEORGE ALLEN, Virginia
JOHN E. SUNUNU, New Hampshire
JIM DEMINT, South Carolina
DAVID VITTER, Louisiana

DANIEL K. INOUYE, Hawaii, *Co-Chairman*
JOHN D. ROCKEFELLER IV, West Virginia
JOHN F. KERRY, Massachusetts
BYRON L. DORGAN, North Dakota
BARBARA BOXER, California
BILL NELSON, Florida
MARIA CANTWELL, Washington
FRANK R. LAUTENBERG, New Jersey
E. BENJAMIN NELSON, Nebraska
MARK PRYOR, Arkansas

LISA J. SUTHERLAND, *Republican Staff Director*
CHRISTINE DRAGER KURTH, *Republican Deputy Staff Director*
DAVID RUSSELL, *Republican Chief Counsel*
MARGARET L. CUMMISKY, *Democratic Staff Director and Chief Counsel*
SAMUEL E. WHITEHORN, *Democratic Deputy Staff Director and General Counsel*
LILA HARPER HELMS, *Democratic Policy Director*

CONTENTS

WITNESSES

APPENDIX

U.S. TSUNAMI WARNING SYSTEM AND S. 50, "THE TSUNAMI PREPAREDNESS ACT OF 2005"

WEDNESDAY, FEBRUARY 2, 2005

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Committee met, pursuant to notice, at 10 a.m. in room SR–253, Russell Senate Office Building, Hon. Ted Stevens, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. TED STEVENS, U.S. SENATOR FROM ALASKA

The CHAIRMAN. Welcome to our first hearing. We're honored to have Senate Majority Leader Bill Frist and, soon, Senator Mary Landrieu here to testify on their recent trip to the countries impacted by the Indian Ocean tsunami. We do thank them for their willingness to come.

In 1994, Senator Inouye and I, along with Senator Hatfield of Oregon, directed NOAA to develop the National Tsunami Hazard Mitigation Program. We had had a tsunami in 1968, after the earthquake. But this was in response to a small tsunami that impacted the West Coast. It reflected the concern we all shared about the frequency of tsunamis in the Pacific. This bill is intended to build on the current tsunami warning network that we have in the Pacific.

I thank the witnesses for being here today.

Let me yield to Senator Inouye, our Co-Chairman.

STATEMENT OF HON. DANIEL K. INOUYE, U.S. SENATOR FROM HAWAII

Senator INOUYE. I'd like to join our Chairman in welcoming our distinguished panel of witnesses, especially the Leader, as they testify on a catastrophe that has left the world in shock, and governments scrambling to react.

We all saw the devastation, the incredible human suffering, and the obliteration of entire communities. The destruction hit everyone and everything in its path, without regard to national or ethnic identity, level of economic development, or technological sophistication.

Our response, as a global community, must, similarly, cut across superficial distinctions among nations and people. Our response, however, must not be a disorderly surge of activity and investment dictated by emotions.

Mr. Chairman, may I request that the rest of my statement be made part of the record?

[The prepared statement of Senator Inouye follows:]

PREPARED STATEMENT OF HON. DANIEL K. INOUYE, U.S. SENATOR FROM HAWAII

I would like to join our Chairman in welcoming our distinguished panel of witnesses today. As they testify on a catastrophe that has left the world in shock, and governments scrambling to react. The tsunami that struck the coasts of the Indian Ocean struck without regard to national or ethnic identity, level of economic development, or technological sophistication. I believe that our response as a global community must similarly cut across superficial distinctions among nations and peoples.

That response, however, must not be a disorderly surge of activity and investment dictated by emotions. Rather, we must study carefully the nature of the threat of tsunami, assess our capacity for detecting and forecasting these natural disasters, and make a plan that both makes sense, and is sustainable over time.

Protecting human life and property from natural disaster requires the ability to reliably detect and forecast, the capacity to broadcast warnings in a timely and informative manner, and the knowledge in communities of how to respond and evacuate to safety. Above all, however, it requires the willingness to invest resources to prepare for a threat that is largely unseen and unpredictable—until the last moment, when a monstrous wave actually strikes.

As we came to understand the broader threat that tsunami posed, Ted Stevens and I worked together in 1994 to direct the National Oceanic and Atmospheric Administration (NOAA) to develop a Tsunami Hazard Mitigation Program. We are pleased to report that this program has laid the foundation for tsunami preparedness in the Pacific. The National Oceanic and Atmospheric Administration has taken the lead in this effort with support from other federal partners, such as the U.S. Geological Survey, and the National Science Foundation. We look forward to hearing reports and testimony from these agencies as they describe where their work has brought us today.

The appalling scope of the Indian Ocean tragedy illustrates the importance and necessity of our work of the past 10 years, and with stark clarity, we can see that despite our best efforts, much remains to be done. Now, as before, Senator Stevens and I have come together to lead the charge toward national and international tsunami preparedness by introducing our bill, S. 50, the Tsunami Preparedness Act, which many of our colleagues here in this room have chosen to cosponsor.

I hope that today's testimony will shed additional light on how we may further improve our bill and come to grips with national and global tsunami preparedness. In particular, I look forward to the testimony of Ms. Eileen Shea, an authority on risk management in the Pacific. Her report on how the Pacific community has come together to form a family—or "ohana"—in order to pool resources for disaster preparedness will be most informative. I welcome her perspectives on how our risk management ohana can integrate tsunami preparedness into an overall portfolio of planning and preparation.

The CHAIRMAN. Thank you very much.

Unless there's objection, we'll have Senators make their statements after the Leader and Senator Landrieu make their statements.

Welcome. Dr. Frist, we welcome your statement.

STATEMENT OF HON. BILL FRIST, SENATE MAJORITY LEADER, U.S. SENATE

Senator FRIST. Thank you.

Mr. Chairman and Senator Inouye, Members of the Committee, it is a real honor for the two of us to present to you, and to share some of our findings on a trip that we made, very early, to the tsunami region. We had a wonderful opportunity to see the very best of compassion and caring expressed and, at the same time, witness the devastation, destruction, sorrow, and the pain that we all know characterized this tsunami. Thanks for holding this hearing as we look at ways to prevent, as well as to respond to, disasters such as the tsunami. This is a very important hearing.

Senator Landrieu and I, on the spur of the moment, did leave the United States to witness this destruction, predominantly in Sri Lanka. As mentioned, 150,000 people, at least, have died, over five million homes destroyed, thousands remain missing. A real focus on children, will be reflected in both of our comments.

Many of the nations' first responders came to help. But I have to say, right up front, it gives us a great deal of pride to watch our Marines, very early on, as part of the 12,000 to 15,000 military personnel who responded quickly with usable forces. It was very impressive to see them coming, moving debris, working with USAID, working in a very cohesive fashion.

The destruction is exactly as described. I have a slide up. It's a little bit shaded, because it's taken through the window of an airplane, but the coast is there. You can see, for those several hundred meters, there's total destruction. What was amazing is, when you flew in a helicopter, there's no end to it. It goes for miles—10 miles, 20 miles, 50 miles, 100 miles, 1,000 miles.

Much remains to be done. Much has been done already. We have psychological trauma that is going to take years to deal with. We have shelter needs that will take years to deal with. The immediate recovery and response, indeed, was quite impressive.

Amidst all the tragedy, what was clear to me is that, in terms of the response, it was not the absence of food, because food was provided fairly quickly, and not the absence of hospitals, although they were overcrowded, but it was the access to something as basic as water, that we all take for granted. What happened with the tsunami, the wells that people had were filled with saltwater, which is not potable water. You had water buckets that were washed away totally; therefore, people, however they got their water initially, were not able to do that.

We had a focus on water. I have a slide up right now that shows the aid that's delivered really typifies everybody coming together, with USAID written on the side of that package. You see Sri Lankan physicians from the Sri Lankan Red Cross there, aid delivered from around the country in the background there, the types of quarters in refugee camps, schools that were taken over to house many people.

Quick action was taken; and, therefore, we didn't see epidemics of malaria or pooling of water that might have resulted. Dredging took place. So as water came in and washed in, early dredging prevented those pools of water from which malaria could have arisen, from which typhoid fever could have arisen, a breeding ground for mosquitoes.

Now we need to look at long-term solutions, which is part of what this hearing is today.

One area that I want to focus on is this area of public health, particularly as it does relate to water. The conditions that we witnessed in the tsunami's aftermath are common conditions around the world. There's about 1.2 billion people who don't have access to potable water today. That will result, probably, in about 135 million deaths over the next 15 to 20 years, all because of this lack of access to clean water.

Three proposals that I'd like to mention:

First, clean water should be, ought to be, a major priority in our development programs, the U.S. development programs. And they're not. Today, we spend about 3 percent of our international development and humanitarian assistance budget on water. That's only about $600 million of $20 billion. We must work to improve the water quality, not only in the areas that were tsunami-damaged, but, indeed, throughout the world. I mentioned 1.2 billion people, today, don't have access to clean water; 2.4 billion people don't have access to basic sanitation. It applies to children, specifically, because there are 4 billion cases, diarrheal cases a year, and that results in 1.8 million deaths of children under the age of 5 each and every year, something that absolutely can be prevented.

I show this slide because what is in my hand are these little packets that we had the opportunity to deliver. This little packet, which costs about 7 cents to make, if we had put in any kind of water, addresses both bacteria and parasites. And this little packet costs 7 cents to make, and will give about 45 days of clean water, which is pretty amazing. This shows that there are inexpensive solutions that we need to be both mobilized up to develop, which we have—this is just 1 of about 4 types of packets like this—but also to be able to distribute very, very quickly, and that was one of the things that Senator Landrieu and I had the opportunity to do.

No. 2, we, I believe, need to use medical assistance and public health as a currency for peace as we engage others around the world. We've missed it in the past, but I believe medicine and public health can be used as a vital tool for international diplomacy as we look ahead and decide how to spend our resources.

The assistance that we give other nations has its greatest impact when it is on the ground, when it touches individuals in very intimate and in very personal ways, at the community level.

I throw this slide in here, because this is a hospital that we visited, and this is one of the victims from the tsunami who had come in. You see the Sri Lankan physicians, in the past we met Scandinavian physicians, they all make a difference, directly impacting people's lives, with their expertise, but also by reaching out and touching people in a very intimate way. And we have missed it. We don't have any national or international programs now that focus on what I will come back to, and that is a global health corps.

I do intend to promote a new version of the type of Peace Corps that we reach out very directly as a global health corps. It would bring together medical professionals, it would bring together people in this country who want to donate a period of time. It might be a month, it might be 6 months, it might be a year, in terms of technology and expertise in public health and medicine, and it also would allow them to come back to this country and help educate us and the American people. When you look at the big, big killers that are out there today, it is still infectious disease. It is HIV/AIDS. It is malaria. It is tuberculosis. So it is a win-win for everyone. This global health corps, I'll be talking more about in the future, but at least wanted to introduce the concept.

So, No. 1, water should be injected into our development policy in foreign aid. And, No. 2, let's begin to think of using medicine and public health as a currency for peace, part of our diplomacy. And a good way to start that is a global health corps.

Third, and last, we should leverage private dollars to develop water infrastructure around the world. We've done it pretty well in the United States of America, but we have not done it elsewhere around the world. We are the Nation who can do that. Private companies, not state entities, will ultimately do the hard work of providing clean, potable water.

In the tsunami-ravaged areas, we saw private businesses, big and small, respond and assist in everything from water purification, through packets like this, to logistics. And what we can do, and should do, is leverage those private dollars into the field, looking for ways to develop, and ways we can do it, and certain models to develop, private/public partnership to inject this capital and help people with their water projects.

In closing, I'll just show this one slide. Again, this was from our trip, because it was one of the clinics that we visited. And there are two children there, because, as Senator Landrieu will say, this tsunami had a huge impact on children. It reminds me of the medical response. These two kids were sleeping in the same bed, because the infrastructure is not fully developed. And as we reinvest in these parts of the world, I hope that we can inject both water infrastructure, as well as public-health infrastructure.

We have much to do. We've got to be bold. I think this hearing is a great start to look both at prevention and appropriate response. The first steps, indeed, can be quite modest. I do hope that my colleagues will support these proposals in responding with water as a major priority in development assistance; No. 2, a global health corps; and, No. 3, policy which will leverage private and public dollars to the benefit of kids like this that are sitting with me in the hospital.

Thank you, Mr. Chairman.

The CHAIRMAN. Senator Landrieu?

STATEMENT OF HON. MARY L. LANDRIEU, U.S. SENATOR FROM LOUISIANA

Senator LANDRIEU. Thank you, Mr. Chairman. It is a pleasure for me to join Senator Frist today and give very brief comments, because he's covered so much of what we realized on the trip.

Let me begin just by thanking you, acknowledging a new Member of this Committee, Senator David Vitter, who I'm sure will be joining us shortly. His willingness to tackle complex problems will, no doubt, continue the impressive work of Senator John Breaux, who served for many years, and most admirably, on this Committee.

I want to just ditto, if I could, the points made by Senator Frist, but add a few new points, if I could.

Jokingly, I told him I'd be happy to accompany him on this trip, if he did not require me to go in any operating room, which, I'm pleased to report, he lived up to his end of the bargain.

Senator FRIST. But we got close.

Senator LANDRIEU. Well, we got close, but he—I was successful in staying out of the operating rooms.

But I want to thank you for your introduction of the Tsunami Warning System bill, which we're here to testify on today, our need to invest in coastal communities, and the immediate and long-term impact of this tragedy on children and families.

First, I would like to say that it's hard to describe the destruction in words. Truly. Not just the intensity of it, but the expanse of the coastline affected. In an instant, Mr. Chairman, thousands of people and structures on miles of coastline were simply eliminated, swallowed up, washed away by a massive surge of water. The only warning that millions of people had was the ominous and awe-inspiring retreat of the ocean's waters, revealing hundreds of feet of sand and beach. Then, in a rush of water, the magnitude of this force wiped out 3,000 miles of shoreline, and carried with it the homes and lives of hundreds of thousands of people.

To give those in our country a better understanding of the magnitude, this chart would be helpful. I've tried to explain this. It would be as if you took an eraser, started at Galveston, Texas, and just erased the coastline all the way up to Bar Harbor, Maine, back as long as a football field, in some instances, or a fourth of a mile to a mile in other instances, eliminated.

The most amazing thing that we saw was actually the fact that the palm trees survived. I've been through many hurricanes in my life, as many of you all have—and, Mr. Chairman, yourself, you've witnessed a lot of the weather's ferociousness in Alaska—but Senator Frist and I commented, as we flew over this coastline, mile and mile, that the palm trees managed to just bend with the wave, and after the wave receded, came back up. But there were no homes or people or structures underneath the palm trees, themselves.

It reminds me to testify, this morning, that we should think of our coastal communities like palm trees, and build them in a way that they can weather these inevitable natural disasters, whether they be tsunamis or hurricanes or the surge of saltwater intrusion. With adequate and improved warning, better planning, and more robust investments in the right kind of infrastructure, our coastal communities here in America and around the world will continue to grow and thrive decade after decade.

Above all, these astonishing images. While the death toll was staggering—it could be over 150,000, 226,000, it's going to be hard to actually get an accurate estimate, of course; in many of these countries the census is not as sophisticated as ours—and over 500,000 were injured. But while the death toll is staggering, it is also extremely disturbing to realize that many of these people could have been saved, even with minimal time involved. People could have simply walked to safety. Experts say that oceans may give people as much as 5-minute warnings to escape to higher ground. Five minutes could have saved hundreds of thousands of lives. Mr. Chairman, even the smallest of toddlers and the most frail of seniors can walk the length of a football field, out of the reach of this wave.

So I'm pleased to lend my support and eye-witness accounts to the Tsunami Preparedness Act. This legislation will improve methods of detecting and warning coastal residents about tsunamis, establish important mitigation programs, enhance our research, and assist our friends abroad, as Senator Frist said, and build peace.

But warning, Mr. Chairman, is not enough. We must also invest and reinvest in our natural barriers, and constantly review our evacuation routes. This giant wave, not only killed a quarter of a million people, it also, as I said, obliterated the natural coastal barriers in the region. The United Nations Environmental Program estimates the damage to the environment could topple 675 million in loss of natural habitat, an important ecosystem function. This number could not only—should not only concern environmentalists that seek the worthy goal of preserving nature's wonders, it should also concern those whose safety and economic livelihood depend on these barriers being intact. We know something about that in Louisiana, and so do you in Alaska. Restoring the reefs and barrier islands and shorelines of these areas will help long-term disaster risk reduction. Without the barriers that act as nature's own line of defense against flooding, storm surges, waves, hurricanes, and even tsunamis, human lives are at risk.

Mr. Chairman, as I told you, from Louisiana, I know how vulnerable coastal communities are. 122 million people in America, 53 percent, live in coastal counties or parishes. The most common threat to these communities is the rapid rise of the water tables, hurricanes, saltwater intrusion.

I'd like to show the next chart, briefly, and then end with just one or two comments.

In the same area that I showed, the areas in red are basically areas in our southern part of the country that are below sea level. And I'm sorry I did not have the charts for the Pacific and the Atlantic coasts. But just the Gulf Coast region will show you, in red, it is 1.5 meters below sea level.

I ask this Committee, as we pass this legislation, what have we done if we warn people of danger, but don't help them escape it? In the hurricanes that ravaged Florida and the Gulf Coast region last year, people left their homes, only to get stuck in gridlock on highways trying to escape the 150–200 mile-and-hour winds that were projected along the Gulf Coast.

So I ask, as you all look forward, not only to this piece of legislation, but in the Oceans Act or oceans legislation that is emerging from the recent study, to think carefully about that. While our work here today will focus on warning, we must also focus on what this disaster means, or disasters like this could mean, to our own communities in Louisiana.

And, finally, one sentence, Mr. Chairman, about the families. Nations are, in fact, built on roads and infrastructure and railroads. But nations are primarily built on families, strong families, united, protective of one another, and focused on building and protecting their communities. Everything we do, in this Committee or the Foreign Ops Committee or in any other Committee in this Congress, should be focused on rebuilding these 11 nations, family by family, picking the one child that was left, uniting them with the one aunt that was left, finding the one grandfather that may still have a fishing boat intact, and trying to put them together to help rebuild these nations, and, in doing so, remind ourselves that building families in America is the best way we can assure our future.

Thank you, Mr. Chairman.

The CHAIRMAN. Well, thank you both very much.

Leader, last year in the Foreign Operations appropriations bill, we put $100 million in there as an add-on to start a program for clean water throughout the world, fashioned after the system that we started in Alaska to deal with the 240-odd villages in Alaska that, until recently, did not have clean water and sewer. We figure that the cost is about $2,000 a well. As we go into places like African villages, it's much less than what's in our state. But I do believe we should followup on your idea with regard to try and find a way to deal with this access-to-clean-water problem. And it's—I don't know how much of it's within the jurisdiction of this Committee, but we're going to take a look and try to work with you on that aspect.

Does anyone have any comment or a statement to make to the Senators?

[No response.]

The CHAIRMAN. We thank you both very much.

Senator FRIST. Thank you, Mr. Chairman.

The CHAIRMAN. We look forward to working with you——

Senator LANDRIEU. Thank you, Mr. Chairman.

The CHAIRMAN.—on this legislation.

Senator FRIST. I do appreciate that focus in appropriations, just real quickly, because I think every Committee needs to go back and look, because we've had this lack of coordination, and we absolutely know that that well, for $2,000, going back to what Senator Landrieu closed on, has an economic impact, has an impact on family. It is a huge women's issue throughout Africa. We traveled throughout Mozambique, had a large bipartisan group, last year, and, indeed, when you talk to women who are walking 3 to 4 hours a day, each day, for water, and you look at their children, you see the huge economic, social, and family impact that a simple well, $2,000, can have on a community.

So thank you for your leadership there.

The CHAIRMAN. Thank you very much. Appreciate you both being here.

Our second panel of witnesses are Jack Marburger, the Director of the Office of Science and Technology Policy; John Kelly, the Deputy Under Secretary for Commerce for Oceans and Atmospheres; Dr. Arden Bement, Director of the National Science Foundation; and Dr. Charles Groat, the Director of the U.S. Geological Survey.

We do thank you for being here today, and would urge you to take your positions.

I must state to Members and to the audience that Admiral Lautenbacher, sadly, is seriously ill and cannot be with us. We will schedule another time for him to appear. But we do send our best wishes to him.

May we proceed in the way that I presented your names, gentlemen? Your statements will be printed, in full, in the record, and we ask you to summarize them as concisely as you are able to do so. It's a highly technical subject, so we do not want to shut you off or limit you unnecessarily.

Mr. Marburger?

STATEMENT OF DR. JOHN H. MARBURGER, III, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT

Dr. MARBURGER. Thank you, Mr. Chairman and Members of the Committee. Thank you for inviting me today to discuss the Administration's plans for the U.S. Tsunami Warning System.

I'll keep my oral remarks short. Thank you for including my written testimony in the record.

I, too, have just returned from the tsunami-devastated area. And I, too, was sobered by the extent by the extensive damage I saw there.

I attended a ministerial meeting on regional cooperation on tsunami early warning arrangements in Phuket, Thailand. Science ministers from approximately 46 countries were invited, including all the countries affected by the December 26th earthquake and tsunami.

The greatest tragedy of this colossal natural disaster is that many of the deaths, as Senator Frist indicated, could have been prevented, if only a warning system had been in place to alert people in harm's way. Preventing deaths in future similar catastrophes will require a high degree of international cooperation, and I will mention, later, steps the Administration has taken, and plans to take in the future, for securing international cooperation and developing a global tsunami warning system as part of the Global Earth Observation System of Systems, or GEOSS.

Mr. Chairman, about 85 percent of tsunamis worldwide occur in the Pacific Ocean, where life-threatening ones appear about once per decade. Because of this risk, the U.S. has led in the development of tsunami detection and monitoring technologies, and has cooperated since 1968 in the International Coordination Group for the Tsunami Warning System in the Pacific, which currently has 26 member countries. This system operates under the auspices of UNESCO's Intergovernmental Oceanographic Commission, or the IOC.

The world's most advanced tsunami-detection systems, NOAA's Deep–Ocean Assessment and Reporting of Tsunami buoys—they're called "DART buoys"—are deployed as part of the U.S. Pacific Tsunami Warning System. The Administration's plan includes enhancing the existing Pacific Warning System to provide more comprehensive coverage and faster alerts to broader populations.

Tsunamis occur less frequently in the Atlantic Ocean, the Caribbean, and the Indian Ocean, but, obviously, they are still a threat. Their potential impact is increasing because of the global migration of populations to coastal areas. By 2025, for example, approximately 75 percent of the U.S. population will live in coastal communities.

The current risk, measured by the frequency of occurrence times the consequences, justifies the investment in expanded detection warning and disaster-reduction systems. The Administration's plan, which you will hear more about in other testimony, will expand our detection and warning capabilities to the Atlantic and Caribbean, permitting very effective detection capability in the event of a U.S. coastal tsunami.

Of course, some of the components of a tsunami detection warning and disaster reduction system are unique to the tsunami hazard, such as the sensors for deep-ocean detection of tsunami waves, but much of such a system has value for other hazards, as well. The communications infrastructure, the emergency evacuation and response plans, damage-assessment tools, public education programs, and many other components are relevant, in general, for disaster preparedness, mitigation, and response.

Many federal agencies cooperate to provide technical support for tsunami readiness. Those represented here today: NOAA, USGS, and the National Science Foundation lead the effort, but agencies like the Department of Homeland Security, with the Disaster Warning System, and NASA's Satellite Remote Sensing, also contribute to tsunami detection and warning, as well as to post-incident damage assessment and response. Such interagency science and technology activities are coordinated through the National Science and Technology Council, managed by my office, to ensure optimal use of public funds.

The U.S. and the international community are well prepared to create a global tsunami warning system. Catalyzed by the U.S., the Intergovernmental Group on Earth Observations——

The CHAIRMAN. I'm constrained to tell you, we would appreciate it if you would summarize, that we have another panel.

Dr. MARBURGER. this is actually an abbreviated version of the whole statement.

Mr. Chairman, I'd like to thank you for this opportunity. I'd just indicate that we are cooperating with other nations in an effective organization. We're ready to carry out the intent of a bill that is introduced, and Administration plans which are consistent with that bill.

[The prepared statement of Dr. Marburger follows:]

PREPARED STATEMENT OF DR. JOHN H. MARBURGER, III, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT

The recent tragic earthquake and resulting tsunami in the Indian Ocean was a natural disaster of almost unimaginable proportion. The U.S. and the world have responded generously with aid to those who have been hurt and with resources to assist in assessing and responding to the damage. What made this event even more tragic is that many of the deaths were preventable—if only an effective warning system had been in place to alert the communities that were in harm's way. The Administration is committed to helping ensure that warning and response systems are put in place—domestically and internationally—that will substantially reduce loss of life and property in the future.

The Tsunami Threat

A tsunami is a series of very long, fast-moving waves that can travel long distances across the open ocean at speeds up to 500 mph. As the tsunami approaches shore, the successive waves may slow to speeds of 20–30 mph and grow substantially in height, with the first wave commonly not the largest or most destructive. Tsunamis are generated by any rapid, large scale sea disturbance. Approximately 90 percent are generated by undersea earthquakes, but not all undersea earthquakes generate tsunamis. They may also be caused by events such as volcanic eruptions or major landslides.

Approximately 85 percent of tsunamis occur in the Pacific Ocean because of this ocean's encircling major seismic zones that are associated with the volcanoes of the "Pacific Ring of Fire." Since 1946, five Pacific Ocean tsunamis have cost the U.S. more than 300 lives and hundreds of millions of dollars in property damage. Because of the much greater frequency of Pacific Ocean tsunamis, prior U.S. and global efforts to develop tsunami warning systems have focused on this region. Since

1968, the U.S. and other Pacific region nations have cooperated in the International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU), which currently has 26 member states. This system operates under the auspices of UNESCO's Intergovernmental Oceanographic Commission (IOC). Currently, the world's most advanced tsunami detection systems, NOAA's Deep Ocean Assessment and Reporting of Tsunami (DART) systems, are deployed in the U.S. Pacific Tsunami Warning System.

Although less likely, tsunamis have some potential of occurring in the rest of the world's oceans, including the Indian Ocean, Caribbean, and Atlantic Ocean. Even though the probability is small, the potential for tsunami-related loss of life and property is increasing because of population migrations to coastal areas. The United Nations reports that already two-thirds of the world's population crowd near the coastline, and within three decades, if trends continue, 75 percent of humanity will reside in coastal areas. By 2025 nearly 75 percent of all Americans are expected to live in coastal counties, many of whom will be in tsunami risk areas. Given a tsunami's great destructive power, expanding tsunami protection for U.S. coastal communities and developing global early detection and warning systems are justified.

While plans to expand the world's tsunami detection and warning capabilities for global coverage were already in development when the December 26 tsunami struck, this event has focused international attention on the need for tsunami detection and warning and has created opportunities for enhanced international cooperation in developing and deploying such systems.

Disaster Warning and Reduction Systems

Some of the components of a tsunami detection, warning and disaster reduction system are unique to the tsunami hazard, such as the sensors for deep ocean detection of tsunami waves. But, I would like to emphasize that a great deal of the investment is not confined to tsunamis alone. The communications infrastructure, emergency evacuation and response plans, damage assessment tools, public education programs, and other components are relevant to many types of disasters.

I would like to outline the generic components for a successful disaster detection, warning, and reduction system, including how these components relate specifically to the tsunami hazard. A complete system includes:

- *Risk assessment*, which is enabled by the detailed modeling of coastline communities and by increased scientific understanding of the formation and propagation of tsunamis;
- *Detection*, to reliably indicate whether a tsunami has occurred, avoiding costly false alarms and the associated erosion of public confidence;
- *Warning*, including the initial issuance; transmission to affected countries, regions, and communities; and communication to the affected population;
- Activation of a *response plan*, already in place in the local communities;
- A "*ready public*," able to respond in an efficient and timely manner through preparedness education;
- *Situational awareness*, with monitoring of the incident until an "all clear" has been sounded;
- *Resilient infrastructure*, protective shelters, reliable supply routes, food and water, medical supplies and medical evacuation procedures; and ultimately
- *Lessons learned*; a post-incident evaluation with feedback to enable future improvements.

Science and Technology for Tsunami Readiness

Mobilizing federal science and technology to support tsunami readiness requires the contributions from a number of federal agencies, and also requires a coordinated approach. The agencies represented here today, NOAA, USGS, and NSF, lead our tsunami readiness effort, but the contributions of other agencies, such as the Department of Homeland Security in disaster warning systems and NASA in satellite remote sensing, contribute in a variety of ways to tsunami detection and warning, as well as to post-incident damage assessment and response. Federal science and technology challenges that draw on the strengths of more than one agency are coordinated through the National Science and Technology Council (NSTC). In particular, coordination through the Subcommittee on Disaster Reduction and the Interagency Working Group on Earth Observations has been critical in assuring the best use of our collective capabilities.

Although we are focused here today on what it will take to deploy a system that will allow faster and more accurate tsunami detection and warning, I would like to point out some of our other significant contributions to tsunami warning and disaster reduction:

- Our ability to do accurate risk assessment and prediction is supported by basic research on seismic and tsunami processes as well as by advances in numerical modeling and simulations of these processes and of their impact on coastal communities.
- Enhanced community warning systems and improved disaster response capabilities are being developed by FEMA and other agencies, capitalizing on an "all hazards" approach to disaster-resilience.
- Research findings from the social and behavioral sciences are being employed to improve emergency response planning.
- Advanced satellite communications technologies and data relay allow real-time monitoring of the situation, and satellite remote sensing images and products are being used by relief agencies to assess the extent of the damage and determine where relief efforts are most critical and how best to carry them out. Satellite images from the December 26 tsunami also provided the first large-scale, open ocean data of a major tsunami event.
- And, tsunami education programs are being developed and used with at-risk populations, such as NOAA's National Weather Service TsunamiReady Program that provides public education and preparedness measures for vulnerable U.S. coastal communities.

Tsunami detection begins with seismic monitoring. The Global Seismographic Network, which is managed jointly by the USGS and NSF with international partners, currently has a network of 137 seismic stations that have been installed around the world in a variety of configurations. The seismographs detect earthquakes and, judging from the location, type and magnitude of the earthquake, can indicate the possible generation of a tsunami. In many areas of the globe, the presence of a tsunami can only be confirmed as the tsunami nears shore and is detected by tidal gauges. However, in the Pacific Ocean NOAA has deployed six Deep Ocean Assessment and Reporting of Tsunami (DART) systems consisting of a seafloor pressure sensor that can detect a tsunami as it passes and relay the information to a moored surface buoy for communication via satellite to Tsunami Warning Centers. DART systems provide earlier and more accurate tsunami detection and significantly reduce costly false alarms.

U.S. plans for improved initial tsunami detection and warning hinge on deploying more DART systems to cover at-risk areas of the world's oceans, and on improving the Global Seismographic Network to provide enhanced coverage as well as improved analysis and communications of earthquake activity. Additional research into seismic and tsunami processes, and public education and preparedness programs, are also essential. The Administration has outlined detailed plans for an enhanced U.S. system that will provide nearly 100 percent detection capability for the U.S. coasts, and we have proposed to commit $37.5 million over the next two years to build and deploy this system. You will hear the details of this proposal from the other members of this panel.

International Coordination for Tsunami Readiness

Tsunamis and many other naturally occurring phenomena are global in scale and require international cooperation in response. The Administration is committed to working with our international partners on the process of developing a global tsunami detection, warning and response capability.

In the aftermath of December 26, a number of countries have called for expanded tsunami warning systems both in the Indian Ocean and globally. Australia, Germany, Japan, India, China and other countries quickly announced proposals for establishing early warning systems for tsunamis or, in the case of China, for all natural disasters. A number of countries and organizations have also proposed special international meetings on these topics. We are endorsing and promoting coordination of efforts among likely key contributors as well as incorporation of these efforts into existing mechanisms for global cooperation on disaster warning and reduction.

We propose that coordination be carried out through the Intergovernmental Group on Earth Observations (GEO). Enhanced Earth observation was a core element of the 2003 G–8 Evian Action Plan on Science and Technology for Sustainable Development. The World Summit on Sustainable Development in Johannesburg in 2002 also called for greater integration of Earth observation systems. Responding to this priority, the U.S. hosted the first Earth Observation Summit in Washington, DC in July 2003. As a result of this meeting, the GEO was established to organize the development of a comprehensive, coordinated, and sustained Global Earth Observation

System of Systems (GEOSS). 56 countries are currently GEOSS partners, including India, Indonesia and Thailand. All nations are invited and encouraged to join. GEO has developed a ten-year plan that is focused on nine societal benefits, including "reduce loss of life and property from disasters" and "protect and monitor our ocean resources." Once implemented, this plan could not only revolutionize our understanding of the Earth and how it works, but how countries cooperate.

It is important to note that UNESCO's Intergovernmental Ocean Commission (IOC) is a GEO member and the coordinating body of the existing Tsunami Early Warning System in the Pacific. Efforts to establish a tsunami early warning system in the Indian Ocean can benefit from the experience and expertise of the IOC, not only in coordinating the Pacific Early Warning System, but also in addressing the full range of ocean and coastal problems through the sharing of knowledge, information and technology among countries.

At the World Conference on Disaster Reduction, January 18–22, in Kobe Japan, the U.S. delegation affirmed U.S. commitment to working with our international partners on a global tsunami warning system. I have just returned from the Ministerial Meeting on Regional Cooperation on Tsunami Early Warning Arrangements in Phuket, Thailand, at which we considered a Thai proposal for developing a regional tsunami early warning system for the Indian Ocean and Southeast Asia. The U.S. has proposed that the development of any regional or global tsunami warning system—particularly in the Indian Ocean—be coordinated through GEO and be a top, near-term priority for GEOSS. This discussion will continue when the Group meets in Brussels, February 14–16 and formally adopts the GEOSS 10-year implementation plan. After the implementation plan is ratified by the GEOSS partners in February, specific country commitments and steps forward will be important topics for the G–8 summit in July 2005.

As part of the strategic planning for this international "system of systems," the U.S. has developed its own *Strategic Plan for the U.S. Integrated Earth Observation System* which, like the international plan, focuses on the nine societal benefit areas. This strategic plan was developed by the NSTC Interagency Working Group on Earth Observations, and provides the essential framework for the U.S. contribution to the GEOSS implementation plan. The expansion of the U.S. tsunami warning system will be implemented in the context of this U.S. Integrated Earth Observation System and as a U.S. contribution to GEOSS.

I should also mention that Admiral Lautenbacher is the U.S. Co-Chair of GEO, along with Japan, the European Commission, and South Africa, and that Dr. Groat is the U.S. representative to GEO. They will also speak in more detail about the development of GEOSS and the U.S. contributions to this important international project.

Conclusion

In closing, I would like to quote David Broder of the Washington Post on this topic: "Just as the world has managed to put aside political, religious, and ethnic rivalries to help the victims of this disaster, so the scientists and environmentalists meeting in Brussels will have an opportunity to show their foresight in making such calamities less likely. *The United States leadership in this international effort is a source of pride for the nation.*"

The CHAIRMAN. We thank you very much. I apologize for the interruption.

General Kelly, we're pleased to have your statement.

Before your statement, I would place in the record the letter we received from the General Counsel of your Department which advises us that the Administration does support this bill.

[The information referred to follows:]

FEBRUARY 1, 2005

Hon. TED STEVENS,
Chairman,
Commerce, Science, and Transportation Committee,
Washington, DC.

Dear Mr. Chairman:

This letter provides you with the Department of Commerce's views on S. 50, the "Tsunami Preparedness Act". The recent catastrophic event in the Indian Ocean highlights the threat tsunamis pose to many coastal communities, and the need to defend American communities against future tsunamis. The Department supports the Committee's efforts to strengthen the National Oceanic and Atmospheric Administration's (NOAA) tsunami detection, forecast, warning, mitigation and education and outreach programs. In light of this event, as well as this past hurricane season, the Department believes that we should take this opportunity to strengthen and clarify NOAA's responsibilities for protecting lives and property from the broad spectrum of natural hazards the nation faces. We would like to work with the Committee this year to pass the Administration's NOAA Organic Act, which provides the necessary authorities and flexibility for NOAA to effectively and efficiently carry out its mission, including tsunami warnings.

While the Department supports the Committee's legislative intent to address tsunamis through the authorization process, we are concerned that the specificity in the proposed bill could unintentionally limit NOAA's ability to effectively manage these programs. Our major concerns are with sections 3(b), which could restrict NOAA's ability to apply new technologies and techniques, and 3(d)(4), 3(e), 4(c)(6), 6(a)(1), 6(b) and 7(c), which seek to restrict the authority of NOAA and the Administrator, and which would impair NOAA's ability to manage its own resources and priorities. Further, we are concerned that S. 50 does not vest authorities in the Secretary of Commerce, who is responsible for all Department of Commerce programs.

Finally, the Department requests that all funding authorized for this purpose be consistent with the amounts contained in the Administration's proposal for strengthening the U.S. Tsunami Warning System, which was released on January 14, 2005. The Department of Commerce appreciates the opportunity to present views on S. 50 and looks forward to working with you to ensure NOAA has the necessary authorities to respond effectively to all natural hazards, including tsunamis.

The Office of Management and Budget has advised that there is no objection to the transmittal of these views from the standpoint of the Administration's program.

Sincerely,

JANE T. DANA,
Acting General Counsel

STATEMENT OF BRIGADIER GENERAL JOHN J. KELLY, U.S. AIR FORCE (RETIRED), DEPUTY UNDER SECRETARY OF COMMERCE FOR OCEANS AND ATMOSPHERE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

General KELLY. Mr. Chairman, thank you for those kind remarks about my boss. I'll pass them to him, and hopefully that will help speed his recovery. I know he really wanted to be here today to talk about this subject, because he keenly cares about it.

The CHAIRMAN. Well, he is a great friend, and we visited with him when he visited the Hawaii Tsunami Center, just recently. So we do send our best wishes.

General KELLY. Chairman Stevens, Senator Inouye, Members of the Committee, I thank you for the opportunity to testify about NOAA's activities with tsunamis, and I appreciate you submitting my written remarks and including them in the record.

What I'll briefly focus on this morning is the U.S. Tsunami Warning Program, how the U.S. can help the world better prepare for tsunamis, and NOAA's role in the Tsunami Warning Program.

NOAA and its predecessor agencies have provided tsunami warning services to this nation since 1949. In 1996, as you mentioned, the National Tsunami Hazard Mitigation Program was established, and it is a NOAA-led effort, to forge partnerships with federal and state entities to detect and, most importantly, prepare for, and respond to, tsunamis.

Your continued support for that program has helped prepare this nation for the next tsunami in three ways. One, creation of tsunami flooding and inundation maps; the use of these maps to establish TsunamiReady committees; and improvements in tsunami warning services through research, better use of seismic and deep-ocean tsunami data, and the development of forecast models. NOAA is proud of the collective accomplishments that both we, on the federal side, and with our partners in the states have accomplished, and believe your investments and NOAA's efforts have already paid big dividends. Yet the tragedy in the Indian Ocean shows that we need to do more to accelerate and expand our tsunami preparedness in this country.

The current Tsunami Warning System consists of two warning centers, the Richard H. Hagemayer Center, in Hawaii, and the West Coast Alaska Tsunami Warning Center, in Palmer, Alaska. These centers are responsible for issuing all tsunami warning/watch advisory and information messages.

As Dr. Marburger mentioned, NOAA research activities developed the Deep–Ocean Assessment and Reporting of Tsunamis, or DART, buoys to measure tsunamis in the deep ocean, and to transmit this information back to the warning centers. These instruments accurately characterize the size of a tsunami by measuring the pressure wave from the deep-ocean floor as it passes. Tsunamis as small as half a centimeter have been measured.

In November of 2003, the DART buoys demonstrated their effectiveness. A large earthquake occurred in the Aleutian Islands and generated a tsunami. The two warning centers evaluated the tsunami, based on data from the DART buoy, and confirmed only a small wave. This accurate prediction of the non-destructive tsunami is estimated to save the government of Hawaii about $68 million in preparation costs. We also have about 100 water gauges used by the Tsunami Warning Center to provide information on the magnitude of the tsunami.

The NOAA Hagemayer Warning Center also serves as the operational center for the International Tsunami Warning Center of the Pacific, which is comprised of 26 nations. The center's primary responsibility is to issue tsunami warnings in the Pacific Basin for tsunamis that may cause damage far away from their source; however, it is the responsibility of the member nation to issue local warnings.

On Sunday the 26th of December, within 7 minutes of notification, and within 15 minutes of the Indonesian earthquake, both centers issued tsunami information bulletins. However, an effective tsunami warning system requires many components: one, an assessment of the hazard; two, near-realtime data; three, highspeed data-analysis capabilities; four, a highspeed tsunami warning communications system; and, last, but probably most important, an effective local communications infrastructure for the timely and effective dissemination of warning and evacuation requirements. Unfortunately, such a system does not exist in the Indian Ocean.

With global attention on this important matter, we have a great opportunity to better prepare the world for tsunamis through the development of a Global Earth Observation System of Systems. The United States has been leading this effort for the past 2 years. Next month, in Brussels, 54 nations of the world, and the European Union, will gather together to reach an agreement that will begin the development of GEOSS.

Vice Admiral Lautenbacher is the co-chair of that effort, and we are going to work to ensure that the GEOSS's first order of priority is to develop a global tsunami warning system. It is my hope that positive changes in technology, education, and cooperation will emerge from what happened in the Indian Ocean.

The Bush Administration recently announced that we are committed to completing the current U.S. Tsunami Warning System by mid-2007. NOAA's contribution to that system includes modernizing and expanding the existing DART buoy network. We plan on installing 32 new operational DART buoys—25 in the Pacific, 7 in the Atlantic and the Caribbean. And, as you well know, Mr. Chairman, the weather in the Aleutians is a real challenge, and it complicates our ability to repair the DART buoys when they malfunction; and so, we are going to place, in the Aleutian area, in the water, three backup buoys, so if a primary one goes down, we'll automatically have an ability to continue to get that data.

We will also procure and install 38 new sea-level monitoring and tide gauge stations, and expand the operation of the Alaska and Hawaii Tsunami Warning Centers to 24 hours a day, 7 days a week. NOAA forecasters will then be better able to protect the United States, and will be able to alert communities within minutes of a tsunami-producing effect.

As you mentioned, Mr. Chairman, the Department of Commerce does support Senate Bill 50, the Tsunami Preparedness Act, and you do have the letter of support from the Department.

In closing, I appreciate your efforts to help better prepare this country for the next tsunami, because it's not a question of if there will be one, it is when it will be and where it will be.

Thank you.

[The prepared statement of Vice Admiral Lautenbacher follows:]

PREPARED STATEMENT OF VICE ADMIRAL CONRAD LAUTENBACHER, JR., U.S. NAVY (RETIRED), UNDERSECRETARY OF COMMERCE FOR OCEANS AND ATMOSPHERE; ADMINISTRATOR, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Thank you, Mr. Chairman and Members of the Committee, for the opportunity to testify before you regarding the National Oceanic and Atmospheric Administrations (NOAA) activities with tsunamis. I am Vice Admiral (retired) Conrad Lautenbacher, Jr., Undersecretary of Commerce for Oceans and Atmosphere and NOAA Administrator.

As the world and our Nation mourn the loss of life from the Indian Ocean tsunami tragedy, we recognize the very real threat of tsunamis and ask, "Could it happen here?" We need to be able to answer that question with a high degree of confidence.

We know a tsunami can affect any community along the coast of the United States. This is particularly true for the Pacific coast, where tsunamis have been more frequent. The recent event in Southeast Asia and Africa highlights the need to identify steps we can take to mitigate the potential impact of such an event here at home.

NOAA and its predecessor agencies have provided tsunami warning services for our Nation since 1949. Following the 1992 Northern California earthquake/tsunami, Congress asked NOAA to examine tsunami preparedness of the U.S. West Coast and the National Tsunami Hazard Mitigation Program (NTHMP) was born. The NTHMP is a NOAA led effort to forge federal/state partnerships to detect, prepare and respond to tsunamis. Your continued support for this program has prepared our country for the next U.S. tsunami in three main ways: (1) Creation of tsunami flooding/inundation maps using advanced numerical models; (2) Use of these maps to develop evacuation procedures, road signs to guide evacuation, educational programs to raise tsunami awareness, and the establishment of TsunamiReady communities; and (3) Improvements in tsunami warning services through the use of better seismic and deep ocean tsunami data and the development of tsunami forecast models. NOAA is proud of the collective accomplishments of federal partners (USGS, NSF, and FEMA) along with our state partners (Alaska, California, Hawaii, Oregon, and

Washington). Over the past 8 years we have identified what needs to be done, but so far there are inundation maps for only 30 percent of the Pacific states coastline, local communities are in need of warning dissemination systems, and the NOAA tsunami warning system needs more deep ocean tsunami detectors to improve warning services. Your investments and NOAA's efforts to date have paid large dividends, yet, in the face of the Sumatra tsunami, we believe our Nation should accelerate and expand our tsunami preparedness efforts.

In this testimony, I will describe our existing tsunami warning program, including a brief overview of our work with the International community; specific actions NOAA took during the recent tsunami; and then briefly outline the Administration's plan for developing a global tsunami warning system.

Tsunamis are natural disasters that can form in all of the world's oceans and inland seas, and in any large body of water near seismic activity. Each region of the world appears to have its own cycle of frequency and pattern for generating tsunamis that range in size from small events (no hazards) to the large and highly destructive events. Eighty-five percent of tsunamis occur in the Pacific Ocean and its marginal seas. This is not surprising as the Pacific Basin covers more than one-third of the earth's surface and is surrounded by a series of mountain chains, deep-ocean trenches and island arcs called the "ring of fire."

Most seismic activity occurs in this ring of fire where the main tectonic plates forming the floor of the Pacific collide against one another or against the continental plates that surround the ocean basin, forming subduction zones. While tsunamis can be generated by any sudden pressure source in the water, such as a meteor, landslide, etc., most are generated from earthquakes. Large earthquakes can create tsunamis that may be locally devastating, their energy decays rapidly with distance. Usually they are not destructive more than a few hundred kilometers away from their sources. That is not the case with tsunamis generated by great earthquakes in the North Pacific or along the Pacific coast of South America. On the average of six times per century, a tsunami caused by an earthquake in one of these regions sweeps across the entire Pacific Ocean, is reflected from distant shores, and sets the entire ocean in motion for days. Although not as frequent, destructive tsunamis have also been generated in the Atlantic and the Indian Oceans, the Mediterranean Sea and even within smaller bodies of water, such as the Sea of Marmara, in Turkey. There have also been tsunamis in the Caribbean, but the lack of any recent tsunami in that area has lowered the level of interest and hindered establishing a warning program in that area.

According to NOAA's National historical tsunami databases, during the 105-year period from 1900 to 2004:

- 923 tsunamis were observed or recorded in the Pacific Ocean.
- 120 tsunamis caused casualties and damage, most near the source. Of these, at least 10 caused widespread destruction throughout the Pacific.
- The greatest number of tsunamis during any one year was 23 in 1938. While most were minor, one event did result in 17 deaths.
- There was no single year during this period that was free of tsunamis.
- 19 percent of all tsunamis were generated in or near Japan; 9 percent were generated off Alaska and the west coasts of Canada and the United States; and 3 percent were generated near Hawaii.

The U.S. Tsunami Warning System consists of two warning centers: the Richard H. Hagemeyer Pacific Tsunami Warning Center (PTWC) in Ewa Beach, Hawaii; and the West Coast/Alaska Tsunami Warning Center (WC/ATWC) in Palmer, Alaska. NOAA conducts research on tsunamis, operates essential ocean buoys and tide gauges to detect tsunamis, and works with other federal, state, local government agencies and universities as our partners in the tsunami warning mission.

The Richard H. Hagemeyer Pacific Tsunami Warning Center in Hawaii was established in 1949 in response to the unpredicted 1946 Aleutian tsunami, which killed 165 people on the Hawaiian Islands. In 1967, the West Coast/Alaska Tsunami Warning Center in Palmer, Alaska, was created as a result of the 1964 Great Alaska earthquake and tsunami. These centers are responsible for issuing all tsunami warning, watch, advisory, and information messages to emergency management officials and the public throughout their respective areas of responsibility. The Pacific Center covers United States interests and territories throughout the Pacific, including Hawaii, while the West Coast/Alaska Center covers Alaska, and the west coast of North America from British Columbia, Canada through California.

About 100 water level gauges are used by the Tsunami Warning Centers and are operated by the United States and our international partners. These gauges are along the coasts of islands or continents around the Pacific Rim. NOAA operates many of these stations, including 33 from NOAA's National Water Level Observation Network in the Pacific Ocean basin, which are equipped with software to support the Tsunami Warning System. Water levels from these gauges can be sent directly to NOAA Tsunami Warning Centers and others who want the information. NOAA is working to upgrade the nationwide network with a real-time capability to provide a continuous (minute-by-minute) stream of water level data for integration with tsunami warning systems and research applications. NOAA also helps support many coastal gauges located in other countries around the Pacific.

NOAA operates six Deep-ocean Assessment and Reporting of Tsunamis (DART) buoys. NOAA research activities developed these buoys to measure tsunamis in the deep ocean and to transmit the information back to the Warning Centers in near real time. These instruments accurately calculate the size of the tsunami by measuring the pressure it exerts on the deep ocean floor as the wave passes over. Tsunamis as small as 0.5 cm have been measured. NOAA began placing DART buoys in the Pacific Ocean in 2002 and plans to have a complete coverage of potential Pacific tsunami source zones over the next few years.

In November 2003, the buoys demonstrated their effectiveness. A large earthquake occurred in the Aleutian Islands and generated a tsunami. The two Tsunami Warning Centers evaluated the tsunami using coastal gauge data but did not "stand down" until a reading arrived from the nearest DART buoy confirming only a small tsunami. During post analysis of the event, DART data were used for a model simulation and the output from the simulation accurately predicted the 2 cm tsunami recorded at Hilo, Hawaii. This NOAA model is still being developed, but an initial version will be transferred to the warning centers for test operations this year. DART data and the forecast model show much promise to help accurately predict tsunami impacts. In the history of the Pacific Warning Center, 75 percent of its warnings to Hawaii have been for non-destructive tsunamis. The DART data combined with forecast models promise to significantly reduce false alarm rates as well as provide a better measure of the severity of destructive tsunamis for Hawaii and all other parts of the Pacific. The accurate forecasting of a non-destructive tsunami in November 2003 saved Hawaii an estimated $68M in projected evacuation costs.

The Pacific Center also serves as the operational center for the International Tsunami Warning System of the Pacific, which is comprised of 26 member nations of the Pacific Rim. These members share seismic and water level information with the Pacific Center so the Center can determine whether a tsunami was generated in the Pacific Basin and assess its strength. The Pacific Center's primary responsibility is to issue tsunami warnings for Pacific Basin teletsunamis—tsunamis that can cause damage far away from their source. It is not the Center's responsibility to issue local tsunami warnings from seismic events outside of the United States. For example, if an earthquake occurs off the coast of Japan and a local tsunami is generated, it is Japan's responsibility to issue a local tsunami warning. However, it is the Pacific Center's responsibility to warn all participating Nations in the Pacific Basin if the Japanese tsunami will cause damage far from its source.

Only Australia and Indonesia have coastlines bordering both the Pacific and Indian Ocean coasts. None of the other countries impacted by the Indian Ocean tsunami have coasts bordering the Pacific Ocean and therefore they do not receive tsunami bulletins via the automated dissemination network.

Thailand and Indonesia are member states within the International Tsunami Warning System in the Pacific (ITSU), but their participation has been limited. Thailand has no coast along the Pacific, and Indonesia's tsunami threat is primarily outside the Pacific Basin. As a member of the International Coordination Group (ICG) for ITSU, the U.S. has actively encouraged non-member States to become ICG/ITSU members. Under the IGC/ITSU, the U.S. has actively supported the need for global tsunami mitigation actions and will continue to provide support through the development of a Global Earth Observation System of Systems (GEOSS), an effort in which the UNESCO Intergovernmental Oceanographic Commission, the UN International Strategy for Disaster Reduction (ISDR), and a number of other UN agencies and programs participate.

NOAA Tsunami Warning Centers have no authority or responsibility to issue tsunami warnings for the Indian Ocean basin. However, knowing the concern Pacific countries might have about the potential devastating impact a large earthquake and resulting tsunami can inflict, on Sunday, December 26, 2004, at 8:14 p.m. EST, within 15 minutes of the Indonesian earthquake, both centers issued Tsunami Information Bulletins. These bulletins included location and initial magnitude (8.0) information and an assessment that there was no tsunami threat in the Pacific. As the Indian Ocean is outside the NOAA tsunami area of responsibility, NOAA Tsunami Warning Centers have no procedures in place to issue a warning for this region. An hour and 5 minutes after the earthquake, as additional information came in from seismic monitoring stations around the world, another bulletin was issued by both Centers revising the magnitude of the earthquake to 8.5. This time the bulletin contained a statement that the potential existed for a tsunami near the epicenter. Unfortunately, there was no sea-level data or other information available to substantiate or evaluate a tsunami until 3½ hours after the earthquake when news reports began coming indicating casualties in Sri Lanka and Thailand. At about the same time, data from the one sea-level gauge in the Indian Ocean (Cocos I; west of Australia) was received indicating a 45cm peak-to-trough non-destructive tsunami.

Sea-level gauges are essential elements of the current Tsunami Warning System in the Pacific. When strategically located, they are used to quickly confirm the existence or non-existence of tsunami waves following an earthquake, to monitor the tsunami's progress, and to help estimate the severity of the hazard. There was no data available from the Indian Ocean to help the warning centers know what was occurring.

An effective tsunami warning system requires (1) an assessment of the tsunami hazard, (2) near real-time seismic and oceanographic (sea-level change) data; (3) high-speed data analysis capabilities; (4) a high-speed tsunami warning communication system; and (5) an established local communications infrastructure for timely and effective dissemination of the warning and evacuation requirements. It is also critical that coastal populations are educated and prepared to respond appropriately to tsunami warnings and calls for evacuations. For the Pacific Basin, these tsunami warning requirements are well known. Unfortunately, for the Indian Ocean basin, they were basically non-existent.

There are currently 6 DART buoys in the Pacific operated by NOAA—3 off the coast of Alaska, 2 off the coast of the western U.S., and one in the eastern Pacific. These first buoys of the currently envisioned 29 buoy array are an example of a successful transition of buoys from research and development into an operational system. Presently, three of the deployed DART buoys are non-operational due to failure of the sea floor pressure unit (buoys 46401 and 46402; Aleutian Islands) and communication module inside the surface buoy (buoy 46404; Pacific Northwest/Washington). The Washington buoy has been out of service for 15 months for various reasons. Initially there was a power failure, but when the buoy was retrieved an explosion occurred. Service to all buoys was stopped while a safety stand-down was held to determine the cause of the explosion and while a redesigned buoy compartment was implemented in all buoys. Upon service, the Washington buoy's sea floor unit failed, indicating a problem with undersea cabling. A technical stand-down led to further refinement of the cables. Weather conditions further delayed our attempts to bring this buoy back online; the sea floor unit was repaired during a service visit in January. Unfortunately, subsequent to that visit the buoy experienced failure of the communications module. A service visit to repair the Washington buoy is expected in mid-February. Of the two buoys in the Aleutian Islands, one has been out of service for 6 months and the other for 1 month. As many of you are aware, particularly you Mr. Chairman, the seas are particularly rough in this region during the winter months. We are currently waiting for a safe weather window, and will service the buoys as soon as that window of opportunity presents itself.

The government of Chile purchased one DART buoy from NOAA, and that buoy is now operating off the northwest coast of Chile; another buoy is in the process of being purchased by Chile at this time. Japan also operates a few cabled deep ocean sensors off its Pacific coasts. The NOAA buoys represent the only current deep ocean capability available to the Tsunami Warning Centers to detect tsunamis. In July of last year, staff from the Pacific Center had discussions with Japanese representatives about the possibility of allowing PTWC access to data from the Japanese cabled buoys.

While technical equipment is required for detection and communication, equally important are continued research and development, and education and outreach to mitigate potential impacts from tsunamis. People must have the knowledge and information to act during potentially life threatening events. Outreach and education efforts, such as NOAA's own StormReady and TsunamiReady programs, are key components of the U.S. National Tsunami Hazard Mitigation Program (NTHMP). These programs foster interaction between emergency managers and their citizens, provide robust communications systems, and establish planning efforts before certification. NOAA also developed multi-hazard risk and vulnerability assessment training and decision support tools using GIS mapping technology to highlight populations, infrastructure and critical facilities at risk for coastal hazards. These tools and other support are critical to land use planning, pre-disaster planning, mitigation efforts, and targeted dissemination of outreach, education and information about high-risk areas.

The International Strategy for Disaster Reduction (ISDR) was launched by the General Assembly of the United Nations to provide a global framework for action to reduce human, social, economic, and environmental losses due to natural and man-made hazards. The ISDR aims at building disaster-resilient communities, highlighting the importance of disaster reduction as an integral component of sustainable development. ISDR is the focal point within the United Nations system for coordination of strategies and programs for disaster reduction and to ensure synergy between disaster reduction activities and those in the socioeconomic and humanitarian fields. One particularly important role of ISDR is to encourage both policy and awareness activities by promoting national committees dedicated to disaster reduction and by working in close association with regional initiatives. As part of this effort, tsunami hazard maps have been produced for over 300 coastal communities in over 11 countries, including 130 communities throughout the United States.

The United Nation's Education, Scientific, and Cultural Organization's (UNESCO) Intergovernmental Oceanographic Commission (IOC) has developed products to help countries implement tsunami response plans. Road signs and other mitigation products are available through the NTHMP (http://www.pmel.noaa.gov/tsunami-hazard). In summary, Tsunami Response Plans are probably the most cost-effective way to create a tsunami resilient community. To be successful, communities must remain committed to a continuous, long-term education program. Tsunamis are infrequent events and it is important to ensure future generations understand tsunami safety.

Protecting near-shore ecosystems, like coral reefs, is equally important for maintaining disaster-resilient communities. The international media and South Asian officials reported less destruction in locations protected by wave-absorbing healthy coral reefs. NOAA and our federal, state, territorial, and international partners work to protect and preserve coral reef ecosystems.

The United States will continue working closely with the international community to help implement recommended tsunami detection and warning measures for the Indian Ocean Basin and other regions of the world currently without adequate tsunami warning capability. A comprehensive global tsunami warning program requires deploying DART buoys along each of the world's major subduction zones; adding real-time sea-level monitoring/tide gauge stations; establishing Regional Centers for Disaster Reduction, assessing hazards, promoting education and outreach efforts; and conducting research and development.

As recently announced, the Bush Administration has a plan to upgrade the current U.S. Tsunami Warning System. NOAA's contribution to this plan includes procuring and installing 32 new DART buoys, including 25 new buoys in the Pacific and 7 new buoys for the Atlantic and Caribbean. We expect to have the complete network of DART buoys installed and operational by mid-2007; 20 buoys should be operational in FY06, with the final 12 in place in FY07. In addition to the DART buoys, NOAA will procure and install 38 new sea level monitoring/tide gauge stations. The Administration has allocated $24M, over the next two years, to NOAA for this effort, including $18.1M for the Pacific Basin and $5.9M for Atlantic/Caribbean/Gulf.

There were many lessons learned from the Indian Ocean tsunami. A key point to make is that, for all coastal communities, the question is not "if" a tsunami will occur, but "when." We know what causes a tsunami to develop, and we know a great deal about how to track them and forecast their path. With expansion of the U.S. Tsunami Warning System, NOAA forecasters will be able to detect nearly 100 percent of tsunamis affecting the United States and will be able to respond and alert communities within minutes of a tsunami-producing event. With expanded education and outreach via NOAA's TsunamiReady program and other efforts, we can rest assured that our coastal communities have the opportunity to learn how to respond to a tsunami event and that we have minimized the threat to American lives.

With global attention on this important matter, we have a great opportunity to help the world better prepare for tsunamis through the development of a Global Earth Observation System of Systems (GEOSS). This system would include a real-time global seismic monitoring network, a real-time DART network, and a near real-time sea level monitoring network. I will be a member of the U.S. delegation at the Third Earth Observation Summit (February 16, 2005; Brussels, Belgium) and will work to ensure that the development of a global tsunami warning system is a high priority for the larger Global Earth Observation System of Systems and the Integrated Ocean Observing System.

In closing, I would like to thank Members of this Committee for their work in developing S. 50, the Tsunami Preparedness Act. The catastrophic event in the Indian Ocean highlights the threat tsunamis pose to all coastal communities, and the need to defend American communities against future tsunamis. The Department of Commerce supports the purposes of this legislation to authorize and strengthen the National Oceanic and Atmospheric Administration's tsunami detection, forecast, warning, mitigation and education and outreach programs. As you know, the Department believes that in addition to improving the ability to detect and forecast tsunamis, it is equally important to educate citizens on what actions to take when they receive a tsunami alert. The Department supports and appreciates the language that calls for strengthening the TsunamiReady program, an administrative initiative to educate and prepare communities for survival before and during a tsunami.

We look forward to working with Congress and other Nations around the world to help take the pulse of the planet and make our world a safer place. Attached to this written testimony submitted for the record is an article published in the International Tsunami Information Center Tsunami Newsletter, which provides detailed information about NOAA's Pacific Tsunami Warning Center. Much more information about tsunamis can be found at http://wcatwc.arh.noaa.gov, http://www.pmel.noaa.gov/tsunami/, http://www.prh.noaa.gov/ptwc/, and http://www.ngdc.noaa.gov/spotlight/tsunami/tsunami.html.

The CHAIRMAN. Thank you very much.

Dr. Bement, the National Science Foundation Director, please?

STATEMENT OF DR. ARDEN L. BEMENT, JR., DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. BEMENT. Thank you, Mr. Chairman, Ranking Member Inouye, and Members of the Committee. Thank you very much for the opportunity to present testimony on the National Science Foundation's role in providing greater——

The CHAIRMAN. Could you pull that microphone up closer, please?

Dr. BEMENT. Is this better?

So, again, I thank you for the opportunity to present testimony on the National Science Foundation's role in providing greater understanding and education of tsunami events through science and engineering research.

Because the National Science Foundation has the mission to build the nation's scientific and engineering knowledge capacity and capability, NSF and the communities we support have a responsibility to undertake relevant research in the context of these events.

Through rapid-response reconnaissance teams supported by the National Science Foundation, we have moved quickly to focus the U.S. research community's efforts to understand the nature of this event, identify relevant lessons for future disasters, and build on the research that we have funded in the past.

Our rapid-response research teams include problem-focused interdisciplinary collaborations. In these collaborations, NSF is working with international partners and countries directly affected, or neighboring the disaster, to improve communications, collaboration, and priority-setting as the immediate and longer-term research efforts get underway.

This disaster has raised awareness of, and attention to, earthquakes and tsunamis and their predictability. NSF has long funded the research and instrumentation aimed at detecting and understanding the impacts of these phenomena.

Prominent examples include the realtime Global Seismographic Network, or GSN, the data from which forged the critical core of the early warning of this event.

From the figures accompanying my written testimony, we see the power of this warning system. Figure 1, on the easel, with the globe in the center, depicts the location of the GSN stations in relation to the epicenter of the quake, which is in the center of the diagram. Figure 2 illustrates the collected seismic measurements from these stations made as the wave front traveled around the world. These charts illustrate the power of this network, which is operated by the Incorporated Research Institutions for Seismology.

The GSN is funded, in partnership, by NSF and the United States Geologic Survey, and it is a primary international source of data for earthquake location and also tsunami warning.

NSF also funds research designated to support damage and loss prediction and avoidance. These efforts include the effects of earthquakes and tsunamis on buildings, bridges, and critical infrastructure systems. Additionally, research efforts center on estimating economic consequences, human and societal impacts, and emergency response and warning capabilities. For example, engineers and scientists at the Earthquake Engineering Research Centers and the Southern California Earthquake Center are working to establish the nature, attenuation, and impacts of subduction-type earthquake ground-shaking. These centers are developing hazard assessments that can be applied to critical infrastructure design in areas threatened by earthquake and tsunami hazards.

Mr. Chairman, more than 75 million Americans in 39 states live in areas at risk for earthquakes. The NSF has recently established the George E. Brown, Jr., Network for Earthquake Engineering Simulation, or NEES, as we refer to it. This is a major national infrastructure project that is revolutionizing earthquake engineering research. It allows NSF-funded researchers to create physical and computational simulations in order to study how earthquakes and tsunamis affect our critical infrastructure. The NEES Tsunami Wave Basin at Oregon State University is the world's most comprehensive facility for studying tsunamis and storm waves.

Mr. Chairman, thank you, again, for the opportunity to testify on a topic of great importance to the science and engineering communities. I hope that I have conveyed to you the NSF's serious approach to generate new knowledge about the natural phenomena that lead to tsunami events, also the design of safer coastal structures, the development of early warning and response systems, and effective steps for disaster recovery.

Thank you very much.

[The prepared statement of Dr. Bement follows:]

PREPARED STATEMENT OF DR. ARDEN L. BEMENT, JR., DIRECTOR, NATIONAL SCIENCE FOUNDATION

Good morning. Mr. Chairman, Ranking Member Inouye, and Members of the Committee, thank you very much for the opportunity to present testimony on the National Science Foundation's role in providing greater science and research to understanding tsunami events.

The events surrounding the December 26, 2004, Sumatra-Andaman Island earthquake and Indian Ocean tsunami constitute disasters for the natural, social, and constructed environments in the region. Because the National Science Foundation (NSF) has the mission to build the nation's scientific and engineering knowledge capacity and capability, NSF and the communities we support have a responsibility to undertake relevant research in the context of the events.

NSF has moved quickly to focus the U.S. research community to address the disaster, response, and relevant lessons for future disasters, building on the research related to these topics that we have funded in the past. Later in my testimony, I will detail the ways our previous research has contributed to the ability of the

United States and others to understand and respond to the disaster, and information on the NSF's role in supporting the U.S. research community's immediate response to the tragedy.

This disaster has revealed several areas in which understanding—as well as infrastructure—were insufficient to deal with the crisis, and where NSF's research communities can bring basic knowledge and relevant infrastructure to bear. The U.S. communities include problem-focused, interdisciplinary research teams, often with international partners in mutually beneficial and sustainable collaborations. NSF is working with counterpart organizations in countries directly affected by the disaster, as well as other countries in the region, to improve communications, collaboration, and priority setting as the immediate and longer-term research efforts get underway.

This disaster has raised awareness of and attention to the phenomena of earthquakes and tsunamis, and their predictability. NSF has long funded scientific and engineering research infrastructure aimed at detecting and understanding the impacts of these phenomena. Prominent examples include the real-time Global Seismographic Network (GSN), the data from which forged the critical core of the early warning of the December 26, 2004, earthquake. This Network, operated by the Incorporated Research Institutions for Seismology, is funded in partnership by NSF and the United States Geological Survey, and is the primary international source of data for earthquake location and tsunami warning.

We also fund research designed to support damage and loss prediction and avoidance for the United States and elsewhere, including earthquake and tsunami effects on buildings, bridges, and critical infrastructure systems, and estimates of economic consequences, human and societal impacts, and emergency response. For example, engineers and scientists at the Earthquake Engineering Research Centers and the Southern California Earthquake Center are working to establish the nature and attenuation of subduction-type earthquake ground shaking, and to develop probabilistic hazard assessments that can be applied to critical infrastructure design in areas threatened by earthquake and tsunami hazards. NSF has recently established the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), a major national infrastructure project to create a complete system of test facilities. The project is revolutionizing earthquake-engineering research. NSF-funded researchers create physical and computational simulations in order to study how earthquakes and tsunamis affect buildings, bridges, ports, and other critical infrastructure. The NEES Tsunami Wave Basin at Oregon State University is the world's most comprehensive facility for studying tsunamis and storm waves.

These globally historic earthquake and tsunami events have heightened awareness in the engineering and science research communities of the huge responsibilities to create new knowledge about our human and organizational environments, natural biologic systems, constructed environments, and about our vulnerabilities in the face of damaging forces. It is important that the work includes all aspects of environmental damage, mitigation, response, and recovery.

The National Science Foundation Research Portfolio

The tremendous loss of lives and destruction of the natural and built environments resulting from the December 26 events brought to the forefront questions about disaster preparation, mitigation, response, and recovery. NSF's research investments have developed a knowledge and human resource base over broad areas relevant to these questions. Current and past pertinent research activities include:

Earthquakes: The Sumatra earthquake occurred along a subduction zone where tectonic plates collide. These subduction quakes are the largest and most destructive type of earthquake, and cause most of the world's tsunamis. NSF researchers have been making exciting advancements in subduction zone research including new techniques and facilities that define the structure, chemistry and dynamics of active subduction zones. A prime example is the findings about the Cascadia subduction zone in the U.S. Pacific Northwest. This fault structure generated a 9.0Mw earthquake on January 26, 1700, with a tsunami that destroyed whole forests on the largely uninhabited Oregon coast, toppled buildings on Vancouver Island, and killed coastal dwellers in Japan.

Tsunami Generation: NSF research includes field studies using research vessels and other platforms and facilities, including the Integrated Ocean Drilling Program's (IODP) drill ship the *Joides Resolution*. NSF research aims to understand the processes by which earthquakes, large slumps, and other landslips generate tsunami waves, and to model how tsunamis interact with the shore zone, including the nature of present and past sediment deposits left by tsunamis.

Rapid Response Reconnaissance: NSF supports the Earthquake Engineering Research Institute (EERI) and its Learning from Earthquakes (LFE) project that trains and deploys rapid-response teams of civil engineers, geoengineers, and social scientists to earthquakes that occur around the world. These teams identify information resources, research needs, and provide ground truthing for remotely sensed observations. NSF also funds the Natural Hazards Research and Applications Information Center at the University of Colorado at Boulder, which supports rapid-response research by social science researchers, and leads the world as a clearinghouse for multidisciplinary and social science studies of hazards and disasters.

Remote Sensing: Remote-sensing technologies quantify damage over large geographic areas and provide reconnaissance information where access to impacted areas is difficult. For the first time, high-resolutions sensors (Quickbird and Ikonos), moderate-resolution sensors (SPOT, LandSat, and IRS), and low-resolution sensors (MODIS, Aster) are recording the Indian Ocean events in near real-time. With this information it will be possible to identify and quantify damage and impacts to critical infrastructure systems (including electric power systems, water supply, sewage, transportation, safe shelter buildings, ports, and harbors). Such assessments can then be verified by on-the-ground inspections.

Physical and Computational Simulation: Tsunami disasters are dominated by coastal damage and loss of life. Scientists and engineers need to predict site-specific wave run-up patterns and determine tsunami-induced forces and scour effects to enable better design of waterfront structures and help guide decision-making processes including vulnerability assessment. NSF research has developed scenario simulations for tsunami hazard mitigation, including tsunami generation, hydrodynamics, warning transmission, evacuation, human behavior, and social and environmental impacts. The NEES Tsunami Wave Basin is being used to construct and test large-scale, realistic models of infrastructure—such as shorelines, underwater pipelines, port facilities, and coastal communities.

Sensor Networks: NSF research investigates new uses for and new kinds of sensors and networks for health monitoring and damage assessment of the civil infrastructure, both physical and cyber. Flexible and scalable software architectures and frameworks are being developed to integrate real-time heterogeneous sensor data, database and archiving systems, computer vision, data analysis and interpretation, numerical simulation of complex structural systems, visualization, probabilistic risk analysis, and rational statistical decision making procedures. NSF has also funded research on socio-technical arrangements for bringing information to policymakers.

Risk Assessment: Risk assessment and decisions about preparing for risks are immediately relevant topics that NSF-funded scientists have researched in depth. Basic science and engineering research provides the in-depth understanding needed to design effective detection, warning, mitigation, response, and recovery programs. Research on risk communication and decision-making regarding low-probability, high-consequence events is being applied to many types of disasters. Key for application of engineering knowledge is to establish the basis for performance-based design to be applied to all critical infrastructure systems and facilities of the constructed environment.

Warning Systems and Evacuation: NSF has supported extensive and long-term research on warning systems and evacuation, with clear implications for managing tsunami events. NSF research includes basic work on integrated warning systems for rapid-onset extreme events, including detection, modeling, and communications technologies, and also the social and organizational components needed for effective warnings: societal and community public education and preparedness, appropriate authorities and resources for organizational and governmental entities responsible for warning and evacuation processes, appropriate messages and means of dissemination to at-risk populations, and the management and maintenance of warning systems over time. One specific focus for research has been sensor networks that must "funnel" a sudden impulse of data that is generated due to an anomalous event such as an earthquake, terrorist attack, flood, or fire. The objective is to understand how to design sensor networks to adequately handle these impulses of data and to feed the information into public warning systems.

Behavioral Responses: Emotional and cognitive responses to stress as well as vulnerability and resiliency in the face of threat and terror are the focus on current research in social psychology. Research in geography and regional science examines patterns of settlement that lead to social vulnerability and the differential impact of hazards, including earthquake hazards, on different groups. An earlier study exploring the restoration of assumptions of safety and control following the 2001 terror attacks has direct implications for understanding the restoration of human wellbeing following these devastating events.

Human and Socio-technological Response: Behavioral and social science research funded by NSF provides insights about how people respond to disasters and identifies the short- and long-term effects. Scientists have documented and analyzed social phenomena in the immediate wake of disasters, such as altruism, volunteerism, convergence, and improvisation. These phenomena vary by country and culture. NSF researchers are developing distributed, reliable, and secure information systems that can evolve and adapt to radical changes in their environment. Such systems would deliver critically important services for emergency communication and management through networked information services and up-to-date sensor data over ad-hoc flexible, fault-tolerant networks that adapt to the people and organizations that need them. Such technology facilitates access to the right information, for the right individuals and organizations, at the right time. This is necessary to provide security, to serve our dynamic virtual response organizations, and to support the changing social and cultural aspects of information-sharing among organizations and individuals.

Emergency Response Research: The complex problems associated with earthquake and tsunami hazard mitigation and response strategies necessitate interdisciplinary and international research efforts, including modeling and computational simulation, large-scale laboratory modeling, geographical information and communication systems, and social sciences and planning. NSF supports research on social, political, and managerial aspects of emergency response activities and aid provision, including need-based distribution of assistance within diverse societies.

Ecology: Research on the ecology of infectious disease contributes to understanding the dynamics of epidemics and change, particularly in the context of ecological changes such as those following natural disasters. Disturbance ecology examines how biological populations, communities and ecosystems respond to extreme natural and human events, including hurricanes and tsunamis. Long-term ecological research is critical to understanding the base line conditions, without which the changes resulting from catastrophic events such as earthquakes and tsunamis cannot be understood.

Microbial Genome Sequencing: NSF funded research on microbial genome sequencing provides key information that enables identification and understanding of the life functions and ecology of microbes that play critical roles in the environment, agriculture, food and water safety, and may cause disease in humans, animals, and plants. Genome sequence information can be utilized to develop tools to detect disease-causing organisms and develop countermeasures such as antimicrobial chemicals and vaccines.

Education and Human Resources: NSF has dozens of active projects funded that target or include Earth science education and understanding of natural hazards. For example, the NSF National Science, Mathematics, Engineering, and Technology Education (SMETE) Digital Library program is supporting a multi-year project to develop a data-oriented digital library collection on education in plate tectonics, the central Earth science paradigm governing earthquakes and resultant tsunamis. Such a collection works to “bridge the gap” between science data archives and libraries, and improves access to the historic and modern marine geological and geophysical data. Further, the project is enhancing the professional development of teachers through interactions with a local school district and with teachers nationwide. Also, NSF has supported the incorporation of advanced technologies in K–12 learning materials in Earth science, including visualizations and working with images from space, real-time data, and experimentation with models and simulations (techniques used in earthquake events to generate model predictions of tsunamis). This work was utilized to update and improve one of the most widely used high-school Earth science textbooks.

NSF Investments in Research Infrastructure

The natural disaster raised awareness of and attention to the phenomena of earthquakes and tsunamis, and their predictability. NSF has long funded scientific and engineering research infrastructure aimed at detecting and understanding the impacts of these phenomena. Prominent examples include:

- IRIS, GSN—Real-time Global Seismographic Network (GSN) data forged the critical core of the early warning of the December 26, 2004, Sumatran Earthquake. The GSN, operated by IRIS (Incorporated Research Institutions for Seismology) and funded in partnership by NSF and the United States Geological Survey, is the primary international source of data for earthquake location and tsunami warning.

- Engineers and scientists at the Earthquake Engineering Research Centers[1] (EERCs) and the Southern California Earthquake Center (SCEC at the University of Southern California) are working to establish the nature and attenuation of subduction-type earthquake ground shaking, and to develop probabilistic hazard maps and shaking levels due to subduction earthquakes in all oceans. This information will support damage prediction for the U.S. and elsewhere, including earthquake and tsunami effects on buildings, bridges and other lifelines, and estimates of economic, safety, and emergency response consequences.
- NSF has completed construction of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), a major national infrastructure project to create a complete system of test facilities that is revolutionizing earthquake engineering research. NSF-funded researchers create physical and numerical simulations in order to study how earthquakes and tsunamis affect buildings, bridges, ports, and other critical infrastructure. The NEES Tsunami Wave Basin at Oregon State University is the world's most comprehensive facility for studying tsunamis and storm waves.

The National Science Foundation's Immediate Response

For more than three decades, NSF has supported quick-response disaster studies that dispatch scientists and engineers to the aftermath of crises ranging from hurricanes and earthquakes to the terrorist attacks of September 11, 2001. Researchers were in the field within days after the South Asian tsunami to gather critical data before it was lost to nature and reconstruction. The ephemeral information, including assessments of physical damage to both the built and natural environments, as well as social science research that will help emergency teams and local leaders better direct future rescue efforts, is vital for scientists and engineers to understand and prepare for future disasters.

A variety of mechanisms are available to support quick-response research, including the following: (1) Small Grants for Exploratory Research (SGER), which may be awarded in order to gather data that is likely to disappear over time after the impact of disasters; (2) supplements to existing awards to fund data collection; (3) specific continuing grants that support quick-response field reconnaissance and research across a variety of disciplines; and (4) flexibility inherent in existing awards that allows for the support of post-disaster investigations. NSF has already utilized all of these types of support in responding to the December 26, 2004, earthquake and tsunami in the Indian Ocean.

Several programs and projects have established funding to send rapid response teams to disaster sites:

NSF Earthquake Engineering Research Centers are undertaking work on damage assessment. The Multidisciplinary Center for Earthquake Engineering Research (MCEER) sent a team of researchers to Thailand in partnership with the Asian Institute of Technology and the Earthquake Disaster Mitigation Research Center from Japan. Shubharoop Ghosh from ImageCat will join a team led by Prof. Yamazaki of Chiba University. The team is examining impacts of the earthquake and tsunami upon buildings and critical infrastructure. Research is also being supported by the earthquake centers on validating the potential of remote sensing data to accurately assess damage and impacts.

Multidisciplinary research has been undertaken through the NSF-funded Learning From Earthquakes (LFE) Program that is managed by the Earthquake Engineering Research Institute (EERI), a non-profit institution in Oakland, California. LFE is sending two teams to Sri Lanka, Thailand, the Maldive Islands, and India. The teams will gather data on estimated wave heights, extent of inundation, geological scouring, and other perishable information related to the physical aspects of tsunamis. They will coordinate their work with teams from Japan and Australia.

In addition, other EERI activities will collect data. Jose Borrero, University of Southern California, was one of the first U.S. researchers to gain access to one of the hardest-hit area of Sumatra. A 13-member team of engineers led by EERI member Sudhir Jain, Indian Institute of Technology, Kanpur, is investigating the structural damage and impacts on port facilities along the eastern coast of India, as well as on the Adaman and Nicobar Islands.

These initial EERI teams include geotechnical, structural, and coastal engineers; geologists; geophysicists; and experts in fluid mechanics. In subsequent efforts, a joint EERI/ASCE team of engineers will travel to the area along with social sci-

[1] MAE (Mid America Earthquake Center at the University of Illinois, Urbana-Champaign), MCEER (Multidisciplinary Center for Earthquake Engineering Research at the University of Buffalo) and PEER (Pacific Earthquake Engineering Research Center at the University of California, Berkeley).

entists from the Disaster Research Center at the University of Delaware. They will focus on damage to lifelines, including highways, bridges, ports and harbors, water delivery systems, sewage facilities, and other utilities. They will also begin to document the resulting impacts on communities and the entire region. These impacts include search and rescue operations, medical response, multinational relief, organizational response, effects on children and families, shelter and housing, and social and economic impacts. Members of EERI and other earthquake engineering experts who reside in the affected countries will also contribute the results of their independent investigations. These reports will be compiled on the EERI website, published by EERI as part of the LFE program, and made available internationally.

NSF's Network for Earthquake Engineering Simulation (NEES) is a major source of information about tsunamis. The O.H. Hinsdale Wave Research Laboratory at Oregon State University, home to the largest tsunami research facility in the world, was sought out as a source of answers to the pressing questions in the wake of the disaster. The lab hosted local news teams as well as CNN, NBC's "Today Show," the Discovery Channel, and Spiegel TV from Germany.

The Directorate for Geosciences is offering SGERs and award supplements to study physical processes in the earthquake-tsunami zone. For example, NSF-funded investigators from the California Institute of Technology who were already studying uplift or subsidence of atolls in the earthquake zone returned to Sumatra immediately after the event to measure earthquake-related vertical displacements. Additionally, scientists from the University of California-San Diego plan to resurvey a network of approximately fifty geodetic monuments in North Sumatra, the Mentawai Islands, and Banda Aceh to determine coseismic and postseismic deformation caused by the Sumatra earthquake. These new data will provide critical geodetic constraints for the seismographic inversion of the earthquake source to constrain models of the subsequent devastating tsunamis and to contribute to the study of the great earthquake cycle in that region. The NSF-funded geodetic consortium UNAVCO Inc. is coordinating efforts by the scientific community to measure the post-earthquake distortion in the region of the earthquake. The NSF-funded seismology consortium IRIS (Incorporated Research Institutions for Seismology) is leading efforts to develop real-time, finite-fault modeling techniques so that information on the actual characterization of the earthquake source can be updated continuously as real-time seismic data are received.

The oceanographic communities are actively mapping the earthquake rupture zone, studying aftershock events, and venting of natural fluids using ocean bottom seismometers, ships, remotely operated vehicles, and potentially autonomous undersea vehicles. In addition, the NSF's Division of Ocean Sciences will sponsor a series of free, on-line workshops for K–12 teachers that will provide them with lesson plans, teaching materials, and access to scientists so that they can present the latest scientific tsunami information to their students. These workshops will reach several thousand teachers this month alone, with additional workshops possible dependent upon demand. A major challenge for these oceanographic studies is gaining permission from the Indonesian government to conduct research in its territorial waters.

The Directorate for Computer and Information Science and Engineering will be offering SGERs and award supplements to extend projects on sensor networks for damage identification, information about the location of survivors, emergency response infrastructure technology, and the ability of organizations to respond to man-made and natural disasters. The San Diego Supercomputer Center at the University of California, San Diego has offered computational and data integration and data backup resources to local universities, facilities, or government agencies that might need them.

The Human and Social Dynamics (HSD) priority area has allocated $1 million to support SGERs for multidisciplinary research, including such issues as warning systems, disaster epidemiology, crisis decision-making, emergency response, and short-term and long-term recovery and mitigation. These awards will be established by the end of February 2005. Additional funding will be available from the NEES program to archive data collected under these SGERs in the central data repository operated by NEES Consortium, Inc. The Directorate for Social, Behavioral, and Economic Sciences has also made special funds available for SGERs pertinent to learning from this event.

Conclusion

Mr. Chairman, as you well know NSF has as its mission the promotion of the progress of science, the advancement of the national health, prosperity and welfare, and the securing of the national defense. Since science is truly global in nature, NSF engages in these activities in collaboration with international partners. As such, NSF will continue to respond to disasters such as the earthquake and tsunami events in partnership with others in the global science and engineering communities.

The South Asian tsunami disaster is representative of an entire class of catastrophic disasters: events that are low probability yet have high consequences. With the right information, communities and nations can characterize such risks and determine how to allocate resources for detection, warning, and preparedness.

Research into decision-making provides insights and tools for characterizing such risks and for addressing future questions about allocating resources to detection and warning. NSF, in cooperation with the world research community, including the scientists, engineers, and students from the affected countries, will continue to generate new knowledge about the natural phenomena of these events, the design of better coastal structures, the development of early warning and response systems that can mitigate loss of life, and recovery from such disasters. These new bodies of knowledge need to be transferable to all regions of the world that can benefit from these efforts. With NSF support, scientists will continue to study societal vulnerability to natural hazards with a view to building resilience through increased knowledge and preparedness, improved natural resource management, and other policy strategies so that we may help stem the loss of life and property in future events.

Mr. Chairman, thank you again for this opportunity to testify on a topic of great importance to the world community. I hope that I have conveyed the serious approach that NSF has taken to help generate new knowledge about the natural phenomena that lead to tsunami events, the design of safer coastal structures, the development of early warning and response systems, and effective steps for disaster recovery.

I would be pleased to answer any questions you might have.

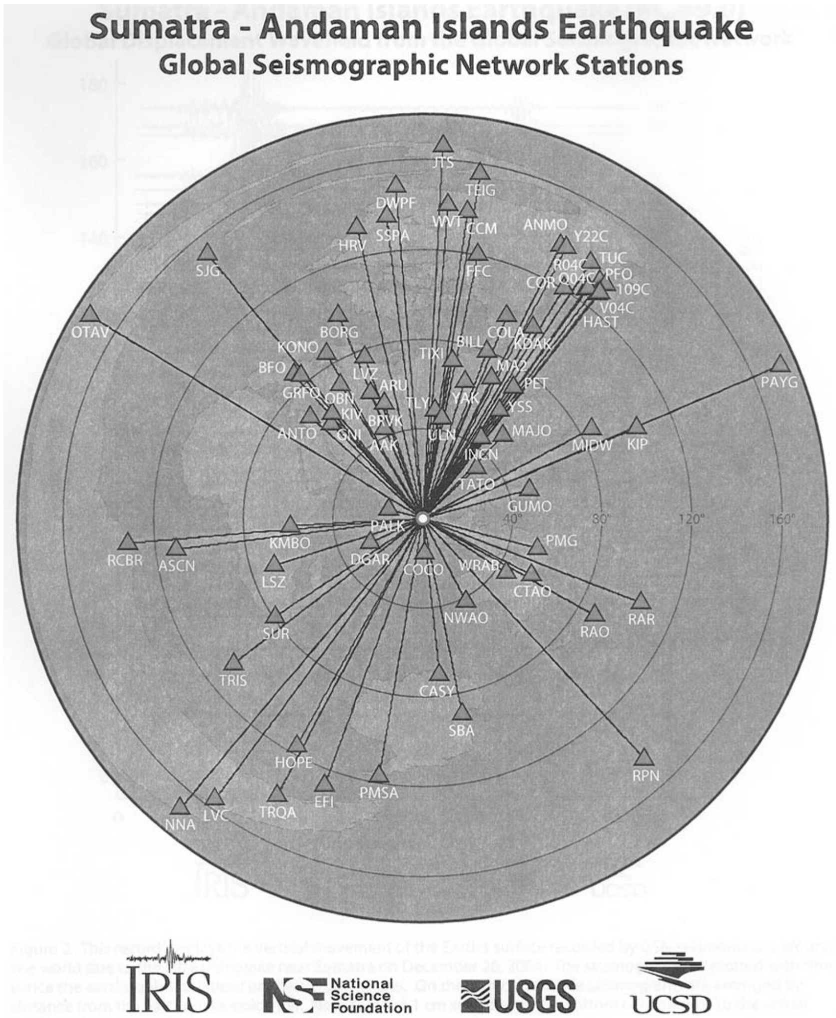
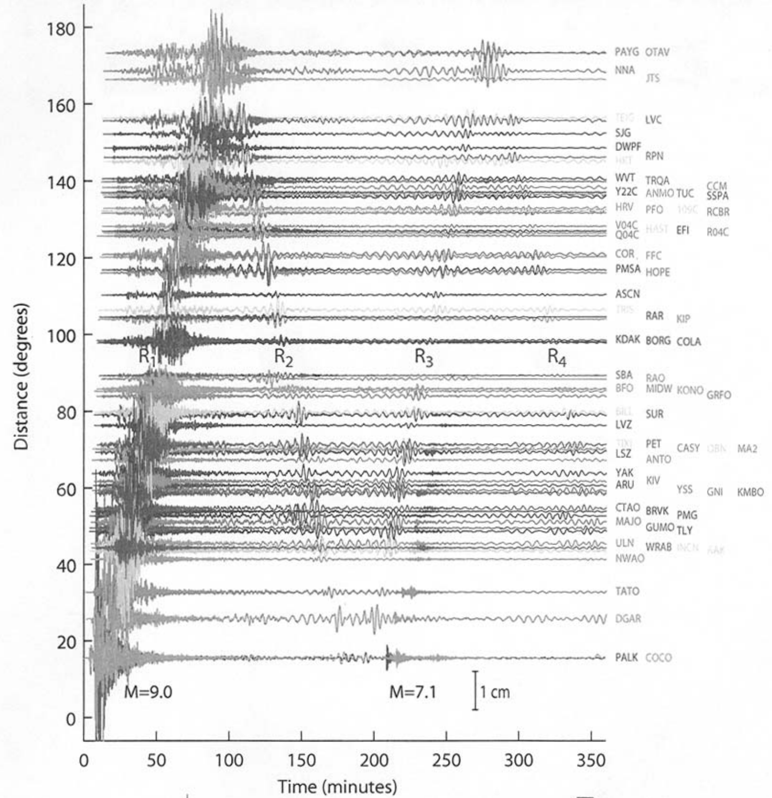


Figure 1. Global map showing the location of GSN stations and great circle paths between the stations and the Sumatra-Andaman Earthquake.

Credit: IRIS

Sumatra - Andaman Islands Earthquake (M_w=9.0)

Global Displacement Wavefield from the Global Seismographic Network



IRIS National Science Foundation USGS UCSD

Figure 2. This record displays the vertical movement of the Earth's surface recorded by GSN seismometers around the world due to the 9.0 earthquake near Sumatra on December 26, 2004. The seismograms are plotted with time (since the earthquake initiation) on the horizontal axis. On the vertical axis, the seismograms are arranged by distance from the earthquake epicenter. Note that the 1 cm scale bar at the bottom corresponds to the actual vertical motion recorded.

The large amplitude signals are surface waves, which travel around the Earth in all directions from the fault. These surface waves are largest near the fault, and they arrive at the closest stations within the first 8 minutes. At the antipode, they arrive from both directions at about 100 minutes after the earthquake. Surface waves continue to circle the Earth, returning to the epicenter after about 200 minutes and then begin another cycle. A major aftershock (magnitude 7.1) can be seen at the closest stations at about 210 minutes after the mainshock.

Credits: IRIS/USGS Global Seismographic Network; IRIS Data Management System and Consortium; US Geological Survey; National Science Foundation; Albuquerque Seismological Laboratory; University of California, San Diego; Richard Aster, New Mexico Institute of Mining and Technology.

The CHAIRMAN. Thank you very much.

Dr. Groat, from the U.S. Geological Survey?

STATEMENT OF CHARLES G. GROAT, DIRECTOR, U.S. GEOLOGICAL SURVEY

Dr. GROAT. Thank you, Senator Stevens.

Senators Frist and Landrieu gave you a good sense of the dramatic impact that this dramatic event had. Let me give you a sense, in beginning, of the forces of the earth that caused it.

The December 26, 2004, a magnitude-nine earthquake was initiated 20 miles below the sea floor off the western coast of Sumatra. It was the fourth-largest earthquake to strike the planet since 1900, and the largest since a magnitude–9.2 struck your state, Alaska, Senator Stevens, in 1964. As with other giant earthquakes, this one took place along the subduction zone, where the tectonic plates that make up the earth's rigid outer layer are thrust beneath one another. This thrusting resulted in a rupture that propagated northward along the plate boundary fault for over 750 miles. Along the length of that fault, the sea floor was jolted upward as much as 15 feet, lifting trillions of gallons of water into the air, and resulting in the forces that provided the tsunami.

While not all tsunamis are caused by earthquakes, most of them are. So, therefore, the earthquake monitoring system that Director Bement referred to is critical in providing information about where tsunamis are likely to occur. And so, the network is extremely important, and it has to be up to the task of providing information about the earthquakes in a very sophisticated and very timely manner. The GSN that he referred to is the key part, on a global scale, of doing that. And with 128 globally distributed seismic sensors that are all very modern, we have the infrastructure in place to provide the core part of the knowledge that is necessary to interpret whether earthquakes will generate tsunamis or not, if they occur in ocean basins.

A little closer to home, in the United States, the USGS operates an advanced national seismic system which provides seismic data to NOAA's Tsunami Warning Centers. That system includes a 63-station backbone network that is, itself, very modern, and provides information supported by 17 regional seismic networks that ensure that the United States has adequate and detailed coverage for providing this kind of information.

As a result of the Indian Ocean tsunami, the President announced and asked the Departments of Commerce and Interior to determine whether our systems were adequate. As a result of that, the United States Geological Survey has put together a plan to upgrade our seismic system capabilities and our interpretive capabilities, both to provide NOAA with the information it needs as to whether these earthquakes that occur on plate boundaries will generate tsunamis, and also to provide information locally to the United States coastal communities, as they need it.

So let me close by just indicating what it is we're doing.

We're implementing 24-by-7 operations at our National Earthquake Information Center, where the information is gathered and sent out.

We're upgrading the hardware and software there to make sure that we have the sophisticated processing that's necessary to give the interpretive information, both on the global sense and in the U.S. sense.

We're also improving the detection response time of the Global Seismographic Network by making data from all stations realtime. In other words, we get the information when it's received by the stations, not with any delays. Only 80 percent of that network is realtime right now.

We're also increasing the maintenance schedules for all of the stations so that we have data available as continuously as possible.

We're also providing some new software that was generated by the California Integrated Seismic Network, which is a USGS university and state partnership, to speed USGS-generated earthquake information directly to local emergency managers. And this is extremely important in coastal communities, because earthquakes that generate tsunamis close to shore have to be responded to very quickly. There isn't the time, nor the instrumentation, between those and the shore to provide the warnings. So the earthquake is a key part of what coastal communities need to have in which to base their warning systems. So we're upgrading our ability to do that.

And, finally, we're also increasing the geologic studies that occur around the margins of the United States and in the Caribbean to understand the past frequency of tsunamis, which gives us some sense of when and where they occur, and the magnitude of those.

The Sumatra Earthquake, which contributed significantly to the loss of lives and property, also continues us to forward our comprehensive concern about earthquakes, themselves, because they do occur more frequently, and they do destroy lives and property on a more regular basis, and in a very destructive basis. And through the National Earthquake Hazards Reduction Program, in which we partner with the National Science Foundation with NIST and with FEMA, we will also work with other agencies and universities to improve tsunami hazard assessments and warnings, and to expand our knowledge of tsunami generation and the impacts, and to evaluate the research and operational requirements for effective hazards planning, warning, and response systems.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Groat follows:]

PREPARED STATEMENT OF DR. CHARLES G. GROAT, DIRECTOR, U.S. GEOLOGICAL SURVEY

Mr. Chairman and Members of the Committee, thank you for this opportunity to discuss the recent tragedy in South Asia and what can be done to reduce the threat that tsunamis and earthquakes pose to coastal communities in the United States and around the globe. Events such as this serve as a tragic reminder of our vulnerability to natural hazards. While the United States is not as vulnerable to tsunamis as other regions of the world, we do face significant risk.

On December 29, the President asked the Departments of the Interior and Commerce to determine whether our systems are adequately prepared for a tsunami on our coasts. As a result, the Administration announced its commitment to implement an improved domestic tsunami detection and warning system. As part of the President's plan, the U.S. Geological Survey (USGS) will strengthen its ability to detect global earthquakes both through improvements in the Global Seismographic Network (GSN), which we support jointly with the National Science Foundation (NSF), and through around-the-clock analysis of earthquake events. The changes that are proposed for USGS clearly have a dual purpose, improving our capacity to respond to earthquakes as well as supporting the tsunami warning program of the National Oceanic and Atmospheric Administration (NOAA).

In addition to earthquake monitoring and reporting, the USGS conducts a number of activities aimed at improving tsunami hazard assessments, education, and warnings, including geologic investigations into the history of and potential for tsunami occurrence, coastal and marine mapping, and modeling tsunami generation. Although most tsunamis are caused by earthquakes, they can also be caused by volcanic eruptions, submarine landslides, and onshore landslides that cause large volumes of rock to fall into the water. All of these tsunami-generating hazards can impact the United States. Consequently, a broad range of USGS work in earthquake, volcano and landslide hazards, and coastal and marine geology, contribute to better understanding of tsunami impacts and occurrences.

Additionally, USGS is playing a role in relief efforts for nations impacted by the December 26 disaster by providing relief organizations worldwide with pre- and post-tsunami satellite images and image-derived products that incorporate information on population density, elevation, and other relevant topics. These images and products are being used by relief organizations to determine where relief efforts are most critical and how best to carry out those relief operations. In our efforts to assist and improve relief efforts, we work closely with partners at NOAA, the U.S. Agency for International Development, other federal agencies, and in academia. For example, USGS scientists are part of international teams conducting post-tsunami investigations in Sri Lanka and Indonesia with the goal of applying the knowledge developed to other vulnerable areas in the United States and around the globe.

USGS is also working with NOAA and other domestic and global partners through the Global Earth Observing System of Systems (GEOSS) and other mechanisms. Through GEOSS, improved monitoring capabilities must be firmly linked into all-hazards warning systems and, the most important link in the chain, public education and mitigation programs. As we move forward, we must bear in mind that this was an earthquake disaster as well as a tsunami disaster, and we must learn from both. This is not just a scientific endeavor; it is a matter of public safety.

Earthquake and Tsunami of December 26, 2004

This was the second year in a row in which a deadly earthquake occurred near the end of the year. In 2003, a magnitude 6.6 quake struck Iran's ancient city of Bam, killing over 30,000 people. In 2004, the deadly quake was a magnitude 9 earthquake that initiated 20 miles below the seafloor off the western coast of Sumatra, the fourth largest earthquake to strike the planet since 1900 and the largest since a magnitude 9.2 earthquake struck Alaska in 1964. The earthquake and resulting tsunami killed more than 150,000 people around the Indian Ocean, two-thirds of them in northern Sumatra, whose inhabitants experienced not only the severe shaking from the earthquake but also the tsunami's full force.

As with other giant earthquakes, this one took place along a subduction zone, where one of the tectonic plates that make up the Earth's rigid outer layer is being thrust beneath another (see Figure 1). The Sunda trench is the seafloor expression of such a plate boundary where the Indian plate is thrusting under the overriding Burma plate. The size of an earthquake is directly related to the area of the fault that is ruptured. This rupture propagated northward along the plate boundary fault for over 750 miles beneath the Nicobar and Andaman Islands almost to Burma with a width of over 100 miles and slip along the fault averaging several tens of feet.

It is difficult to comprehend the scope of a magnitude 9 earthquake. When we hear the term earthquake magnitude, we think of the Richter scale, which was the first of several scales developed to measure the earthquake size from the seismic waves they generate. These scales are logarithmic such that each whole number represents an order of magnitude larger in the seismic waves generated. So a magnitude 7 earthquake is 10 times larger than a magnitude 6 and 100 times larger than a magnitude 5. However, the amount of energy released goes up much faster. This magnitude 9 earthquake released 32 times more energy than a magnitude 8 earthquake and 1000 times more energy than a magnitude 7 earthquake such as the one that struck the San Francisco Bay area in 1989. The energy released by the Sumatra earthquake is roughly equal to that released by all the earthquakes, of every size, everywhere in the world since the mid-1990s. It's important to remember that our own coasts, Alaska in 1964 and the Pacific Northwest in 1700, were the site of earthquakes as large as the Sumatra earthquake.

A great deal of that energy was transferred to the Indian Ocean's waters and ultimately to its surrounding shores. Along the length of the fault rupture, the seafloor was jolted upward by as much as 15 feet, lifting trillions of gallons of sea water—a volume more than 30 times that of the Great Salt Lake—and generating the tsunami that swept both east, inundating the coast of Sumatra, Thailand and Burma, and west, crossing the open ocean at hundreds of miles per hour on its way to the coasts of India, Sri Lanka, and eventually eastern Africa.

Tsunamis strike the Indian Ocean less frequently than the Pacific Ocean, which is ringed by subduction zones, but there have been at least a half dozen Indian

Ocean tsunamis caused by earthquakes in the past 200 years. What had been the deadliest tsunami in the region was not caused by an earthquake but by the explosion of Krakatau volcano in 1883. The tsunami generated by the collapse of that volcano killed 36,000 people on Java, Sumatra and neighboring islands.

It is important to emphasize that not all large subsea earthquakes generate tsunamis. For example, four days before the Sumatra earthquake, a magnitude 8.1 earthquake struck the seafloor south of New Zealand near the Macquarie Islands. Instead of generating a thrusting motion as in a subduction zone, this earthquake occurred on a strike-slip fault, moving side to side like the San Andreas Fault, a motion much less efficient at creating a tsunami. No tsunami was generated. Even earthquakes generated in subduction zones may not produce tsunami, depending on whether the fault rupture reaches the seafloor, the amount of displacement on the fault and other factors. One of the key roles of a tsunami detection system is to avoid false warnings that cause costly and unnecessary evacuations that can undermine people's willingness to heed warnings in the future. In addition to buoys and tide gauges, seismic data may be able to provide an additional check, and research in this area could improve our ability to recognize tsunami-causing events in minutes.

U.S. Earthquake Monitoring Networks and Their Role in Tsunami Warning Center Operations

To monitor earthquakes in the United States, the USGS has begun to install and operate the Advanced National Seismic System (ANSS), which was established by the National Earthquake Hazard Reduction Program (NEHRP) in 2000 (Pub. L. 106–503). The system includes a 63-station ANSS Backbone Network, which is capable of locating most felt earthquakes nationwide and provides data in near-real-time to USGS. Extending our capability in high-hazard areas of the country are 17 regional seismic networks that provide detailed coverage and rapid response, local expertise in event analysis and interpretation, and data. Our ANSS partnerships—which include universities, state government agencies and NSF—greatly leverage USGS seismic monitoring capabilities. The key products of the system are rapid and accurate earthquake locations and magnitudes, delivered directly to users for emergency response.

In several of the highest-risk urban areas in the United States, dense arrays of seismic sensors designed to record strong ground motion have been deployed under ANSS. These areas include the Los Angeles, San Francisco, Seattle, Anchorage and Salt Lake City metropolitan regions. When triggered by an earthquake, data from these sensors are automatically processed into detailed maps of ground shaking ("ShakeMaps"), which in turn feed loss estimation and emergency response. Also, because earthquake losses are closely tied to the vulnerability of buildings and other structures, USGS monitors earthquake shaking in structures in support of engineering research, performance-based design, and rapid post-earthquake damage evaluations. If placed in certain critical facilities, these sensors can contribute to critical post-earthquake response decisions.

USGS has set a minimum performance goal of determining automated locations and seismic magnitudes within 4 minutes or less in the U.S. This is exceeded in many ANSS regions; for example, the magnitude 6.5 San Simeon, California, earthquake of December, 2003, was automatically located within 30 seconds. Earthquake data, including locations, magnitudes, other characterizations and, where requested, the actual seismograms, are automatically transmitted from USGS and regional centers to federal response departments and agencies such as the NOAA tsunami warning centers, the Department of Homeland Security, including the Federal Emergency Management Agency (FEMA), state governments, local emergency managers, utility operators, several private sector entities, and the public and media. USGS does not currently have 24 × 7 earthquake analysis, but analysts are on-call in the event of a large earthquake worldwide. The Administration has recently proposed 24 × 7 operations as a key needed improvement in response to the Indian Ocean tsunami disaster.

To monitor seismic events worldwide, the Global Seismographic Network (GSN) maintains a constellation of 128 globally distributed, modern seismic sensors. USGS operates about two-thirds of this network, and the University of California, San Diego, operates the other third with NSF support. NSF also funds the IRIS (Incorporated Research Institutions for Seismology) Consortium to handle data management and long-term archiving. Two GSN stations were the first to detect the December 26, 2004, Sumatra earthquake, and automated analysis of these data generated the "alerts" of strong recorded amplitudes sent to NOAA and USGS. At the present time, about 80 percent of GSN stations transmit real-time data that can be used for rapid earthquake analysis and tsunami warning. The Administration is request-ing funding to extend the GSN's real-time data communications, as well as to improve station uptime through more frequent maintenance. These changes will result in improved tsunami warning in the United States and globally.

Through the National Tsunami Hazard Mitigation Program, the USGS, NOAA, FEMA, and five western States (Alaska, California, Hawaii, Oregon and Washington) have worked to enhance the quality and quantity of seismic data provided to the NOAA tsunami warning centers and how this data is used at the state and local level. This program has funded USGS to upgrade seismic equipment for regional seismic networks in Northern California, Oregon, Washington, Alaska and Hawaii. The seismic data recorded by the USGS nationally and globally are relayed to the NOAA tsunami warning centers. USGS and NOAA also exchange earthquake locations and magnitude estimates, with USGS providing the final authoritative magnitudes of events. USGS is also working with emergency managers in the Pacific Northwest to support public warning systems in coastal communities there.

Improving earthquake monitoring in the United States—with consequent improvements to public safety and the reduction of earthquake losses—can be achieved through the modernization and expansion of the ANSS, including expansion of seismic sensor networks nationwide, the upgrading of the associated data processing and analysis facilities, and the development of new earthquake products. Funding over the past three years has focused on installation of over 500 new seismic sensors in high-risk urban areas. The FY05 appropriation for ANSS is $5.12 million. The President's proposed increase in funding to USGS in response to the tsunami disaster would allow USGS to make critically needed improvements to performance in one key element of ANSS, providing 24 × 7 operations capacity and completing software and hardware upgrades to speed processing times. These improvements will enhance USGS support of NOAA's tsunami warning responsibility.

The Threat From Tsunamis and Great Earthquakes in the Pacific

The concentration of U.S. tsunami warning efforts in the Pacific reflects the greater frequency of destructive tsunami in that ocean. Approximately 85 percent of the world's tsunamis occur in the Pacific. This is due to many subduction zones ringing the Pacific basin—the source of submarine earthquakes of large enough magnitude (greater than ¢7) to produce tsunami. While Hawaii's position in the middle of the Pacific makes it uniquely vulnerable to ocean-wide tsunami, this chain of volcanic islands also faces a hazard from locally generated tsunami due to local earthquakes or submarine landslides. In 1975, a magnitude 7.2 earthquake just offshore the island of Hawaii caused a tsunami that killed 2 with maximum runup height (elevation reached by tsunami as they move inland from the shoreline) of 47 feet.

U.S. Insular Areas in the Pacific also face a threat both from ocean-wide tsunami as well as ones generated locally. The volcano Anatahan in the Northern Marianas, which began actively erupting on January 5, 2005, serves as a reminder that inhabitants and U.S. military interests in the Commonwealth of the Northern Mariana Islands and the Territory of Guam are threatened by nine islands with active volcanoes that have the potential to generate hazardous ash plumes as well as tsunamis through eruption-induced collapse. The risks from tsunamis to the inhabited islands are poorly understood, and tsunami inundation modeling is needed to assess the threat represented by such an event.

Our knowledge of what may be the greatest risk to the United States does not come from our tsunami experiences of the last half century, but rather to the detective work of USGS and other scientists in the Pacific Northwest. In contrast to the San Andreas Fault, where the Pacific and North American plates are sliding past one another, a subduction zone known as Cascadia lies offshore further north, its size nearly identical to that of the rupture zone of the Sumatra earthquake (see Figure 2). On January 26, 1700, the Cascadia subduction zone broke in a great earthquake, probably from northernmost California to the middle of Vancouver Island. Along the Pacific coast in Oregon, Washington, California, and British Columbia, this huge event of the same general size of the Sumatra earthquake, caused coastal marshes to suddenly drop down several feet. This change in land elevation was recorded by the vegetation living in and around the coastal marshes. For example, along the Copalis River in Washington State, Western Red Cedar trees that have lifespans of over 1000 years were suddenly submerged in salt water. Over the next few months, those trees died. By comparing tree rings of the still standing dead trees with nearby trees that were not submerged, paleoseismologists established that the trees were killed during the winter of 1699–1700.

Digging through river bank deposits along the Copalis and other rivers in Cascadia, paleoseismologists found a pervasive, black sand sheet left by the tsunami. Because the sands deposited by the tsunami are transported by the tsunami waves, paleoseismologists can combine the location of tsunami sands with the change in marsh elevation to get an approximate idea of the length of the rupture for the 1700 earthquake. Tsunami sands have been found from Vancouver Island to Humboldt Bay in California.

Once paleoseismologists found evidence of the 1700 event, they combed written records in Japan to see if evidence existed of an unknown tsunami wave. Several villages recorded damage in Japan on January 27, 1700, from a wave that people living along the coast could not associate with strong ground shaking. The coast of Japan had been hit, not unlike Sri Lanka and Somalia, by a distant tsunami, but this tsunami came from the west coast of North America. By modeling the travel time across the Pacific, paleoseismologists were able to establish the exact date of the last Cascadia subduction zone event.

Based on estimates of the return interval, USGS scientists and others have estimated that there is a 10–14 percent chance of a repeat of the Cascadia magnitude 9 earthquake and tsunami event in the next 50 years. Since that initial discovery in the early 1980s, many of the elements of the seismic systems for the Pacific Northwest described above have been put in place along with improved building codes to address the higher expected ground shaking and increased public education through the efforts of state and local emergency managers.

The December 26, 2004, earthquake and tsunami together cause us to focus on the similar threat from the Cascadia subduction zone that faces the Pacific Northwest as well as our long Alaskan coastline. Here I cannot emphasize enough the critical role played by our partners in state and local government, especially the state emergency managers. Largely through the efforts of the National Tsunami Hazard Mitigation Program partnership, much has been accomplished. Seismic systems have been improved, allowing NOAA's West Coast and Alaska Tsunami Warning Center to issue warnings within minutes of a significant offshore earthquake. Inundation maps, graphic representations of estimates of how far inland future tsunami waves are likely to reach, are available for most major communities in northern California, Oregon, and Washington. Working with FEMA, public education has been stressed, and emergency managers have begun installing all-hazard warning systems. USGS is co-funding a $540,000 pilot project in Seaside, Oregon with FEMA and NOAA to develop risk identification products that will help communities understand their actual level of risk from tsunami in a way that could be conveyed on existing flood maps. The goal of the project is to develop techniques that can be used to determine the probability and magnitude of tsunami in other communities along the west coast of the United States.

Tsunami Threats in the Atlantic

With respect to tsunami hazard risk to the U.S. East coast, it should be noted that subduction zones are scarce in the Atlantic Ocean. But the Atlantic Ocean is not immune to tsunami. A tsunami following the great 1755 Lisbon earthquake, generated by collision of the African and Eurasian tectonic plates, devastated coasts of Portugal and Morocco, reached the British Isles, and crested as much as 20 feet high in the Caribbean.

In 1929, the magnitude 7.2 Grand Banks earthquake triggered a submarine landslide and tsunami that struck Newfoundland's sparsely settled coast, where it killed 27 people with waves as high as 20 feet. An event like this, involving a submarine landslide, may be the most likely scenario for the Atlantic coast. Scars of past large submarine landslides abound on the continental slope off the U.S. Atlantic coast. As in the 1929 Grand Banks event, some of the slides probably resulted from large earthquakes. If earthquakes are the primary initiator of the observed landslide features, the hazard to the Atlantic coast is limited as large earthquakes rarely occur in the vicinity of the U.S. and Canada Atlantic coast—perhaps once a century, on average (Boston area, 1755; Charleston, 1866; Newfoundland, 1929). Additionally, this type of tsunami would affect a much smaller geographical area than one generated by a subduction zone, and its flooding effect and inundation distance would be limited. Much work is needed, however, to more fully understand the triggering of submarine landslides and the extent of that threat in the Atlantic.

Another tsunami scenario for the Atlantic coast that has been widely publicized is a landslide involving collapse of part of the Cumbre Vieja volcano in the Canary Islands into the sea. While this collapse would be dramatic and might indeed induce a transatlantic tsunami, such a collapse may occur only once every hundred thousand years. Furthermore, unlike the West Coast with the abundant record of past ocean-wide tsunami deposits, no such regionally extensive deposits have been found to date along the Atlantic coast.

Tsunami Threats in the Caribbean

The Caribbean is subject to a broad range of geologic processes that have the potential to generate tsunami. Indeed, the Caribbean tectonic plate has almost all of the tsunami-generating sources within a small geographical area. Subduction zone earthquakes of the type that generated the Indian Ocean tsunami are found along the Lesser Antilles and the Hispaniola and Puerto Rico trenches. Other moderately large earthquakes due to more local tectonic activity take place probably once a century, such as in Mona Passage (1918 tsunami) and in the Virgin Islands basin (1867 tsunami). Moderate earthquakes occur that may trigger undersea landslides and thus generate tsunami. An active underwater volcano (Kick'em Jenny near Grenada) where sea floor maps show previous episodes of flank collapse also poses a tsunami hazard. Above-water volcanic activity occurs, wherein the Lesser Antilles periodically generate landslides that enter the sea to cause tsunami. And finally, the possibility exists of tele-tsunami from the African-Eurasian plate boundary, such as the great Lisbon earthquake of 1755 described above.

In 1867, an 18-foot high tsunami wave entered St. Thomas' Charlotte Amalie at the same time that a 27-foot wave entered St. Croix's Christiansted Harbor. Were that to occur again today, the 10-fold increase in population density, the cruise ships, petroleum carriers, harbor infrastructure, hotels and beach goers, nearby power plants, petrochemical complexes, marinas, condominiums, and schools, would all be at risk.

On October 11, 1918, the island of Puerto Rico was struck by a magnitude 7.5 earthquake, centered approximately 15 kilometers off the island's northwestern coast, in the Mona Passage. In addition to causing widespread destruction across Puerto Rico, the quake generated a medium sized tsunami that produced runup as high as 18 feet along the western coast of the island and killed 40 people, in addition to the 76 people killed by the earthquake. More than 1,600 people were reportedly killed along the northern coast of the Dominican Republic in 1946 by a tsunami triggered by a magnitude 8.1 earthquake.

In contrast to the Caribbean, the Gulf of Mexico has low tsunami risk. The region is seismically quiet and protected from tsunami generated in either the Atlantic or the Caribbean by Florida, Cuba, and broad continental shelves. Although there have been hurricane-generated subsea landslides as recently as this fall, there is no evidence that they have generated significant tsunami.

Lessons Learned: What the United States Can Do to Better Prepare Itself and the World

Natural hazard events such as the one that struck Sumatra and the countries around the Indian Ocean on December 26, 2004, are geologically inevitable, but their consequences are not. The tsunami is a potent reminder that while the nations surrounding the Pacific Ocean face the highest tsunami hazard, countries around other ocean basins lacking basic tsunami warning systems and mitigation strategies face considerable risk. Reducing that risk requires a broad, comprehensive system including rapid global earthquake and tsunami detection systems, transmission of warnings in standardized formats to emergency officials who already know which coastal areas are vulnerable through inundation mapping and tsunami hazard assessment, and broadcast capabilities to reach a public already educated in the dangers and how to respond. For tsunami crossing an ocean basin, an adequate system of earthquake sensors, Deep-ocean Assessment and Reporting of Tsunamis (DART) buoys, and tide gauges should allow for timely warnings if the rest of the system is in place. For tsunami generated near the coastline, time is considerably more critical. For tsunami warnings to be effective, they must be generated and transmitted to the affected coastline within a few minutes of detection, local emergency responders must be prepared, the population must be informed, and the entire system must be executed without delay.

The Sumatra earthquake and its devastating effects will encourage us to continue forward on the comprehensive NEHRP approach to earthquake loss reduction. USGS is committed to do so in partnership with FEMA, the National Institute of Standards and Technology, and NSF to translate research into results through such initiatives as ANSS, the George E. Brown, Jr. Network for Earthquake Engineering Simulation, the plan to accelerate the use of new earthquake risk mitigation technologies, and development of improved seismic provisions in building codes.

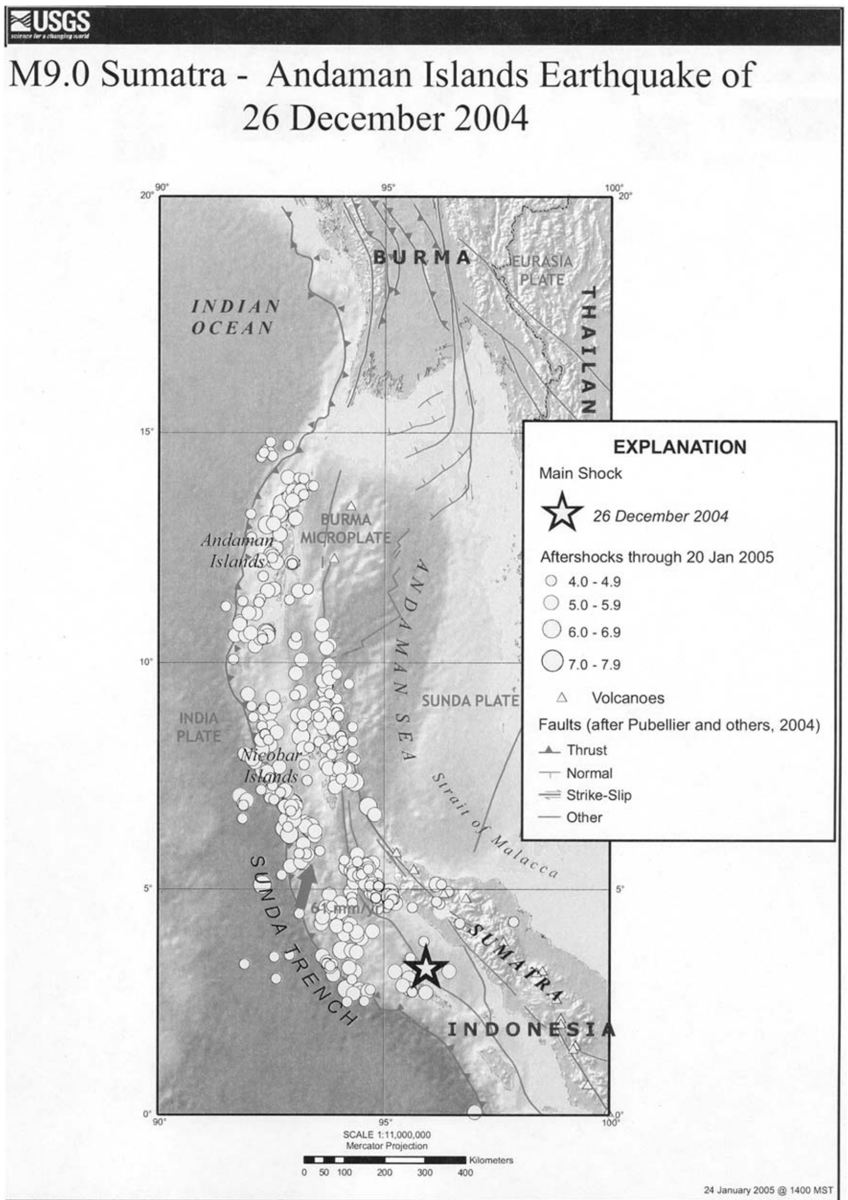
As part of the President's plan to improve tsunami detection and warning systems, the USGS will:

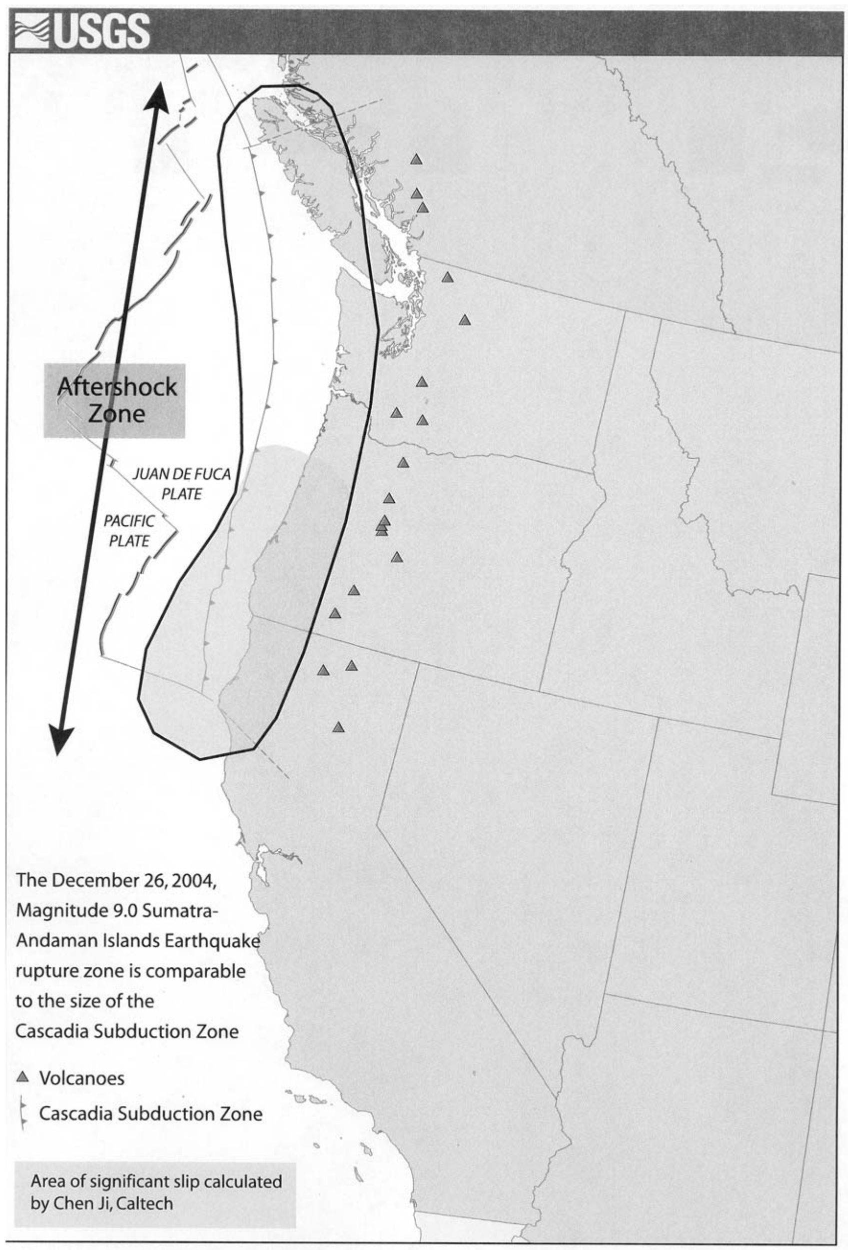
- Implement 24 × 7 operations at the National Earthquake Information Center and upgrade hardware and software systems in order to improve the timeliness of alerts for global earthquakes. As part of the upgrade, USGS will fully develop what is now a prototype system to estimate the number of people affected by strong ground shaking after an earthquake using our ShakeMap model and databases of global population. Known as Prompt Assessment of Global Earthquakes for Response (PAGER), this system can provide aid agencies and others with a quick estimate of how significant the casualties might be well in advance of reports from affected areas where communications may be down.

- Support research to develop more rapid methods for characterizing earthquakes and discriminating likely tsunamigenic sources.
- Improve the detection response time of the Global Seismographic Network by making data from all stations available in real time via satellite telemetry and improving station up-time through increased maintenance schedules. Improved coverage in the Caribbean region will be achieved through the addition of stations and upgrades of existing stations through international partnerships and cooperation.
- Further the use of software developed by the California Integrated Seismic Network (a USGS, university and state partnership) to speed USGS-generated earthquake information directly to local emergency managers with a dual use capability to also provide NOAA tsunami warnings.
- Enhance existing USGS geologic and elevation mapping for coastal areas in the Caribbean. Such mapping is critical to development of improved tsunami hazards assessments for Puerto Rico and the U.S. Virgin Islands.

The USGS will also continue its ongoing efforts to improve tsunami hazard assessment and warnings through geologic investigations into the history of and potential for tsunami occurrence; coastal and marine mapping; modeling tsunami generation, source characterization, and propagation; and development of assessment methods and products such as inundation maps with NOAA, FEMA, and other partners. USGS will also continue strong partnerships with state tsunami and earthquake hazard mitigation groups and contribute to public awareness efforts. An example of the latter is the 2001 publication, USGS Circular 1187, *Surviving a Tsunami: Lessons Learned from Chile, Hawaii and Japan*, which was prepared in cooperation with the Universidad Austral de Chile, University of Tokyo, University of Washington, Geological Survey of Japan, and the Pacific Tsunami Museum. Continuing investigations of the Indian Ocean tsunami provide a critical opportunity to expand our knowledge of tsunami generation and impacts and to evaluate the research and operational requirements for effective hazard planning, warning, and response systems.

Mr. Chairman, I thank you for this opportunity to appear before the Committee and would be happy to answer any questions now or for the record.


USGS
M9.0 Sumatra - Andaman Islands Earthquake of
26 December 2004
BURMA
EURASIA PLATE
THAILAN
INDIAN OCEAN
Andaman Islands
BURMA MICROPLATE
ANDAMAN SEA
SUNDA PLATE
INDIA PLATE
Nicobar Islands
Strait of Malacca
SUNDA TRENCH
SUMATRA
INDONESIA
EXPLANATION
Main Shock
26 December 2004
Aftershocks through 20 Jan 2005
4.0 - 4.9
5.0 - 5.9
6.0 - 6.9
7.0 - 7.9
Volcanoes
Faults (after Pubellier and others, 2004)
Thrust
Normal
Strike-Slip
Other
SCALE 1:11,000,000
Mercator Projection
Kilometers
0 50 100 200 300 400
24 January 2005 @ 1400 MST



The CHAIRMAN. Thank you very much.

We have just created a new Subcommittee on Disaster Prevention and Prediction. We hope that that Subcommittee will keep your two agencies pretty busy, because we think we have to find some way to make this a more robust system.

Let me ask you, Dr. Marburger, what's the timeline for the Administration's improved Tsunami Detection and Warning System? Can you tell us the timeline, how soon are you going to move into it? As I understand it, we're going to finish the one we've already got going, but there's a tremendous expansion of it. How long is it going to take us to do that?

Dr. MARBURGER. That's correct. The agencies indicate to us that they ought to be able to have substantial improvement of the existing system within 2 years, at the end of 2 years, if I'm not mistaken. Fortunately, all the technology is available. The systems are up and running, and it's improvements and—improved maintenance and additional deployment of things like these new buoys that's required. So it should be doable in a relatively short period of time. Mid–2007 are the dates that I've heard. They can be confirmed by others.

The CHAIRMAN. As I understand it, General Kelly, several of these buoys are not working right now. The DART is on the surface of the ocean. They're connected to a detector at the bottom. Tell us what is leading to the malfunction of these warning devices now?

General KELLY. Many things.

The CHAIRMAN. I can't hear you, I'm sorry.

General KELLY. Many things. And you are correct, there are six DART buoys sited in the water today. Three of the six are not operational. One has not been operational since October of 2003. There are two complicating factors. One is the weather, the weather in the Aleutians, there's a narrow window when we can get boats in there, or ships in there, to repair them, and then, two, a number of components have failed, different components have failed at different times. And so, part of our plan is, in fact, to put a better buoy in place of the existing ones, and then expand the network.

The CHAIRMAN. Could you put that chart up again, showing where these new buoys are going to be——

General KELLY. Yes, sir.

The CHAIRMAN.—and where the existing ones are? As I understand it, half of the buoys we've detected—we've deployed right now are not functioning?

General KELLY. That is correct.

The CHAIRMAN. Which ones?

General KELLY. (Indicating.) The red ones.

The CHAIRMAN. Tell us, for the record.

General KELLY. Three along the Aleutians.

The CHAIRMAN. Three along the Aleutian chain.

General KELLY. Yes. Yes, sir.

The CHAIRMAN. And what's the plan for replacing those?

General KELLY. Within the last—within the last several weeks, we—or last month—we attempted to repair one, got it in the water, and then a component malfunctioned. And we are ready now, as soon as we get a break in the weather—we have forward-deployed the parts into Alaska—as soon as we get a break in the weather—and we need about 7 days of good weather—we'll get a ship out there and replace the buoys.

The CHAIRMAN. Whose job is it to maintain and assure that they are functioning?

General KELLY. NOAA's.

The CHAIRMAN. Which part of NOAA?

General KELLY. The National Weather Service.

The CHAIRMAN. Do they have the equipment to do that?

General KELLY. Well, they certainly don't own the ships to do it, and they use the NOAA Corps to do that, or we contract out. But they have—we have a National Data Buoy Center in Bay St. Louis, which has the capability——

The CHAIRMAN. Where do you have it?

General KELLY. Bay St. Louis, Mississippi. And——

The CHAIRMAN. The center's in Mississippi, and all the buoys are in the Pacific?

General KELLY. Well, no, sir, we have other kinds of buoys along the Gulf Coast and along the United—and along the——

The CHAIRMAN. We're talking about tsunami warning now.

General KELLY. Well, yes, sir, but we're also talking about buoy technology. And they have engineers and they have scientists, and they work closely with the Pacific Marine Environmental Lab. So our operational and maintenance repair facility is in Bay St. Louis, Mississippi.

The CHAIRMAN. How long have they been down, those three?

General KELLY. One has been down since October 2003, one was down in—one went down in December 2004, and another went down in August 2004.

The CHAIRMAN. Is there a specific program looking at the reliability of these buoys we're going to deploy?

General KELLY. Yes, sir.

The CHAIRMAN. Who's in charge of that?

General KELLY. We're working jointly with the Pacific Marine Environmental Lab and our experts at the National Data Buoy Center.

The CHAIRMAN. All right. That worries me a great deal. If we're going to spend money expanding the system we're going to put out there—the buoys have been failing at this rate, it, sort of, looks to me like the taxpayer may be just financing a facade.

General KELLY. It is not our intent to put a one-for-one replacement of the buoys that are out there as we expand this network. We need to put out buoys that are more robust and survive longer. And, in fact, given the challenges that we've had in—as I mentioned earlier, including—included in the plan will be three buoys that I will call "in-water backups," so, in case one does malfunction, we will still have something providing us data.

The CHAIRMAN. Thank you very much.

Dr. Groat, the problem of these earthquakes and prediction and tying them into this system, can you tell us, we have these buoys deployed, but you're not relying on those buoys for your predictions and detection of earthquakes, are you?

Dr. GROAT. No, sir. We rely on the Global Seismic Network, local networks that are subsidiary to it, to understand the earthquakes and the potential for generating a tsunami. Many earthquakes are very large, but don't generate tsunamis, even those that occur in the ocean. The key is getting that earthquake interpretation to NOAA in a timely fashion so that if it's likely to have generated a tsunami, then they can be prepared to use that information.

The CHAIRMAN. Is there a way to tie together what you've got and the other systems here to make a prediction telling us if an earthquake occurs at any particular place, there will or not be a tsunami? We seem to only get tsunamis as a reaction to the earthquakes, mainly in the Pacific, right?

Dr. GROAT. Correct.

The CHAIRMAN. So are we tied together—can we say, if there's an earthquake at such-and-such a place on the Aleutian chain, there probably would be a tsunami that would go any particular direction?

Dr. GROAT. With the upgrades that we've talked about in our seismic monitoring system and the data processing, we will do a better job of predicting whether the earthquake was of a type that would generate a tsunami. There are many large displacements that go this way, and they don't generate anything.

The CHAIRMAN. OK. But if you can predict there's going to be a tsunami, can you predict where it's going to go?

Dr. GROAT. Well, they go—it's, sort of, like dropping a rock in a pond, the waves go in all directions. So once we know where it is, then we can watch where the waves will go. And we can predict that pretty well.

The CHAIRMAN. Thank you. That's what I was looking for. I watched the Discovery channel the other night. You all did a very good job on that, and I did not know that until then, that it is like dropping a stone in a pond. There will be tsunamis everywhere if it's located, say, around Senator Inouye's country, it's possible it could affect the whole Pacific, right?

Dr. GROAT. Very much so.

The CHAIRMAN. Senator Inouye?

Senator INOUYE. Like most of my colleagues, I'm concerned about the six DART buoys. Three have been out of commission for about 15 months. And if it weren't for the tragedy of biblical proportions, the likelihood is that this Congress would not have been notified. Am I correct?

General KELLY. Yes, sir.

Senator INOUYE. We would not have known that three were out of commission.

General KELLY. You're correct. But I would point out that the DART buoys, while important, are not the only components in the network.

Senator INOUYE. I realize that there are many circumstances that would cause problems, such as weather and the budget. Why was it impossible for NOAA to notify the Congress that three of the six were out of business?

General KELLY. Senator, within NOAA, there are a number of observing systems out there. And, as a matter of practice, we routinely don't notify the Congress when a given sensor, or a series of sensors, goes out.

Senator INOUYE. You don't know whether the system is working or not?

General KELLY. Well, no. We know, but we don't routinely notify the Congress. We sometimes have problems with satellites, with a given sensor on a satellite, and, at least in my experience, we have not routinely provided an update to the Congress of a problem with a satellite sensor. We try to work through it, and, in most cases, get it resolved.

The CHAIRMAN. Would the Senator yield just there?

Senator INOUYE. Sure.

The CHAIRMAN. Who do you notify when a buoy goes down?

General KELLY. When a buoy goes down, the head of the National Weather Service gets notified, the two Tsunami Warning Center directors get notified, and it is the responsibility of the head of the National Weather Service to get those buoys repaired.

The CHAIRMAN. So they don't tell your Governor, or mine.

Senator INOUYE. These buoys are obviously very important. They not only prevent the loss of lives, they prevent the unnecessary expenditure of funds. I'm just thinking to myself, if that disaster that we experienced in Indonesia and Sri Lanka had occurred in Washington or Oregon or Alaska, and we weren't warned because the three buoys were not operational, the atmosphere in this room would be, I think, much more heated.

General KELLY. I agree with you, Senator Inouye, but I believe that, while the three buoys are important, we still have the capability to warn. And even if that earthquake had occurred somewhere in the Pacific, warnings would have gone out. Because even with the three buoys being down, the Pacific Tsunami Warning Center did issue a—what we call an information advisory that a tsunami had, in fact, been generated. So, while the three are down, and that's regrettable, and we're working to get them repaired, we are not totally defenseless because those three are down. And I am not trying to condone the fact that they are down, or they've been down as long as they have, but I think it is important that we don't leave here thinking that we are totally defenseless in providing information and warnings. And you are correct that one of the great benefits of those DART buoys are, it gives confirmation as to the characterization and the magnitude of the tsunami, and, in fact, helps reduce the number of what we call false alarms, and then saves the local governments money, in terms of responding. And, frankly, most importantly, a whole string of false-alarm tsunami warnings will cause the citizens not to pay attention to it, and that is a critical thing we need to work against.

Senator INOUYE. By indicating your position, you're not suggesting we don't need any more DART buoys.

General KELLY. No, sir, I am not indicating we don't need any more DART buoys. They will improve the system. I am trying to get the message across that we are not totally defenseless with the existing systems, and the citizens of Hawaii and the citizens of Alaska and the West Coast of the United States ought not to get unduly alarmed.

Senator INOUYE. I have just one more question, to any one of you. Within 24 hours after the disaster in Southeast Asia, major stations, such as CNN and all of the networks began criticizing, and suggesting that they should have been notified so that they could have used their offices and facilities to warn the people. Is that a valid criticism? Could that have been done?

Dr. MARBURGER. Well, it certainly could have been done. I do not know what the protocol is for notifications, but the National

Weather Service is notified instantly, and usually their information is shared immediately with the media.

General KELLY. Senator Inouye, it is my belief that many of those news organizations did, in fact, get the tsunami bulletin that was sent out from the Hagemayer Warning Center in Hawaii. I think what they were asking for was some type of protocol being established wherein the watch officer might make a telephone call to them or somehow take an explicit step to get the information to them.

Senator INOUYE. Is that a valid request?

General KELLY. I think we have to do some analysis of it and what we are talking about. Now, let's take the National Hurricane Center. When hurricanes are coming, there is a large press presence in the Hurricane Center. Fortunately, with hurricanes, we have a bit more time to start alerting the public. With tsunamis—and while this earthquake, as Dr. Groat said, was one of the more massive in the century, I mean, we had time to watch the tsunami perpetuate across the Pacific. Frequently, in Alaska and Hawaii you only have minutes, and I'm just not sure, given one watch officer trying to issue bulletins, clarify the bulletins, that there's sufficient time for him to be talking to the press. There may be other arrangements that can be made with the press for them to get the information differently.

The CHAIRMAN. There was another criticism, in that we did notify the countries involved, but the receiving facility was not operational. Is that a valid one?

General KELLY. When you're talking about the "receiving," you're talking about the receiving system in the in-country?

Senator INOUYE. Yes.

General KELLY. As I said in my testimony, we have an agreement with 26 countries in the Pacific Rim to provide information to them, and then they have the responsibility of developing their local warnings and distributing them to their country. No such system exists in the Pacific Ocean, so I—I'm sorry, in the Indian Ocean—and so, that is—there's some truth in that, that countries were not prepared to deal with it.

As I said in my testimony, tsunami preparedness has a number of variables in it. To my mind, the most important one is, when you get the warning, have you got a way, internally, to get it out to your citizens, and have you educated them and worked with them so that they know what to do? Thanks to both of your help with the Tsunami Mitigation Program legislation in 1996, we've been able to do a fair amount of that work on the West Coast and in Hawaii.

Senator INOUYE. Thank you very much.

Thank you, Mr. Chairman.

The CHAIRMAN. Gentlemen, if necessary, Senator Inouye and I will send you a letter, to each of your agencies, for this request. We would ask that you report back to us, in 2 weeks, what it would take to establish a system to notify the entities who have been mentioned—specifically, 911, the Weather Channel, the emergency disaster systems that exist in the 50 states.

The CHAIRMAN. We're concerned primarily with this country because of our Committee's jurisdiction. I'm sure others will be asking the question about the international aspects of the system to come. But, right now, we thought we had a system, and we found, when this occurred, that it was—half of it was dormant, was not working. And we think we ought to have a system that not only—we're notified if something's gone wrong, but we also have adequate apparatus to detect the problem and get at it now.

And, beyond that, though, I think that the news media have a legitimate cause to object. There's no reason why we can't have an interconnection with 911 or with the Weather Channel or with the disaster system or with FEMA. That can—we also handle communications, gentlemen, and that can be done automatically. Once you press the button, it can be very ubiquitous and go throughout the country, if it's set up right.

So we'd like to know, What will it take to do that? And if you need money, the appropriations bills are coming up, we'll see to it you'll get it.

General KELLY. Mr. Chairman, I may have misunderstood your question. I thought, when you were talking about the press, you were talking about internationally. We work—we, in NOAA, work very, very closely with the Weather Channel. We work very, very closely with FEMA. We will provide the information you requested. I will be surprised, in fact, if those organizations you talked about did not have information about this tsunami. The fact was, though, that the tsunami was not going to impact the United States, and, therefore, some of their interest may not have been as great on it. But internationally—dealing with the international press, I'm not sure what the arrangements are.

The CHAIRMAN. Well, of course, we're talking here about when it might be coming our way, and those buoys are supposed to tell us that.

General KELLY. Well, that's what I'm telling you. I believe the system is in place if this one would have affected the United States.

The CHAIRMAN. Yeah. I'm sorry to take your time.

Senator Nelson?

STATEMENT OF HON. E. BENJAMIN NELSON, U.S. SENATOR FROM NEBRASKA

Senator BEN NELSON. Thank you, Mr. Chairman. And thank you, gentlemen, for helping us understand what is involved in detecting and—tsunamis and communicating the information.

As it relates to a globalization for a warning system so that it's not only—we're not only capable of communicating the information to affected locations, what would be involved in making sure that the receiving end of the information is capable of, not only receiving, but acting on this information? If the information goes out, and there's no reaction to it, obviously, then, it's not terribly helpful. We will have committed our—we will have fulfilled our responsibility, but we're certainly not going to get the result we're looking for. And if $350 million of aid is going from the United States, given the fact that there's also private aid that will go, what would be involved in making sure that we have receivers at the other end so that there could be action taken on it? And, also, what barriers might we encounter? And some idea of the cost. I suspect that if we're looking at this in terms of dollars and cents, there may be a way to quantify it. There is no way to quantify or qualify the untold misery and loss of life and the disruption to entire areas around the world.

Dr. Marburger?

Dr. MARBURGER. Yes, let me take a crack at that.

First, the most important part of the receiving nation's capability must be communications and education systems, country by country, in the affected countries. And it is necessary for some of those countries in the Indian Ocean periphery to build from scratch. There's a great deal of unevenness in the state of development in those countries, as you well know. The most capable countries are already on their way toward building systems like ours in their countries.

Senator BEN NELSON. Were they in the process of doing that before this, or is this subsequent to the event?

Dr. MARBURGER. I believe that some of those countries were, countries like India and Australia and Indonesia, Thailand all have important capabilities. And as a result of the meeting that I attended last weekend in Thailand, it became clear to me that those countries are likely to be the centers. Just as the U.S. and Japan and some other countries around the Pacific have strong systems, I believe those systems will begin to emerge in the Asian nations around the Indian Ocean.

The U.S. will participate in advising and helping those nations to develop strong programs, which include more than just the sensing systems. We have a great deal of experience. We work closely with the UNESCO IOC, and they are on the scene and helping to advise those countries, as well. I believe that aid will be required, and that aid will be delivered through the normal channels, but, at this time, I can't make an estimate of how much might be necessary.

Senator BEN NELSON. Could somebody else help us? Yes?

Dr. BEMENT. I think education and preparation is vitally important, especially in being able to do risk and vulnerability assessment. It's critically important that there be lifelines that are robust and can function under this type of a disaster. And I think our field surveys will inform that process.

We're discovering that there are many bridges that were not pinned to their support structures, that were washed away. That affected, not only food and water supply, but also medical evacuation. There are many structures on the coastal regions that were not built to earthquake codes. We're still sorting out what was earthquake-related and what was tsunami-related. Unfortunately, they both reinforced one another.

But detection is one thing. Casting that detection into a suitable warning system based on risk and vulnerability assessment that's done before-the-fact, so you can at least have an understanding of how much damage can be done and what prior preparation would help mitigate the event, I think, is critical——

Senator BEN NELSON. So——

Dr. BEMENT.—in this particular instance.

Senator BEN NELSON.—our ability to detect, without the capability to followup, is inadequate in order for these countries to be able to respond, even though we may. And I suspect that those three buoys will be corrected rather quickly in the Alaskan area. I sense the Chairman's——

Dr. BEMENT. I think Dr. Marburger, in his——

Senator BEN NELSON.—interest in doing that, yes.

Dr. BEMENT.—Dr. Marburger, in his written testimony, I think spelled out all the elements that are needed for a robust system, and it involves, not only detection and warning, it requires a good response plan, a good recovery plan, and it also requires an infrastructure that has lifelines that will survive the event.

Senator BEN NELSON. Now——

Dr. GROAT. Senator, could I—oh, excuse me.

Senator BEN NELSON. Sure. Yes, Dr. Groat?

Dr. GROAT. Just one particularly challenging aspect of this, not only internationally, but domestically, that we all have to worry about is the fact that if the rock drops in the pond, and the waves come from some great distance, we have plenty of time—literally hours, in some cases. And if there is a structure in place to get warnings to citizens—news media, weather—whatever it happens to be—were in decent shape, particularly in the United States. The challenge comes if this subduction-zone-caused earthquake-generated tsunami is just a few miles off the coast, as it was in the case of Sumatra, where we have very little time, then the challenge of getting that information, that it is likely to have generated a tsunami, into the hands of the response agencies, even when they're sophisticated, as they generally are in the United States, and then eliciting the proper response from the citizens, is a super challenge for all of us. And that's where these communication links and education links and programs, such as the program that NOAA supports, are so important, and the engagement of local governments and regional governments and all of the preparedness agencies is so critical.

So literally you have little time, other than to say there's a likely tsunami, the tide gauges and others indicate that it may be coming is to—the run-for-your-life business has to be communicated very quickly and very effectively. And that's a challenge even in our country, where we could probably do it pretty well, but in the countries that we were just talking about, it's a whole other order of magnitude to do that.

Senator BEN NELSON. Is it possible for us to improve from "pretty well" to "very well"?

Dr. GROAT. I think we can. I think the Subcommittee you described as having created is going to create a much broader awareness of the array of natural hazards that we have. Tsunamis are certainly one, but earthquakes, landslides, hurricanes, all of those things that affect populations very quickly, need to be paid attention to, not only from how-they-occur, when-they-occur warnings systems, but creating that education process that puts our populations-at-risk at less risk. And I think this Subcommittee can go a long way in helping that happen.

Senator BEN NELSON. Thank you.

And thank you, Mr. Chairman.

The CHAIRMAN. Thank you. Thank you for your comments.

If the information we're getting from some people about global climate change is correct, we may be in for a lot more of these than we anticipate right now, so I think it's essential that we take this action. That's why we created that Subcommittee.

Senator Smith?

STATEMENT OF HON. GORDON H. SMITH, U.S. SENATOR FROM OREGON

Senator SMITH. Thank you, Mr. Chairman. I wonder if I can ask that my longer opening statement be included in the record.

The CHAIRMAN. Sure. It will be.

Senator SMITH. Gentlemen, thank you for being here and for considering our implications of S. 50, which is the subject of this hearing.

As a Senator from a coastal state, I'm very mindful that 85 percent of tsunamis occur in the Pacific. I'm also mindful that Oregon is right in the middle of a Cascadia Subduction Zone. Apparently, according to your written testimony, Dr. Groat, about every few hundred years there's a major shift in this zone. And the last time it shifted was in 1700, and that that produced a tsunami on the Oregon coast the equivalent of what occurred in Southeast Asia. And I understand you're saying that there is a 10 to 15 percent chance that that will occur in the next 50 years.

Dr. GROAT. That's correct.

Senator SMITH. I guess, on the basis of that, that we're at the end of that likely millennial period where we could suffer another. I'm wondering if S. 50, and the changes that are proposed in that bill, are sufficient to give Oregonians, Washingtonians, Californians, and Alaskans the warning time that they would need to avoid the kind of devastation we saw in Southeast Asia.

I say that, because I understand that this plate is close enough to the coast of Oregon that it would only give coastal residents somewhere between 10 to 30 minutes to retreat. Are the systems in place to save their lives?

Dr. GROAT. Let me first comment, Senator, from the role that the USGS plays in this—and that is that if the upgrades that we're talking about in the seismic systems, and the ability to interpret the information that would occur from an earthquake in the zone you just described, were processed and communicated in the way—I think, in a technical sense, the bill does recognize the role that we would play in providing that information to the appropriate places and to the appropriate agencies. I would have to rely on others to comment as to whether—once that got communicated, whether there was a system in place that would, in fact, warn Oregonians quickly enough to respond in the way that I just described.

Senator SMITH. I'm mindful, having come from my state legislature, that we have done a great deal of work on this issue, but I wonder if you're aware, Are other states on the Pacific Coast—are they making sufficient preparations for warning systems? I mean——

General KELLY. Senator, let me address it from the National Weather Service point of view. Within the National Weather Service, we have a program called TsunamiReady. It is not a very complicated program. It is—you ask the coastal community to have some point where the warning information could come. You ask that that be manned 24 hours a day, 7 days a week. You ask that they have developed a communications system to get that warning out to the citizens in that community, and that they have thought through where we would evacuate the citizens to in the event that warning came, and they have some scheme or practice schedule to practice evacuations.

And if they have that, we, in the Weather Service, designate them as TsunamiReady. They get a number of big placards that go on the state highways and the roadways coming in. There's little notes at the bottom of them which says things like, "If you feel the ground shake, get away from the waterfront." That's applicable in your State of Oregon. We work in the state of Washington. It's in the State of Hawaii. It's in the state of Alaska. The local forecast offices up and down the West Coast work with the local emergency managers.

I would love to tell you that 99 percent of the local communities are enrolled in that TsunamiReady program, but I would be misleading you. I think up and down the West Coast there may be a combination of 15 cities, slash, counties that are in the program.

So what we need to do is redouble our efforts to start working with the local areas, because, in the final analysis, the local communities have to be where the action will take to get the citizens ready to move out of the way of this event.

Senator SMITH. Are you gentlemen, in your positions, are you familiar with the Hinsdale Wave Research Center at Oregon State University?

Dr. BEMENT. Well, the National Science Foundation supports that center, so we're very familiar with it.

Senator SMITH. I had the privilege of touring that with Dr. Cox, who will be on the next panel. I hope you make good use of it. It is a spectacular facility that certainly taught me a lot about tsunamis, long before this one occurred in Southeast Asia. And it's a remarkable asset that we have to spread information about what we're facing if you live on the coast.

And I'm wondering about inundation mapping. Can that help ensure that coastal residents immediately know when to go and what to do? How——

Dr. BEMENT. I think that's part of the prevention and education. Some of our reconnaissance teams now are trying to infer wave heights based on water lines and inundation surveys that they're currently doing, because one of the weak points in our predictive models are the runup part of the event, where it hits the shore. And enclosed bays, estuaries, and the beach gradient can have a big effect on how large that wave will be when it hits. And those are areas where we need to refine our current models.

Senator SMITH. Not only refining the models, but my question is, because of what happened in Asia, Do you have sufficient funding to complete these inundation mappings? Because I think that that—if not, we need to get you the money, because people need to know where they can go, in their geography, to avoid the wave.

Dr. BEMENT. Well, we do need to respond to that in our future-year budgets. Currently, we're planning workshops this spring and summer to assimilate and understand the data coming back from the survey teams. And based on those reports, we will be developing longer-range research activities, and we'll probably have to incorporate that in our budget for next year.

Senator SMITH. I would strongly urge you to do that. Senator Stevens has a lot of sway on the Appropriations Committee. And I just think if you need funding for inundation mapping——

Dr. BEMENT. Well, I did shift some funding for next fiscal-year request to help address some of that, but it may not be adequate.

Senator SMITH. Anything that it needs—you need to make it adequate, on behalf of the people of Oregon, please do it.

Dr. BEMENT. Thank you.

Senator SMITH. Thanks.

[The prepared statement of Senator Smith follows:]

PREPARED STATEMENT OF HON. GORDON H. SMITH, U.S. SENATOR FROM OREGON

Mr. Chairman, I want to thank you for holding this hearing and for including on today's witness list Dr. Daniel Cox from the O.H. Hinsdale Wave Research Center at Oregon State University (OSU). I had the opportunity to tour OSU's research facilities with Dr. Cox last year. I look forward to hearing from him as well as the other panelists. I want to thank each of today's witnesses for being here.

As a Senator from a coastal state, I have a very obvious interest in today's proceedings. Eighty-five percent of tsunamis occur in the Pacific Ocean. While in the United States we have been fortunate not to have experienced destruction on the scale currently seen in southeast Asia, the recent tragedy reminds how important it is that our communities are prepared in the event that a major tsunami strikes our coast.

Running along the Pacific Northwest—stretching from northern California to British Columbia—lies the Cascadia Subduction Zone. Research has shown that the Cascadia Subduction Zone has unleashed massive earthquakes off the coast of the Pacific Northwest every few hundred years. The last such quake occurred in January 1700. This event was similar in magnitude to the Sumatra earthquake and sent huge tidal waves barreling into the shores of the Pacific Northwest.

In testimony prepared for today, Dr. Groat writes that "there is a 10–14 percent chance of a repeat of the Cascadia magnitude 9 earthquake and tsunami event in the next 50 years." Scientists estimate that given the proximity of the subduction zone to the coast—approximately 70 miles off shore—it would take a tsunami roughly 10 to 30 minutes from the time the fault line ruptured to strike the Oregon coast.

Warning and detection systems are important, but alone they are not enough to protect our coastal communities. Our coastal residents must know where to go and what to do when the ground begins to shake. To protect the safety of our coastal residents, we must continue to work with our state and local partners to accelerate tsunami inundation zone mapping and ensure contingency plans are in place for rapid evacuation of vulnerable low-lying communities.

I was pleased to join Senator Inouye, Senator Stevens, and a number of my other Senate colleagues last week in introducing the Tsunami Preparedness Act of 2005. By improving tsunami detection and warning systems, as well as inundation mapping and community outreach and education, I am hopeful that this legislation will go along way toward helping our coast be better prepared should a tsunami strike. Thankfully, these events are rare and the cost of preparing for them is miniscule compared to the loss of life and property that could result if we are caught ill-equipped.

Mr. Chairman, I thank you again for holding this hearing and for the opportunity to speak. I look forward to learning more from today's panelists. I also ask unanimous consent that the testimony of the Oregon Coastal Zone Management Association be entered into the Committee record.

The CHAIRMAN. Senator DeMint?

STATEMENT OF HON. JIM DeMINT, U.S. SENATOR FROM SOUTH CAROLINA

Senator DEMINT. Thank you, Mr. Chairman.

I'm from South Carolina, so I'm on the Atlantic side, and I think what you're suggesting, we're not at nearly as much risk, is that what I understand from the panel? Although there may be some applications that we need on the East Coast.

Just a quick question, I guess, to anyone on the panel, in the—is, I appreciate the information that you've shared. I certainly don't pretend to be anywhere near an expert on what you're talking about after a few minutes, but, based on what you've told me, I have a—somewhat of a concern that we might be quickly expanding antiquated technology in order to cover our bases as quickly as we can. The failure rate of these buoys is apparently a concern to everyone who's heard that, and it doesn't sound like a quick fix or a few new parts is going to solve the service problem of these. And my question is simply, Has there been a coordinated attempt to look at all the technology that's available to see if water-based is really the way to go? Are there land-based water-level measurements that could go out several hundred miles that could give, particularly states like Oregon that expect a very short notice, a quicker way to respond than something that's floating around in the ocean that may not be working? That would be my only question. I think everyone is going to be interested in funding whatever works. But from what I've heard today, I'm a little concerned that what we may be funding might not be the most reliable way to go.

General?

General KELLY. Senator, on the observation side, there are two components to it. One, there is—there are the DART buoys. Larger in number are the tide gauges I mentioned. We're going to put some 38 new ones in. There are a number of tide gauges up and down the United States coasts today. They serve multiple purposes, not just for tsunamis.

The utility of the DART buoy is, with it being out in the deep water, you get an earlier confirmation as to whether a tsunami has or has not occurred. On the side that it has not occurred, that prevents the number of false alarms from being too high. On the fact that it did occur, then you can give more positive statements to the citizens that something not very nice is coming their way.

Yes, we have challenges with the DART buoys. We've had trouble maintaining them. I would point out that we know of no other country in the world that has developed a technology like this. The Germans contend they have a system. But the best I can determine, no one has ever gotten any data from the system and been able ever to see—to operate.

So I don't want to minimize the technical accomplishments that the researchers that have developed these DART buoys have made in doing it. And, yes, indeed, we do have some reliability problems with them, but when you're dealing with high-tech equipment—and I'm not trying to minimize that—that's not an unusual thing. It is not our intention to, with all the new DART buoys that are going out there, to replicate old technology that has given us maintenance problems. We are going to try to make it more robust.

But we believe the data from the DART buoys is an essential element of the observing network. It is not the only element, as I tried to say earlier. It's regrettable that three of the six are down. We still have some capability. We would like to have more capability.

But we do believe that the DARTs are an important part, and we are going to try to make them more reliable.

Senator DEMINT. I yield back, Mr. Chairman.

The CHAIRMAN. Thank you very much.

Senator Cantwell?

STATEMENT OF HON. MARIA CANTWELL, U.S. SENATOR FROM WASHINGTON

Senator CANTWELL. Thank you, Mr. Chairman. I ask that my statement be inserted in the record.

The CHAIRMAN. Without objection, it is so ordered.

Senator CANTWELL. Thank you, Mr. Chairman. And thank you for holding this hearing on the Tsunami Preparedness Act of 2005. I had an opportunity, in the last 10 days, to visit the Pacific Marine Environmental Laboratory in Seattle that is part of the NOAA operations. And, first and foremost, I want to thank the Chairman and the Ranking Member for their diligence on this issue.

When a crisis happens, you go back and look and see how prepared we are to date, and one thing that is very clear to me is that Senator Stevens and Senator Inouye, because of incidents that have happened in their states, have put a lot of energy into focusing on this issue and getting us where we are to date.

I had the chance to see the current DART buoy, and to understand the information system that connects to it and how it relays information. And I also got a chance to see the next-generation buoys, which will be much easier to deploy. So I have a good sense of where we're heading with the technology, which, for taxpayers and security reasons, will be much more cost-efficient and reliable. Instead of spending hundreds of thousands of dollars on a research vessel trying to go out hundreds of thousands of miles to deploy this, we might even be able to push them out of an airplane or off of any kind of vessel. So we're making good progress.

That doesn't mean that we, in the Northwest, don't want to know when the current buoys are going to be fixed. And I know my colleagues have raised these questions already, so I won't say anything other than we're very concerned, and we'd like them to be, obviously, operational as quickly as possible.

The one thing that is clear when you see the technology at the Pacific Marine Environmental Laboratory is that this act is really about the preparedness element. It is about mapping. It is, in the sense of what happened in Indonesia, understanding that the effects of such devastation basically wipe out roads and bridges and they hinder not just evacuation, but also support in the future.

So my question to General Kelly or to Dr. Groat is just, How far can—how fast can we get this mapping done? As you know, the last time we had a major earthquake was in the year 1700. A 30-foot-high tsunami smashed into our coastline, and the USGS estimates that there is a 10 to 14 percent chance that another major Cascadia quake could happen in the next 50 years. We're very interested in how soon the mapping could happen. And exactly, then, what does the mapping provide us, in the sense of local law enforcement and others, regarding the certainty of our preparedness efforts?

Dr. BEMENT. Senator Cantwell, the field data that's coming back will help inform the mapping process. But we currently have remote sensors—high resolution, medium resolution, low resolution sensors that are actually gathering data in real time of the affected regions in this latest disaster. Once we assimilate that data, we will be able to accelerate, I think, the mapping effort. And by learning through our predictive models we can infer what the damage zones would be if such an earthquake were to happen, for example, at the Cascadia fault line, which is about as large as the fault line in the Indian Ocean. The extent. It's almost a similar event.

As far as timelines are concerned, I'm not at the position to really lay that out in any great detail, but I think we're going to be much better informed about how to go about doing that.

Dr. GROAT. If I could comment, Senator Cantwell, you've hit upon a very sensitive point, I think, with both U.S. Geological Survey and NOAA. There are several kinds of maps that are useful in this process. Inundation maps clearly are important. Accurate maps upon which models can be built are important. But they depend on, in our case, the topographic maps that show the details of the topography on the onshore areas, and, in the case of NOAA's responsibilities, the bathymetric maps that are offshore. Having the most modern, current information about what the land looks like and what the sea bottom looks like is really critical to providing the information for inundation maps and for providing information to response agencies about surges in areas that might be affected.

I know in our case—and I can't speak for General Kelly—getting that information as current as it needs to be—many of our maps are 27 years old—so that it reflects the coast as it is today, and the infrastructure as it is today, is a real challenge for us. And if we're talking about funding challenges to provide information needed for those efforts, this is one, in our case, where the topography—the mapping of the topography needs to be modern, needs to be current, needs to be digital, so that it can go into the models and into the inundation mapping. And I know General Kelly has similar concerns.

General KELLY. I'll just second what Dr. Groat said. It is a challenge to get current surveys of the undersea and what the shoreline and the surface—sea surface is.

Senator CANTWELL. So are we talking years?

Dr. GROAT. I think the capabilities are there now, with LIDAR and some of the technologies that provide information about the landscape in digital form, to turn those into digital map products, that we don't have to be talking about very many years in critical coastal areas. In other words, we're not talking about decade-long programs. I think in a matter of a few years, with the funding, we could have current, update digital information about the areas of the coast that are likely to be impacted by this sort of event.

Dr. BEMENT. I can say that, if you look at just the area—the terrain that's above the water level, the inland terrain, there are geodetic surveys that are currently underway, some involving Caltech, other universities that are involved. And that's part of the survey work that's currently going on at the present time. Now, how all that geodetic information will be factored back into topological maps and update the maps, that's outside the science area. That's more than the——

Dr. GROAT. We do have a framework for that, called the National Map, and it's an attempt to bring information from the sources that Dr. Bement described, and others who are gathering relevant digital information about the landscape, into one framework so that it is the same around the coast, so we have a product that has set standards, set approaches to providing this information that everyone can use in a standardized fashion.

So we do have the framework, we do have a lot of organizations gathering it. What we don't have is sufficient support to gather that information as quickly as we would like to have it.

Senator CANTWELL. Well, I think that was the point I was trying to draw out. It's not a next-week project, but it isn't, also, a 10-year time-frame before we'll have the results we need.

Dr. GROAT. Exactly.

Senator CANTWELL. And the sooner that we can get to the mapping, the better preparedness plans we'll be able to develop.

I see my time is almost up, Mr. Chairman, but if I could just ask another question about inland waterways.

I think a lot of people think of this tsunami threat as unique to coastal regions, but Puget Sound, with its population base, cities of Seattle and Tacoma and up the coastline of Puget Sound, Bellingham and others, may be as susceptible to a tsunami threat as the outer coasts. How do you see the inundation mapping efforts helping to prepare large communities with, in terms of not just evacuating communities but also protecting infrastructure?

Dr. GROAT. I think the mapping is, as you're pointing out very accurately, needs to extend into those inland bodies, those sounds, those estuaries, those bays, that are accessible to the sea, where waves can come in—as they have in all cases with these tsunamis, if there is an inlet, they'll come through them—and that the infrastructure, as well as the people in there, needs to be accurately represented so—on these maps. And that's part of the National Map, is to include not just the terrain, but the infrastructure that's there—houses, buildings, bridges, so forth. And that needs to be as much in place for areas facing—you know, areas on these inland bodies connected to the sea as it is on the raw coast. And that is part of the structure that we're talking about.

Senator CANTWELL. I see. And if I could just throw this in—if we had this mapping done prior to December 26, 2004, and we knew what was going to happen in Indonesia—which, in fact, I know the minute the earthquake happened, people ran to the lab at the Pacific Marine Environmental Laboratory in Seattle and started trying to model scenarios, but by the time they got information, the tsunami was actually hitting—but say we had gotten all this mapping done 3 or 5 years ago. What would we have done differently in preparing that community?

Dr. MARBURGER. Let me say, the main problem in the Indian Ocean countries was not the technical warning. The main problem was the absence of local public education and local communications systems. That was the biggest thing that was there. There were warnings available, based on seismic data alone, that were transmitted to some spots in the Indian Ocean that could receive them and knew what to do, but the biggest challenge that we have is to provide infrastructure in those nations so that they can educate their people and communicate with them when they get the information.

So while simulations and additional instrumentation in the Indian Ocean are important, nevertheless, the most important thing is the public education and the identification of the critical infrastructure long before the tsunami hits.

Dr. BEMENT. One thing that's going to be a major unknown is what really changed as a result of the tsunami and the earthquakes with regard to the relationship between groundwater and surface water and what damage was done to the aquifers that may not be reversible. Had that information been baselined, we might be able to detect or determine what changes took place. Now, that's one thing we can yet do in our own coastal regions, is to develop that baseline data, so that we would be better informed what possible damage might be done to aquifers and other sources of fresh water.

General KELLY. Senator Cantwell, you put your finger on the real challenge. And while the death—the number of deaths pale in comparison to what happened in the Indian Ocean, it was a very active hurricane season last year. They were, overall, very well forecast. The Government of Haiti was provided good forecasts and good information on what was likely to happen with the hurricane, and they still lost 3,000 of their citizens due to flooding. And it's my belief, in large measure, that that's tied to the infrastructure challenge that that particular government faced. And so, it cuts across all natural disasters, and it is a big challenge.

Senator CANTWELL. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator.

Thank you very much, gentlemen.

I'll just drop a little pebble in this small bowl up here. Do you ever think what would happen if the Madrid fault slipped again? I mean, I heard that bells rang in the churches in Boston and the Mississippi changed its course. So, I mean, we still have problems all over this country. It's not necessarily coastline.

And, second, back years ago, the Navy was building up Adak, and we finally ended up with about five different naval bases on that little island. We built a tsunami-proof shelter. We didn't build any more, because of the cost of that one. But there are things we must think about, and that is, can we get a tsunami-proof shelter in the areas where they might be needed? I would—I hope that our Subcommittee that we're going to create will go into things like that.

And we look forward to working with you, but we're very serious about this coordination thing, now, and I hope you will help us by giving us your ideas of, what could we do to assure that there would be proper notification to all the public sources that would help disseminate news.

[The prepared statement of Senator Cantwell follows:]

PREPARED STATEMENT OF MARIA CANTWELL, U.S. SENATOR FROM WASHINGTON

Thank you, Mr. Chairman.

And thank you for holding this hearing and for championing this critical bill. Your leadership and foresight—along with that of Senator Inouye—created the existing tsunami warning system, and I look forward to working with you to further upgrade and modernize this essential service.

Mr. Chairman, the loss of life and infrastructure incurred as a result of the recent tsunami in the Indian Ocean provides a jarring reminder of the need to evaluate the risk of tsunamis to our own coastal populations.

That's why this well thought out bill, developed in cooperation with the Administration, is so important. I am pleased to be a cosponsor of it.

I recently visited the Pacific Marine Environmental Laboratory in Seattle, which provides research support for all aspects of the U.S. tsunami program. While I was greatly impressed with their work, I also learned that we can and must do more.

Whether it is developing more reliable monitoring buoys, or improving our nation's vulnerability assessments, more resources are needed.

I also learned more about the massive Cascadia fault that lies off the coasts of Washington, Oregon, and Northern California and the fact that it is similar in size and geologic character to the fault that produced the devastating Indian Ocean tsunami.

A major Cascadia earthquake—the last which occurred in the year 1700 and led to a 30-foot high tsunami smashing into Washington's coastline—could happen at any time. The U.S. Geological Survey estimates there is a 10 to 14 percent chance of another major Cascadia quake within the next 50 years.

Since a Cascadia-generated tsunami would allow for only 10 to 20 minutes of warning, I am pleased that this legislation includes community-based tsunami hazard mitigation program and an acceleration of critical vulnerability assessments and inundation maps. This information is critical for coastal communities to plan for future tsunami events.

I'd also like to thank Senator Inouye and Stevens for accomodating my request and including language in this bill that requires an assessment of tsunami risks in vulnerable inland bodies of water. Earthquakes within the Puget Sound have historically produced significant tsunamis, which today would cause significant flooding along the waterfront of Seattle and other inner coastal communities.

So again, Mr. Chairman, thank you for holding this hearing. I fully support the Tsunami Preparedness Act and believe it is essential if we are to prevent the devastation caused by the Indian Ocean tsunami from one day becoming realty on our coasts as well.

Senator Inouye?

Senator INOUYE. I just wanted to clarify the record. In November of 2003, one of the DART buoys issued data and suggested that a massive tsunami was on its way to Hawaii. But thanks to the efficiency of NOAA, they immediately clarified the data and suggested it was not hitting us. And we've calculated that it saved the State of Hawaii about $70 million; otherwise, we would have spent all that money. So I want to thank you very much.

And, Mr. Chairman, may I submit written questions?

The CHAIRMAN. Yes. *

The CHAIRMAN. I'd appreciate it if you would respond to questions that will be submitted by the individual Senators. And, again, we thank you, gentlemen, for joining us. We consider this to be a very important first hearing.

We'll now turn to the second panel—or maybe the third panel, Dr. Roger Hansen, Professor of the University of Alaska in Fairbanks, the Director of the Tsunami Warning and Environmental System for Alaska; second, Ms. Eileen Shea, Project Coordinator of the East West Center, of Honolulu, Hawaii; and, third, Dr. Daniel Cox, the Director of the Hinsdale Wave Research Laboratory at Oregon State University.

Senator Smith has a conflict, so, as a matter of courtesy, Dr. Cox, we're going to call on you first.

* Written questions and responses are printed in the Appendix.

We do hope that you all will give us a summary of your statements, or at least shorten them somewhat, but all of your statements will be printed in the record as though read.

Senator SMITH. Mr. Chairman?

The CHAIRMAN. Senator Smith?

Senator SMITH. May I thank you for that courtesy and also welcome Dr. Cox. He has taken the redeye to be here. Senator Cantwell and I know that flight very well. Welcome.

The CHAIRMAN. Dr. Cox, I welcome you. I left Oregon State College to go to war, some 50-odd years ago. Nice to see you here.

STATEMENT OF DR. DANIEL COX, DIRECTOR, O.H. HINSDALE WAVE RESEARCH LABORATORY, OREGON STATE UNIVERSITY

Dr. COX. Thank you very much, Mr. Chairman and Members of the Committee, for this opportunity to discuss the research that we're doing at Oregon State in the Hinsdale Wave Research Laboratory. I'm the director of that laboratory, and also associate professor in civil engineering.

We are home to the world's largest facility specifically constructed for tsunami research, and I'd like to give you, just, sort of briefly, the history of it, just to show you that this has been many, many years in the making, planning long before I got there. I've only been there for about 2½ years.

And I'd also like to tell you just, sort of, how the tsunami community has come together, a little bit about what we're learning about today's—the recent events, and then how we're trying to improve the nation's ability to respond to tsunami disasters, emergency planning, and so on.

In the 1990s, there was a series of NSF workshops to decide what are the nation's needs for tsunami research. And, as a result of these workshops, there was a proposal to come up with a very large wave basin. This is a large rectangular concrete basin that can very accurately repeat a tsunami-like wave. It's called a soliton. And the main purpose of this facility is to provide proof that the numerical models are working well. We've heard a lot of testimony today talking about inundation mapping and the reliance on these maps for telling people where to go, directing them, deciding what kind of infrastructure will be in place after the tsunami event happens, and so on. But all of these computer models have to be tested very carefully before we rely on them.

And we use, to some degree, the fieldwork that's been done, trying to piece together the clues from the site reconnaissance surveys. But they don't have enough information. They don't give you the wave height, the wave direction in all locations. And so, we can very accurately make physical models with very carefully controlled conditions, and then compare the results of the physical models with what the numerical models predict. And that's how we use our facility.

We also use it as a sort of a center for the research community. It's a great place where people gather and share ideas, exchange information. We had two of our professors going to Madras, to India, to look at the survey, the damage, and then they'll come back, share their results, hold a series of seminars, and so on. So it's also provided a great focal point for the research community.

There was also a report published by the National Research Council for the NEES program. And, in that report, it outlines very specifically what are the challenges for the research in our areas—and that includes better understanding of the tsunami inundation that we heard about earlier today—and also the tsunami impact, what happens when that wave hits buildings and bridges and other critical lifelines that would be necessary in an evacuation.

The long-term goal is really to develop a comprehensive numerical model that includes not only the hydrodynamics of the wave and the wave impact and the debris flow, but also includes human factors—how people will respond in a crisis—and this will greatly improve our ability to plan for tsunami attacks—tsunami disasters.

So I just—I'd like to finish here and just say that I think we have an extremely unique tool here for the Nation to use. It's a shared-use facility. It's hosted at Oregon State, but it's really designed with a number of researchers in mind. We bring them here, we do the—the research—the tsunami research is supported by the National Science Foundation. So if their proposals are accepted, then their work is supported in our lab for free, or by the National Science Foundation.

And, yeah, with that, I'd be happy to answer any questions that you might have.

[The prepared statement of Dr. Cox follows:]

PREPARED STATEMENT OF DR. DANIEL COX, DIRECTOR, O.H. HINSDALE WAVE RESEARCH LABORATORY, OREGON STATE UNIVERSITY

Thank you, Mr. Chairman and Members of the Committee for the opportunity to discuss how research will continue to improve our nation's ability to deal with tsunami risks. I am Daniel Cox, Director of the O.H. Hinsdale Wave Research Laboratory at the Oregon State University College of Engineering, home to the world's largest and most-wired facility specifically designed for tsunami research.

Today, I would like to provide some information on how this new Tsunami Wave Basin facility is helping this country better prepare for the next tsunami scenario, including development of more effective tsunami warning systems, safer evacuation routes and procedures, and better building and bridge design.

As mentioned in previous testimony and elsewhere, advanced numerical models are essential for tsunami mitigation and evacuation procedures. These simulation tools have been developed at research universities like Oregon State over the past several decades. The guidance and validation of these models, especially the inundation process of the tsunami wave impacting the coast and flowing over the land, has been achieved through careful comparison with laboratory studies. It is important that we continue to use the latest numerical techniques to improve their predictive capability and systematically test their accuracy with benchmark data before we rely on them for emergency planning, zoning, and construction guidelines.

Background on the Development of the Next-Generation, Shared-Use Facility for Remote Tsunami Research

In the 1990s a series of NSF-supported workshops were convened by the tsunami research community to determine the needs for supporting the further development of tsunami research and numerical models. These workshops led to a document that outlined the requirements of a large wave basin, capable of generating solitons (or solitary waves which have tsunami-like behavior). In addition to the physical requirements and instrumentation of the new facility, the workshops stressed collaboration and a close integration of physical experiments and computer simulations through data sharing and research guidance based on field work and practical applications. Many of the researchers who participated in these early workshops were also actively involved in post-tsunami surveys, for example in Nicaragua, Indonesia, and Papua New Guinea. Their graduate students have gone on to successful careers at places like the NOAA's Pacific Marine Environmental Laboratory to work on tsunami inundation mapping.

In the late 1990s, the need for a tsunami wave basin was recognized at the NSF, and funding for up to two facilities was included in the initial call for proposals in the first solicitation of the George E. Brown Jr. Network for Earthquake Engineering Simulation (or NEES) program. Through a competitive proposal process, Oregon State University was awarded a $4.8M grant, which was augmented by approximately $1.2M from the Oregon State University College of Engineering. One of the first steps was to establish an advisory board of tsunami experts, coastal engineers, and computer scientists from universities such as Cal Tech, Cornell, USC, and Delaware, as well as government agencies including NOAA. A second step was to actively engage the tsunami and coastal research community for input on the design of the new facility, instrumentation, and data sharing requirements. In parallel with this, the Principle Investigators of the tsunami project at Oregon State continued to work with the entire NEES consortium. The NSF funding also helped the OSU College of Engineering attract a world-class team of tsunami experts, computer scientists, and ocean engineers who appeared in many national media reports following the Asian tsunami last December. Construction of the new facility was completed ahead of schedule and commissioned during a ceremony on September 13, 2003. The Tsunami Wave Basin at Oregon State University was selected as one of four out of 15 NEES sites showcased in the NSF's live demonstration of the NEES program in November, 2004.

The Tsunami Wave Basin facility itself (Figure 1) is a large, rectangular basin, measuring 160 ft. long by 87 ft. wide by 7 ft. deep (48.8 m x 26.5 m x 2.1 m) with a wavemaker consisting of a series of programmable wave boards at one end. These paddle-like wave boards can be programmed to move in a carefully prescribed motion that generates a soliton (or solitary wave), which is a simplified form of a tsunami. At the end of the basin opposite of the wavemaker, researchers install contoured terrain characteristic of coastal features, such as bays or points of land. On this terrain, researchers can place models of coastal infrastructure such as bridges and buildings, for example, instrumented with sensors to measure the impact of the wave or debris. It is important to note that although the soliton is a simplified representation of the tsunami, it is complex enough to provide a strict test for numerical models. In other words, if a numerical simulation can not reproduce the simplified conditions of the laboratory, it will have little use as a decision-making tool. In addition to the construction of the physical basin, the NSF grant provided for the development of cutting-edge information technology (IT) infrastructure. This IT infrastructure assists in experimental planning, archiving, and sharing of data. It also enables researchers anywhere in the nation to remotely participate in experiments in real-time, saving travel costs and speeding research.

Grand Challenges for the Network for Earthquake Engineering Simulation (NEES) and Tsunamis

A National Research Council report published in 2003 outlines the challenges in earthquake engineering as well as a research agenda for the NEES program, including tsunamis. The report provides the historical perspective of tsunami research, critical knowledge gaps, and outlines short-term and long-term research goals.

The report recommends that:

> "A complete numerical simulation of tsunami generation, propagation, and coastal effects should be developed to provide a real-time description of tsunamis at the coastline for use with warning, evacuation, engineering, and mitigation strategies."

The short-term goals outlined in this report include:

1. Better understanding of tsunami inundation—how the wave travels over dry land.
2. Better understanding of sediment transport under tsunamis.
3. Quantify the impact forces of the tsunami wave and debris on structures.
4. Determine the effects on buildings and groups of buildings.
5. Work with the National Tsunami Hazard Mitigation Program (NTHMP) to refine research needs to best support NOAA's mission.

Medium-term goals include:

1. Verify and validate numerical models for defining runup limits.
2. Work with the geotechnical community to study the mechanics of landslide generated tsunamis.

The long-term goal is summarized as:

> Develop comprehensive, interactive scenario simulations that integrate the physical aspects (generation, propagation, inundation) with societal issues such as transmission of warnings to the public, evacuation, environmental impacts, rescue tactics, and short-term and long-term recovery strategies.

What is the Role of the Tsunami Wave Basin for Future Tsunami Disasters?

The intended purpose of the Tsunami Wave Basin at Oregon State University is to provide the research community with a controlled environment for the systematic study of primarily tsunami inundation and tsunami generation from landslides.

Post-tsunami (reconnaissance) surveys provide new insights and valuable lessons learned about the real effects of the actual events. However, it is impossible to collect sufficient and accurate data from surveys to improve numerical models because the data/information are ephemeral and difficult to obtain. There is no way to make advance preparations to obtain data since it would be a formidable task to install a sufficient number of sensors in the field prior to a very unpredictable and rare tsunami event. For example, the speed of the wave is an important variable when considering evacuation or the safe design of buildings or bridges, but this data are rarely available. Wave height and direction are also extremely important but elusive quantities.

All numerical models require known boundary conditions and initial (or starting) conditions. Because we have almost no quantitative information about the real tsunami as it approaches the shore, we can not properly prescribe the initial condition, and therefore we can not easily compare the damage at the site to the damage predicted in the model. The laboratory, however, provides us with a tool that can provide boundary and initial conditions as well as the resultant force of the tsunami as it impacts the coast. We can prescribe the same initial condition to the numerical simulation and then through comparisons with laboratory data, we can verify (or refute) the accuracy of the simulations. The increasing computational speed of numerical simulations has shown that we can simulate large geographical regions with complex shapes. The remaining questions are the accuracy of these simulations and inclusion of realistic features such as wave-impacts and debris flows.

Development of Collaborative Tools for Natural Hazards Mitigation

We have been developing three separate but closely related research programs on integration of hazard mitigation tools and information: (1) tsunami scenario simulations, (2) computational portal, and (3) tsunami digital library. These activities heavily rely on the advanced information technologies, and have direct impacts on hazard mitigation practice.

Scenario simulations:

An alternative to a full-scale field investigation is to perform repeatable and precisely controlled “scenario” simulations. A scenario simulation means a case study, either in a real or hypothetical background setup. Tsunami phenomena and effects are simulated for given geographical, seismological, geological, and societal conditions. Simulations must be comprehensive and integrated not only in tsunami generation, propagation, runup motion (flow velocities and inundation) and flow-structure interactions, but also other types of simulations such as warning transmission to the public, evacuation, environmental impacts, rescue tactics, and short-term and long-term recovery strategies. The simulation exercises should include physical models, numerical models, informatics, human behavior, communication simulations, and other exercises that will integrate the tsunami source with its eventual effects on communities and the environment. This activity is by nature a multi-university, multi-community, and multi-disciplinary effort. The goal is to provide damage estimates based on best available information, ultimately leading to earthquake related risk analysis/assignment for an urban region and to provide a rich problem-solving environment for the education of students. A tsunami simulation scenario must actually expand this concept to include the modeling of human behavior, since a primary emphasis of tsunami hazard mitigation is not only minimization of structural damage but also the saving of lives through evacuation. It is emphasized that this type of work must be collaborative. The collaboration with only a few researchers is insufficient; the entire community involvement is essential for the success.

Tsunami digital library:

In recent years, the Internet has become the primary source of information and data. Before the Internet, the challenge was limited access to information and data. Now the problem is locating information relevant to their discipline and validating the quality of such information. Existing web search technologies are insufficient to retrieve information that is relevant to a particular scientist’s context and guaranteed to have some level of quality assurance. New technology for information search that addresses both quality and context will substantially increase the effectiveness of scientists studying natural hazards and their mitigation, enabling greater understanding of hazards and more effective preparedness and response.

Such information and data are highly diverse, and serve a very diverse community. The unique information challenges presented by tsunamis, the history of research collaboration among the tsunami scientific community, and increasing public awareness of the danger to life posed by natural hazards combine to make tsunamis an obvious focus for the first digital library of natural hazard information. The software components to be developed as part of this project will be used to develop digital libraries for other natural hazard domains.

Computational portal:

Numerical modeling is an essential tool for advancing our understanding of natural hazards, allowing us to study hazard characteristics, impacts, and prediction. At the same time, highly sophisticated models impose complex requirements for data, computational resources, and knowledgeable interpretation. Typically, it is individual researchers and mitigation personnel who must grapple with these problems. We are developing a coordinated, Web-based environment for sharing knowledge about tsunami prediction and mitigation. It will provide points-of-entry through which users can access computational models without the difficulties usually involved in managing data, computing resources, and other operational requirements.

Summary

The Tsunami Wave Basin at Oregon State University provides tsunami researchers with a unique tool to develop and test the next-generation of numerical models for tsunami simulations. The basin is designed as a shared-use laboratory, meaning that is researchers from around the country can access it through the Network for Earthquake Engineering Simulation program supported by the National Science Foundation through 2014.

I would be happy to answer any questions you might have.

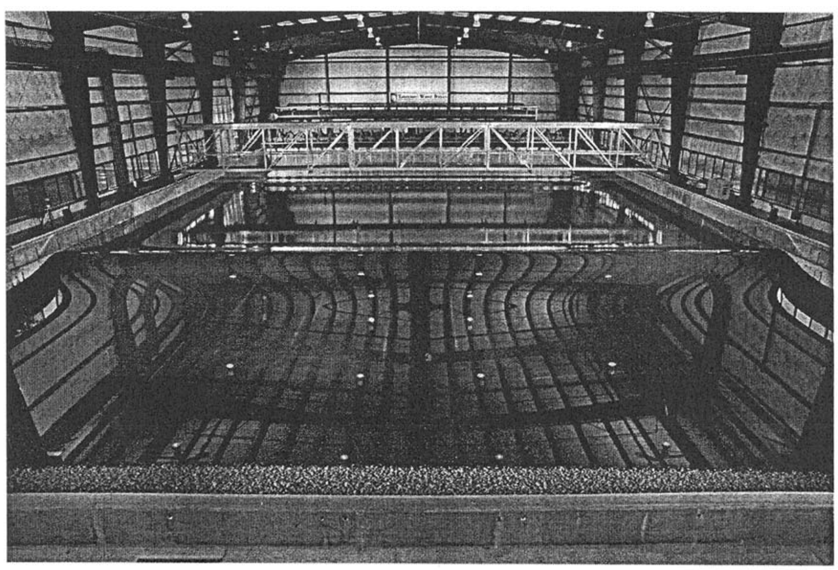


Figure 1: Tsunami Wave Basin at the Oregon State University College of Engineering funded as part of the NSF NEES program.

The CHAIRMAN. Thank you very much.

Senator do you have any questions? I'd be pleased to yield to you.

Senator SMITH. Thank you very much, Senator.

Dr. Cox, thank you for being here. I very much enjoyed the tour that you gave me. Having listened to today's testimony—and yours, as well—I'm curious as to your thoughts, if you've had a chance to review S. 50 and the Administration's proposal from an academic perspective. Do you see these proposals as adequate, in terms of research, mapping, and education? Do you think—is this a sufficient step forward?

Dr. COX. I think it's a step in the right direction, and I think the points that are outlined today, the importance of education—once you have a warning system, and you tell people—you've got to tell them what to do, and they have to know how to respond. There's no time to educate them during the time of crisis. So I think these are all steps in the right direction.

We've talked about inundation mapping. The future of inundation mapping is really trying to start to measure the—or map the intensity of the event, not just where the last water line is. And the intensity is really related to whether or not a building is going to withstand the attack or not. So there's, I think, a lot more work that we need to do to better prepare ourselves for the inevitable tsunami.

Senator SMITH. Thank you, Dr. Cox, for being here, and, Mr. Chairman, for your courtesy. I appreciate that.

The CHAIRMAN. Thank you, Senator.

May we proceed, then? Ms. Shea?

STATEMENT OF EILEEN L. SHEA, PROJECT COORDINATOR, EAST–WEST CENTER, HONOLULU, HAWAII

Ms. SHEA. Thank you, Mr. Chairman, Senator Inouye, Members of the Committee. It's my honor to be here today, and thank you for the invitation to talk about S. 50, the U.S. Tsunami Preparedness Act, as well as your general interest in building disaster-resilient coastal communities.

I first sat in this hearing room over 30 years ago, as a NOAA employee, in Congressional Affairs, and I believe that S. 50 represents just another step in your long legacy in this Committee of commitment to the coastal communities, the coastal resources, and the coastal businesses of this nation. And, therefore, it is an honor to be here.

I'd actually like to just touch on three things, in particular, and they have all come up, in one form or another, today.

The first is, I want to commend the Committee for taking a multi-hazard perspective on this bill and on building our resilience to tsunamis and other natural hazards. The same coastal communities in Southeast Asia and along the United States that are subject to tsunamis are also subject to other natural disasters—coastal flooding, typhoons, hurricanes, high wind and wave events. All of those events have the potential to threaten life and property, and all of those events are things that we need to address if we're going to build what I like to call an effective risk-management information system.

I believe that S. 50 and much of the discussion in the testimony today is headed in the direction of building that kind of risk-management information system, but I'd like to pick up on something that, Senator Inouye, you mentioned in your opening remarks, Senator Cantwell has, Senator Nelson has, others have mentioned, the idea of focusing on the receivers of these informations. It really doesn't matter how accurate and how efficient the arm of a quarterback is. If there isn't a person at the other end waiting to receive it, and a team of people—NGOs, the media, the civil-society community leaders, the governments, at a local level—a team of people who can help get that individual down the field and in the end zone.

It is essential, if we are to pursue building disaster-resilient coastal communities, that we do focus on those receivers of this information. An effective warning system, like we've heard discussed by many of the panelists today, is a part of that information system, but we really must invest in that education program.

And TsunamiReady communities is a good example of helping to reach out to communities and prepare them, but it's only part of the picture. And we've heard several witnesses today, as well as several of the Members, talk about the broader education effort, formal and informal education, technical training, and also leadership training, building the next generation of leaders of these institutions that will be responsible for warning and response.

The second element of a—for me—of an effective risk-management system is this concept of a better understanding of vulnerability and our choices for adaptation, our choices for building resilience. We've heard much talk today about these inundation maps. These are parts of tools for understanding how exposed we are to a risk. How sensitive are we to a risk? The other part of the equation is, how prepared are we to deal with that? How resilient are we? How much like those palm trees that Senator Landrieu mentioned are we, are our businesses, our infrastructure, our key economic sectors, and the people in our communities who call the coastal zone "home"? Building that partnership, building those—that understanding of vulnerability, and our ability to adapt is an essential part of what we're about.

I think that it's important to remember that building this understanding of vulnerability is not just a matter of funding a few socioeconomic studies. It's about establishing a new way to doing science. It's about participatory research in which the decisionmakers and the community leaders and the scientists and the technical experts work together in a process of shared learning and joint problem-solving.

It's also important to remember that this is probably best done at a regional level. One size does not fit all when it comes to education programs, warning systems, or adaptation. It's really important, I think, as we consider the next steps, that we consider the regional effect.

And, finally, it's important to build critical partnerships. I don't have to add much to the discussion today about the international partnerships involved in the tsunami, but I will mention that—and thinking about those receivers again—that one institution that wasn't mentioned in the tsunami arena is the International Tsunami Information Center in Honolulu, which is the focus of the receiving-education—reaching out, education and training both in the U.S. and abroad.

Finally, I would like to touch on a regional activity. There is, in the Pacific now, something called the Pacific Risk Management Ohana. "Ohana" means family. "Ohana" means working together. Three years ago, under the leadership of the NOAA Pacific Services Center, all of the federal agencies in the Pacific Islands region who work in disaster management sat around a table together to talk about better coordinating the work that they do. As a result of that initial meeting, the scientific institutions active in risk management in the Pacific, the Federal agencies active in risk management in the Pacific, and state and local entities and organizations are all now acting together in the context of PRiMO, a coordinated effort on the part of all of those interested institutions to work together.

In one way, it's an example of the kind of coordination that you're calling for in S. 50. In other, it's a reflection of how important it is to do this at the regional level, because it is at the regional level where we can work together, touch each other in ways that the Majority Leader mentioned today. It's about understanding the people, the resources, and the businesses in these communities. And I think we're on our way.

Thank you for the opportunity. I'll be happy to answer any questions.

[The prepared statement of Ms. Shea follows:]

PREPARED STATEMENT OF EILEEN L. SHEA, PROJECT COORDINATOR, EAST-WEST CENTER, HONOLULU, HAWAII

Mr. Chairman, Senator Inouye, Honorable Members, ladies and gentlemen, ALOHA and thank you for the opportunity to share some thoughts on the U.S. tsunami warning system and enhancing our efforts to build disaster-resilient coastal communities in the wake of the December 2004 Indian Ocean tsunami. Your initiative and leadership in this endeavor is crucial and is an important next step in this Committee's longstanding legacy of commitment to the communities, businesses and natural resources that call the coastal zones of the world home. According to the Global Forum on Oceans, Coasts and Islands, coastal areas (within 60 km of the shoreline) are home to 50 percent of the world's populations and two-thirds of the world's largest cities are located on coasts. The final report of the U.S. Commission on Ocean Policy notes that approximately 52 percent of the U.S. population resides in coastal counties which constitute 25 percent of the U.S. land area and include economic activities that contribute approximately $4.5 trillion (roughly half) of the Nation's annual GDP. I am honored by your invitation to contribute to your deliberations. My thoughts today are based largely on my work in climate vulnerability assessment and risk management in the Pacific, including the use of climate forecast information to support decision-making.

The tragic loss of life and property associated with the December 2004 Indian Ocean earthquake and tsunami highlights the complex and close relationship between achieving national development goals and the ability to anticipate, prepare for, respond to and recover from natural disasters. Increasingly, international and regional development bodies like the United Nations Development Programme, the World Bank and the Asian Development Bank are recognizing that effectively managing the risks associated with natural disasters such as tropical cyclones, coastal inundation from storm surge, droughts, floods and geologic hazards such as earthquakes and tsunamis, is an essential component of an effective, long-term development strategy.

It is important to remember that the same nations that suffered the greatest impacts from the December 2004 tsunami are also highly vulnerable to other natural disasters. Typhoons, floods, and high wind and wave events are frequent visitors to the same coastal communities affected by the recent tsunami. As we take steps to reduce the vulnerability of coastal communities to high-impact, low-frequency events such as future tsunamis, we should also be strengthening their resilience in the face of other, more frequent and often devastating natural disasters including weather and climate-related extreme events such as hurricanes and typhoons, floods, landslides, drought and high wind and wave events. In other words, a comprehensive, multi-hazard approach is needed that establishes the *social* (human, institutional and political) as well as scientific and technical infrastructure necessary to anticipate and manage risks. If we focus only on the tsunami hazard itself, I fear that we will be like the proverbial general planning for the past war.

In the *2004 World Disasters Report: Focus on Community Resilience,* the International Federation of Red Cross and Red Crescent Societies advocates a stronger emphasis on proactive, people-centered approaches to building resilience—rather than simply understanding and describing a community's vulnerability to natural and man-made disasters. In this context, the 2004 report highlights the importance of "understanding the ability of individuals, communities or businesses not only to cope with but *also to adapt to* adverse conditions and to focus interventions at building on those strengths" with an emphasis on risk reduction and development work. I commend your Committee for emphasizing a comprehensive, longer-term approach in your initial planning for an effective U.S. response to the December 2004 tsunami. In this context and in light of other testimony, let me highlight the particularly important elements of such a program. These elements include:

First, *building information systems* that support pro-active, comprehensive risk management;

Second, *improving understanding of vulnerability and effective adaptation strategies*; and

Third, *establishing and sustaining the critical partnerships* required to develop disaster-resilient coastal communities.

Comprehensive Risk Management Information Systems

Following the December 2004 disaster, we all focused on what could have been done to prevent such an awful loss of lives. Immediate attention was, appropriately, given to the technical systems that can provide the basis for more effective advance warning of future tsunamis. The expansion of seismic and ocean monitoring programs, the establishment of warning centers and the improvement of communications infrastructure to disseminate warnings and alerts are all critical and should be pursued aggressively. In this context, I would like to reinforce the importance of providing warnings and forecasts in language and formats that are accessible, understandable, useful and usable. In many parts of the U.S. and the world, this will involve translation into local languages and the use of relatively simple forms of communication such as radio, phone, facsimile and visual and auditory cues (such as warning flags and sirens) as well as the involvement of trusted, local knowledge brokers such as NGOs, religious, civic and, in the case of indigenous populations, traditional leaders and teachers. As we saw with the Indian Ocean tsunami, many of the most vulnerable populations lived in remote communities without access to the communications infrastructure of large urban centers. Reaching these communities remains perhaps the biggest challenge for disaster warning systems. Meeting that challenge should be of the highest priority as we move toward a pro-active risk management information system since the system will only be effective if it reaches those in danger.

Decades of natural hazards research, responding to weather extremes as well as my own experience in exploring adaptation to climate-related extreme events in the Pacific suggests, however, that good international and local warning systems are only one part of an effective risk management information system. As a colleague of mine pointed out recently, a successful pass in the NFL requires not only a skilled quarterback but a skilled receiver who not only knows where on the field to be to catch the ball but also what he's expected to do once he has the ball. In addition to knowing that more effective warnings are produced and disseminated, we should also be concerned with enhancing the knowledge, skills and capabilities of the receivers of those warnings including disaster management agencies and other national and local government officials, community and business leaders, NGOs and other key elements of civil society such as women's and youth groups and, ultimately, the public.

The concept of enhancing public awareness is, of course, not new in the disaster management world. There is a strong foundation of ongoing disaster preparedness education programs underway funded by a number of U.S. Government agencies (e.g., NOAA, FEMA, USGS), other national and local governments; scientific and educational institutions as well as regional and international organizations and technical institutions. NOAA's Tsunami Ready Communities program is a good example of this existing foundation. I hope that our response to the Indian Ocean tsunami will provide us with an opportunity to strengthen those programs and expand their focus beyond warning and immediate response to include a broader public awareness of the social, institutional and political challenges associated with building more disaster-resilient coastal communities.

In this context, warning and communications system improvements should be accompanied by a broad *education program* designed to enhance the cadre of individuals and institutions in the region capable of assessing vulnerability, communicating warnings and managing risks associated with natural disasters. Such a program should include:

- *Targeted technical training* to increase awareness of recent scientific developments in key hazard areas (e.g., tsunamis, weather extremes, climate variability and change) and make new tools and technologies in vulnerability assessment risk management decision support available to a wider Asia-Pacific community;
- *Leadership training programs* in risk assessment and management for representatives of government agencies, businesses, universities, NGO's, and coastal communities; and
- *Formal and informal education programs and materials* to broaden public awareness and understanding of disaster risk reduction challenges and opportunities by introducing them to the multi-disciplinary suite of issues involved in development and implementation of risk reduction strategies. Such a program would recognize the importance of knowledge of local communities and cultures as well as the technical aspects of risk assessment and management including: environmental science and technology, land use planning, health, civil society, and cultural aspects of leadership, problem solving and decision-making.

As we move forward, we also need to more effectively engage the media as a critical component of an effective, comprehensive risk management information system.

Understanding Vulnerability and Promoting Enhanced Resilience

An effective risk management information system also requires a better understanding of the multi-hazard vulnerability of coastal communities with an emphasis on strengthening the resilience of critical infrastructure, key economic sectors, valuable natural resources and, most importantly, the people who call those communities home. As some of today's witnesses have suggested, the provision of high-resolution imagery, geospatial (GIS) technology, risk and vulnerability maps and model-based decision support tools are important elements of work in this arena. I encourage the Committee to complement these traditional vulnerability assessment tools with **an integrated program of research and dialogue focused on building disaster-resilient coastal communities** that would draw on the broad multi-disciplinary expertise of and technical capabilities of partners in government, academia, business and civil society. Such a program would recognize the connections among social, economic and environmental goals to reduce significant risks and build sustainable communities. In our internal deliberations following the tsunami, my own organization, the East-West Center, has decided that the multi-hazard approach to building resilience in coastal communities is the framework in which we will organize our post-tsunami program.

Emphasizing a multi-hazard approach to comprehensive risk management such a program might include:

- *Targeted research* to improve our understanding of the links between disaster risk reduction and sustainable development; assess vulnerabilities for key sectors, resources and populations; identify and explore opportunities to minimize the economic and social impacts of disasters; support the integration of traditional and local knowledge and practices with new scientific insights and technology to enhance risk management and adaptation; and explore local, national and regional governance options for effective risk management;
- *Enhanced risk reduction information services* including the provision of high-resolution imagery, geospatial (GIS) technology and model-based decision support tools as well as support for local, regional and international discussions to support the emergence of an effective, multi-hazard warning and disaster risk management systems at local, national, regional and international levels; and
- *Dialogue on local, national, regional and international governance options* for effective risk management—exploring how to better coordinate the roles of government, civil society and local communities in disaster warning, response and risk reduction.

This last item reflects the importance of using a collaborative, participatory approach that effectively engages the scientific community and decision-makers in a process of shared learning to understand vulnerability and enhance resilience. Returning to my earlier football analogy—as we all know, that successful long pass requires more than just the quarterback and his receiver; it requires a team of individual players and coaches each contributing their special talents and unique expertise as part of a coordinated team effort informed by history, a shared understanding of individual roles and expectations and months or years of practice in working together toward a common goal. In thinking about building and sustaining disaster-resilient coastal communities, we'll want to build a powerhouse team of international, regional and international institutions, government officials, businesses, resource managers, scientists, engineers, educators, NGOs, the media and community leaders—each bringing their own insights and expertise to the table in a combined effort focused on the future.

Building and Sustaining Critical Partnerships

Building these partnerships will be a critical factor in our success. As the overwhelming response to the December 2004 Indian Ocean tsunami demonstrates, there are a large and diverse number of players on a risk management team ranging from individual community volunteers to international organizations like the United Nations. Many of the witnesses today have emphasized the importance of setting the international elements of a U.S. tsunami response program in the context of existing multi-national programs and institutions such as the United Nations International Strategy for Disaster Reduction (ISDR); the United Nations Educational, Scientific and Cultural Organization (UNESCO); the United Nations Development Programme (UNDP); the World Bank and regional development banks; and the planned Global Earth Observing System of Systems (GEOSS) among others. Earlier I referred to the importance of integrating local and cultural knowledge to enhance the effectiveness of technology and, in this context, we will also want to capitalize on the expertise and networks of a number of regional organizations and institutions. In the Pacific, for example, development of an effective multi-hazard, risk management system will likely involve technical, government leaders; disaster management and development agencies from all Pacific Rim nations, including the United States; the UNESCO International Tsunami Information Center; the South Pacific Applied Geosciences Commission (SOPAC), the Secretariat for the Pacific Regional Environment Programme (SPREP), scientific, technical and educational institutions throughout the region. Hawaii alone, for example, is home to a number of technical and educational institutions that stand ready to contribute to the emergence of an effective, multi-hazard risk management system in the Asia-Pacific region including the East-West Center, the Pacific Disaster Center, the University of Hawaii, and the Center of Excellence for Disaster Relief and Humanitarian Assistance as well as the regional programs of a number of U.S. Government agencies such as NOAA, USGS, FEMA and others. As we consider the more local components of a comprehensive risk management system, of course, the team will expand to include state and local agencies, communities and NGOs. Coordinating the work of these diverse partners is a challenge but meeting that challenge is essential to fulfilling our shared obligation to this and future generations.

I'd like to take a moment to highlight an ongoing partnership in the Pacific that is already beginning to demonstrate the value of innovative collaboration and cooperation in the area of risk management. About three years ago, the NOAA Pacific Services Center convened a roundtable discussion among the various federal, state and local agencies, scientific and educational institutions and regional organizations active in disaster management in the American Flag and U.S. Affiliated Pacific Islands. Those individual players are now working together as part of a Pacific Risk Management Ohana (PRiMO). The Hawaiian word Ohana means family and, as the name suggests, the various agencies and organizations active in PRiMO are identifying opportunities to work together in creative new ways to advance critical elements of an effective local and regional multi-hazard risk management system including: coastal and ocean observing systems; data management; decision support tools; communications infrastructure and information dissemination; post-disaster evaluation and performance indicators; education, outreach and training; and traditional knowledge and practices. The enhanced level of collaboration represented by PRiMO helps put the Pacific in a strong position to take advantage of new technological capabilities and support the emergence of a comprehensive risk management information system in the region. An enhanced program of risk assessment and adaptation in the Pacific could contribute significantly to enhancing the resilience of the communities, businesses and natural resources of the region and, I believe, provide a demonstration of the value of not only new technologies but also of innovative institutional partnerships focused on comprehensive risk management.

Concluding Remarks

The overwhelming magnitude of the disaster generated by the December 2004 Indian Ocean earthquake and tsunami will, I suspect, keep the images of suffering and devastation in our minds for some time. With those vivid images has come a remarkable level of energy, generosity and commitment to assist those in need. I fear, however, that if history is precedent, that commitment—like the images from the newspapers and television—will begin to fade in the collective memory of those not immediately affected by the tragedy. The testimony of today's witnesses and this Committee's leadership in developing an effective, long-term response, however, suggests that this tragedy can lead to a new level of collaboration and commitment that will last far into the future. From the devastation of a single event in the Indian Ocean, I believe that we can work together to build disaster-resilient coastal communities in the United States and around the world. Perhaps the ultimate legacy of this recent disaster will be the emergence of a comprehensive risk management program that will protect the people, communities, economies and natural resources who call this planet home.

Mahalo nui loa—thank you very much—for the opportunity to share these thoughts with you and Godspeed in your deliberations. I would be happy to answer any questions you may have.

The CHAIRMAN. Thank you.

Dr. Hansen?

STATEMENT OF ROGER A. HANSEN, PROFESSOR, UNIVERSITY OF ALASKA FAIRBANKS; DIRECTOR, ALASKA EARTHQUAKE INFORMATION CENTER

Dr. HANSEN. Thank you, Mr. Chairman and Members of the Committee, for inviting me today.

I am the——

The CHAIRMAN. Pull that mike toward you.

Dr. HANSEN. I'm the state seismologist for Alaska, and a research professor at the Geophysical Institute at the University of Alaska Fairbanks. I've been invited today to give testimony on the tsunami warning system in Alaska.

Today, tsunami safety in Alaska comes from a strong partnership between several state and federal agencies as a result of the participation in the National Tsunami Hazard Mitigation Program, which has been——

The CHAIRMAN. I'm sorry to tell you again. I can see people back there straining to hear you, Doctor. Pull that mike right up to you, please.

Dr. HANSEN. Is this better? OK.

Today, tsunami safety in Alaska comes from a strong partnership between several state and federal agencies as a result of the participation in the National Tsunami Hazard Mitigation Program, which has been aided in Alaska by expanded roles for the University of Alaska, the State Geological Survey, the State Emergency Management Agency, and the West Coast and Alaska's Tsunami Warning Center, run by NOAA. This program consists of hazard assessment of our coastal communities through tsunami forecasting, monitoring and warning guidance, and education and mitigation at the local levels. I will speak briefly on each of these topics.

On March 27th, 1964, a magnitude 9.2 earthquake ripped through the Prince William Sound in Southern Alaska, generating a devastating tsunami. Though the death toll in 1964 is minuscule compared to the Indian Ocean disaster, Alaska today still faces difficult challenges for warning its at-risk communities of the occurrence of tsunamis.

These challenges come, in part, from the nature of our remote location, our irregular coastlines with complex bathymetry and topography, the vast size of our state, where our coastlines extend from equivalent distance of California to the tips of Florida, that we live in one of the most seismically active regions of the world, and the lack of infrastructure throughout the area for both operations and maintenance of monitoring systems, and for consistent and timely communication of warning messages.

Warning guidance. First and foremost, we must be able to detect events that can trigger tsunamis. And this is done with the use of seismology and seismic networks as the primary method to detect earthquakes that may cause tsunamis. Sea-level data, both tide gauges and deep-ocean buoys, are also monitored to verify the existence of, and the danger posed by, tsunamis. But our primary hazard comes from the local tsunami generated by nearby large earthquakes in or near the coast of Alaska.

The deep-ocean buoys, while a part of the larger warning system designed for the Pacific-wide tsunamis, are secondary indicators for local Alaska warnings. This is because a locally generated tsunami wave will likely hit most of Alaska's coast long before it reaches the deep-ocean buoys. Therefore, we must rely on the rapid warnings that can be issued from the detection of large earthquakes by a seismic network.

Modern seismic recordings can provide rapid information on earthquake location, size, and the distribution of sea-floor deformation that generates tsunamis. However, since much of the seismic network in Alaska has been in operation since the 1960's, many stations are in need of modernizations to achieve this goal.

Over the past few years, the Alaska Earthquake Information Center, the state's seismic network operator, was tasked, through the National Hazard Program, to develop 18 of these modern stations for Alaska and ensure the timely delivery of this data to the warning centers. The university program has now increased the number of modern stations that we can provide to augment this sparse improvement, and, through applied research efforts, provides some enhanced information on the local earthquakes. However, even with the funding of both the national program and the university program, nearly 75 percent of Alaska's seismic network still relies on outdated equipment. This leaves vast areas of Alaska, and, in particular, the very seismically active Aleutian Islands, still underpopulated with modern seismic stations.

Mitigation. It is important to recognize that a tsunami warning system must go beyond just the ability to detect a tsunami and send a warning message. The most important aspect of tsunami warning systems is the existence of a mechanism for disseminating warning information to the people on the shorelines and for the recipient of the warning messages to understand how to react.

Tsunami hazard mitigation requires a long-term sustained effort of continuing public education and responsible planning decisions in coastal communities. The power of education is clear.

The state of Alaska partners are well aware of our difficulties in reaching our more than 80 communities at risk to tsunamis. Improving the warning communication and outreach infrastructure at the state and local level for both emergency managers and the public represents the most important improvement to be made in Alaska for saving lives.

Hazard assessment. Tsunami warning and safety procedures require an understanding of hazards and risks associated with tsunamis. In Alaska, led by researchers at the University of Alaska Fairbanks, we are evaluating the risk by constructing inundation maps for all the at-risk communities through our super-computer modeling of tsunami water waves from scenario earthquakes and landslides.

Reliable modeling results, however, require that we have accurate bathymetry. And, in fact, we need this bathymetry to a resolution that is not available in Alaska today.

Much of the sea floor along the shallow waters off the coast of Alaska have not been mapped in many years. Some areas not since before the 1964 Prince William Sound magnitude 9.2 earthquake. And note that large earthquakes can change bathymetry in local areas of the sea floor by tens of meters.

Collection of improved bathymetry along Alaska's coastal communities should be a top priority for enhanced funding of any tsunami program. In addition, it is important to stabilize the funding necessary to create the numerical models and inundation maps.

In summary, Alaska has in place a partnership to address the threat from tsunamis, yet we still have continuing needs for improved monitoring with seismic and tide-gauge networks, scientific infrastructure for numerical forecasting of tsunamis, and the civil infrastructure to educate and warn people.

Thank you, again, Mr. Chairman and the Members of the Committee. I'm happy to answer any questions you have.

[The prepared statement of Dr. Hansen follows:]

PREPARED STATEMENT OF ROGER A. HANSEN, PROFESSOR, UNIVERSITY OF ALASKA FAIRBANKS; DIRECTOR, ALASKA EARTHQUAKE INFORMATION CENTER

Mr. Chairman and Members of the Committee, thank you very much for inviting me to testify. My joint appointment as the State Seismologist for Alaska and as a Research Professor at the Geophysical Institute of the University of Alaska Fairbanks (UAF) places me in a unique and advantageous position to partner in a tsunami hazard mitigation program for Alaska bringing together operational monitoring, education, and research activities. I have been involved in the National Tsunami Hazard Mitigation Program (NTHMP) since its inception as a co-author of the Implementation Plan nearly 10 years ago, and continuing to this day as a strong facilitator and member of the NTHMP Steering committee representing Alaska. My unique position also serves to manage the Alaska Earthquake Information Center which operates and maintains the over 400 station Alaska Seismic Network for regional monitoring of earthquakes and volcanos in Alaska. Our decades long collaboration and partnership with the Alaska Tsunami Warning Center for seismic data exchange has been recently strengthened by our involvement in the NTHMP and the related Tsunami Warning and Environmental Observatory for Alaska (TWEAK) programs. TWEAK has funded the creation of a virtual center at UAF, called the Alaska Tsunami Center and Observatory, that combines the strengths of the Geophysical Institute, the Institute of Marine Sciences, and the Alaska Regional Supercomputer Center into one organization in partnership with our federal and state agencies.

Tsunami Safety in Alaska comes from a strong partnership between several state and federal agencies. The NTHMP was created with the understanding that the best way to address the hazards posed by tsunamis was through a state/federal partnership that leveraged an improved "coordination and exchange of information to better utilize existing resources." Through participation in the NOAA National

Tsunami Hazard Mitigation Program (NTHMP), this partnership provides improved levels of warning guidance, hazard assessment, and mitigation; allowing an integrated response in Alaska to a potentially tsunamigenic earthquake.

It is important to recognize that tsunami warning systems require a sophisticated infrastructure that goes well beyond just the ability to detect a tsunami and send a warning message. This infrastructure must include a continuing partnership between the state and federal agencies and the local communities at risk to assess the hazard and provide levels of mitigation to minimize the risk to life and property. Nowhere in the U.S. is such a partnership more important than in Alaska. Much of Alaska is remote, with little built infrastructure for communications, harsh winters, and communities that are located in one of the most seismically active regions of the world. Our primary hazard comes from the "local" tsunami generated by nearby large earthquakes in or near the coast of Alaska, rather than from the "distant" tsunami that travels across the open ocean. In this case, the deep ocean buoys, or "tsunameters", while a part of the larger warning system designed for U.S. Pacific-wide tsunamis, are secondary indicators for Alaska warnings, because a locally generated tsunami wave will hit the Alaska coast long before it reaches the deep ocean buoys. We must rely on the rapid warnings issued from the detection of the earthquake; and even more so on education, hazard assessment, and mitigation as to how to respond to the potential of a tsunami.

The U.S. Tsunami Warning System consists of two warning centers: the Pacific Tsunami Warning Center (PTWC) in Ewa Beach, Hawaii and (important to Alaska) the West Coast/Alaska Tsunami Warning Center (WC/ATWC) in Palmer, Alaska. These centers work in cooperation with other NOAA units to perform their mission. In Alaska, state agencies such as the Alaska Department of Homeland Security and Emergency Management (ADHS&EM) and the Alaska Division of Geological and Geophysical Surveys (ADGGS), and the Alaska Tsunami Center and Observatory at the University of Alaska Fairbanks (UAF), are strong partners in the tsunami warning mission.

Warning Guidance

First and foremost, we must be able to detect events that can trigger tsunamis. The current tsunami warning systems are triggered by information from earthquake seismic networks. Typically, earthquake magnitudes above certain levels cause tsunami warnings to be issued. In Alaska the WC/ATWC has the responsibility for issuing all tsunami warning, watch, advisory, and information messages to emergency management officials. As earthquakes trigger most tsunamis, the WC/ATWC monitors data from seismic networks throughout Alaska and worldwide. While the WC/ATWC maintains a backbone network of 11 seismic stations in Alaska, in order to monitor for large coastal earthquakes they receive a subset of about 40 stations from the 400-station combined seismic network of the Alaska Earthquake Information Center (AEIC) and Alaska Volcano Observatory (AVO). The data are processed in near-real-time and initial warnings for tsunamis from large earthquakes are based solely on seismic data. This is the reason that it is so critical to have modern instrumentation for application to modern techniques for rapid determination of earthquake magnitude. Sea level data (both tide gauges and deep ocean buoys) are also monitored to verify the existence of and danger posed by tsunamis. Bulletins are issued through standard NWS channels, such as the NOAA Weather Radio and the NOAA Weather Wire as well as the FAA NADIN2 system, FEMA's National Warning System, State Emergency channels, and other means. (All Alaska earthquakes are then re-processed by AEIC utilizing the entire combined Alaska Seismic Network and included in the authoritative catalog at AEIC). The NTHMP funded upgrades to ¢55 seismic stations in regional networks throughout the western U.S. This leveraged NTHMP resources with the already substantial investments in seismic networks in order to provide high quality data to the tsunami warning centers. AEIC was tasked through NTHMP to develop 18 of these stations for Alaska for delivery to the warning centers. At the request of ATWC, the TWEAK program has now substantially increased the number of modern stations AEIC can provide to augment this sparse improvement. Yet many vast areas of Alaska (and in particular the Aleutian Islands) still remain underpopulated with modern seismic stations.

Hazard Assessment

Well recognized in the NTHMP, a second part of the tsunami warning and safety procedure requires an understanding of hazards and risks associated with tsunamis in Alaska. Without a clear understanding of what areas are at risk and which areas are unlikely to be flooded, it is impossible to develop effective emergency response plans and education programs. To ensure reliable tsunami early detection and hazard assessment capabilities, it is essential to create a numerical model to forecast future tsunami impact and flooding limits in specific coastal areas. The NTHMP made it a priority to develop the expertise within each state for providing tsunami flood maps for the states communities at risk. In Alaska we are evaluating the risk by constructing inundation maps for at-risk communities through modelling of the tsunami water waves from scenario earthquakes and landslides. This effort for Alaska is being led by the UAF Alaska Tsunami Center and Observatory in close collaboration with ADHS&EM, ADGGS, the UAF SuperComputer Center, and other state and federal partners. As inundation maps for communities are completed, they are presented to both state and local emergency managers who then use the information for planning and exercising evacuation routes and safe zones for the communities visitors, tourists, and local residents. Maps for several communities on Kodiak Island, Homer, Seldovia, and Seward have been or are nearly completed, and we now wait for needed information on bathymetry for the many other at-risk communities for which maps will be made. The earlier example of the remoteness of Alaska again affects our productivity in map generation. Many regions along the shallow waters off the coast of Alaska have not been mapped in many years. Some areas not since before the 1964 Prince William Sound M9.2 earthquake. Reliable modelling results require that we have accurate bathymetry to a resolution that is not generally available except in the lower 48 states, and at a very few communities in Alaska. Collection of improved bathymetry should be a top priority for enhanced funding of any tsunami program. In addition, it is important to stabilize the infrastructure necessary to create the numerical models within Alaska.

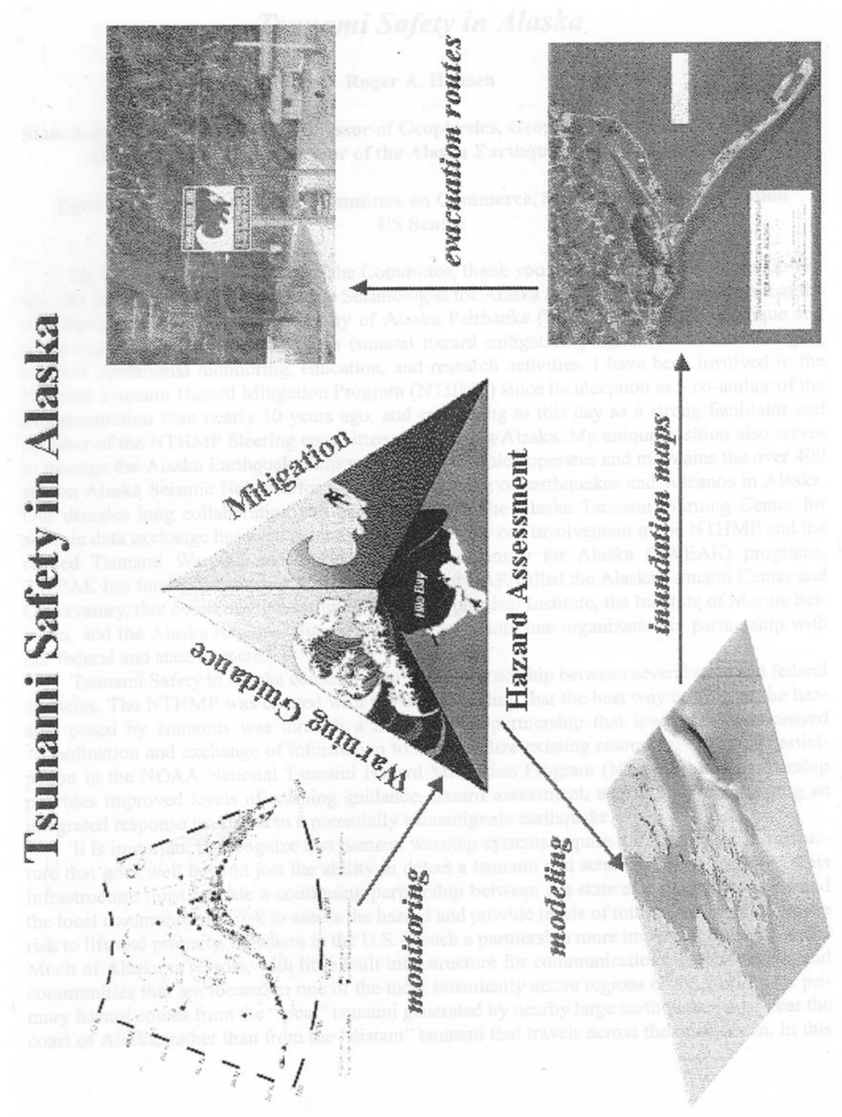
Mitigation and Response

Arguably the most important aspect of tsunami warning systems is the existence of a mechanism for disseminating warning information to the people and businesses on the shorelines. It has been recognized that tsunami hazard mitigation requires a long-term sustained effort. Tsunami mitigation needs to be an institutionalized part of continuing public education, emergency management and responsible planning decisions in Alaska's coastal communities. Tsunami education materials, inundation maps, community evacuation maps and signs, warning sirens, and numerous other mitigation-related products are being developed as part of the NTHMP program. These materials are brought to communities by a team of scientists and statewide emergency planners on a routine schedule to establish the infrastructure for education and outreach with respect to tsunami hazards and warnings. This infrastructure of communication between UAF, WC/ATWC, emergency management officials, ADGGS, and local communities is what allows warnings to be disseminated and acted upon in an efficient manner throughout the Alaska Communities. The TWEAK program is assisting this through an active education and outreach program, as well as partnering with ATWC and ADHS&EM to purchase and install tsunami warning sirens in at risk communities. Discussions with the emergency management community and the Director of the Alaska Tsunami Warning Center both concluded that the most useful improvement to be made to the warning system in Alaska is to improve the warning and communication infrastructure at the local level for both emergency managers and the public. Again, increased funding for tsunami programs for Alaska should also include as a top priority resources for expanding the warning dissemination infrastructure and mitigation activities.

What is Needed for the Future

While Alaska has created an infrastructure for efficient tsunami warning and safety procedures, our efforts are only beginning. As mentioned earlier, the weak link of information and communication must include not only improvements to infrastructure and data collection and processing, but also include a continuing state/federal partnership for education and outreach.

Important to tsunami safety for Alaska, the TWEAK program between UAF and the Alaska regional level of the NOAA Weather Service, is a program in support of the NTHMP that provides direct assistance to the issues most critical to tsunami safety in Alaska. The TWEAK program has brought the federal, state, and university partners within Alaska into a mature organization of tsunami activities described above. A virtual center, called the Alaska Tsunami Center and Observatory, has combined the strengths of the Geophysical Institute, the Institute of Marine Sciences, and the Alaska Regional SuperComputer Center in one organization in partnership with our federal and state agencies. This Center will continue to support the goals of the National Tsunami Hazard Mitigation Program that are unique to the difficult setting of Alaska through improvements and enhancements in monitoring, modeling, and education and outreach.



The CHAIRMAN. Thank you very much, Dr. Hansen. Sorry to be reading a memo that just came in from my office. I'm told that you just made a little history, Doctor, you just lectured your graduate students at the University of Alaska who are tuned in and watching this on a live broadcast through our Webcast. So thank you for coming here. And your students, I'm sure, will appreciate the fact that you're here and they're there.

[Laughter.]

Dr. HANSEN. They got a free breakfast.

[Laughter.]

The CHAIRMAN. I think we ought to thank them. You realize what time they had to get up to watch you?

Dr. HANSEN. Yes.

The CHAIRMAN. It's 4 hours earlier than we are.

But, anyway, I want to ask you, first, Dr. Cox, Am I correct, in reading your testimony, that you think you could test things like buildings?

Dr. COX. Yes, sir.

The CHAIRMAN. Could you test a model of a tsunami survival hut, if we could devise one?

Dr. COX. Yes, sir.

The CHAIRMAN. Could you devise one?

Dr. COX. We're working on it. And I think, also——

The CHAIRMAN. Are you thinking something that's big enough for a lot of people, or just a little one for individual islands?

Dr. COX. It—I'm at a loss for words. But the—what we're looking at is really, Can the computer—let's say, Could a numerical simulation correctly predict the impact force on the building, however that building is constructed. And so, what we measure in our laboratory is the actual force of that wave on a building.

But we're—and then, let's say, for example, how—let's say, if you were to design breakaway walls, for example, if—let's say, in a hotel, a modern hotel, if you had two strong walls and two weak walls, at what point would the weak walls break away, for example?

The CHAIRMAN. But I'm going at it a different way. When we did the——

Dr. COX. Sure.

The CHAIRMAN.—the building in Adak, we looked at what could survive a wave going over it and coming back over it. OK?

Dr. COX. Yes.

The CHAIRMAN. In terms of a lot of people. Can you look at that for the purpose of determining, could we start a program of some sort of fairly inexpensive shelters designed in a fashion that could resist a wave, force it to go over it and come back over it?

Dr. COX. Yes, sir. And in addition to the design of one particular building, what we're finding out from the field surveys is that it's often the arrangement of the buildings that can either increase or decrease the forces. So that's something else we'll be testing in the laboratory, is, how does the arrangement of particular buildings improve our ability to withstand the tsunami.

The CHAIRMAN. Well, we devised wings that were capable of standing up at greater than the speed of sound, so I think you ought to be able to find a way. But the question is, can you do it so we can produce them and really help the world to provide some shelters for these people, like in areas just—what we just witnessed out there.

Dr. COX. Yes, sir, that's one of the goals at the laboratory. Sure.

The CHAIRMAN. Thank you.

Ms. Shea, you—how do you interface with the concept of, you know, warning to people in the outer islands?

Ms. SHEA. It's a very big challenge. Part of it is a communications challenge, actually, not just the physical technological systems, but also language, and communicating in language that is understandable. But the other is actually building local networks of people who are skilled in understanding what's coming through as a warning and then can communicate locally, in local languages and in local context. So——

The CHAIRMAN. Do you use commercial media?

Ms. SHEA. Absolutely. And, in fact, the role of the media is important, but it's also important to remember that many of the communities, those remote fishing communities, for example, that were—whose structures were completely wiped away, didn't have access to some of the media. In the United States, we can rely on the media the way the Weather Service has done for years. And I think it's really important that we consider the role of the media in warnings in the United States, as well as internationally. But I also think we have to build that local community network, those community leaders entrusted—those trusted information brokers in a community who can help.

The CHAIRMAN. A lot of them didn't have a public media——

Ms. SHEA. That's right.

The CHAIRMAN.—wireless media.

Ms. SHEA. That's right. And——

The CHAIRMAN. My feeling is, maybe we should assist them to get wireless media so it will be there. It would be maintained by the local people. You put up some warning system, someone's going to forget to turn it on.

Ms. SHEA. Yeah.

The CHAIRMAN. It's really providing a continuous service, in terms of some sort of weather service or whatever it might be. I should think, on a wireless basis, they would have gotten the information much better out there.

Ms. SHEA. I think that's true. And I think there are also some fairly low-tech solutions that include Hi–Fi radio, HF radio, and satellite downlinks in a wireless way from warning centers that then can be rebroadcast by HF radio. That's relatively inexpensive. The other is, then, combining that wireless link, the information that comes from the wireless link, with low-tech capabilities like warning flags or siren systems. Those two can be used without having to rely on that infrastructure that you so rightly point out is not available in many of these communities.

The CHAIRMAN. Dr. Hansen, how about using those graduate students out there—I assume they're still watching—why don't you review our proposal to have this new Subcommittee of Disaster Prediction and Prevention, and ask them what they think we ought to go into. What should we ask the Subcommittee to start out on? What's the most important areas that we could look at to see where there are deficiencies in prediction and prevention? Could you do that for us?

Dr. HANSEN. Yes.

The CHAIRMAN. Thank you.

Dr. HANSEN. I will.

The CHAIRMAN. Senator Inouye?

Senator INOUYE. As we have demonstrated, it usually requires a disaster of biblical proportions to get all of us acting. For example, it took the tsunami disaster in Southeast Asia to bring about the creation of the Disaster Prevention and Prediction Subcommittee.

I don't know if you have the expertise to respond, but do you believe that the bill that we are proposing, S. 50, would do what you believe is necessary?

Ms. SHEA. Yes. I think it's a really good start. I think that if I were looking at S. 50, I might suggest broadening the education components of S. 50, and I also might suggest that we look at ways of broadening that vulnerability and adaptation research component. And, in particular, leveraging ongoing activities. These same communities that are subject to tsunamis are also, as several people have mentioned today, subject to other coastal threats. There are other coastal warning systems out there. There are climate forecast systems out there, in the United States and around the world. And if we can leverage those, find those partnerships, we can make a significant advance in the receiver end of this problem without an investment of a significant amount of new resources. It's really about bringing those partnerships.

Senator INOUYE. Would you favor this Committee with the memos carrying out those proposals?

Ms. SHEA. Absolutely. Be happy to, Senator. Happy to.

Senator INOUYE. It would be very helpful.

Ms. SHEA. Great.

[The information follows:]

EAST-WEST CENTER
Honolulu, HI, February 9, 2005

Hon. TED STEVENS,
Chairman,
Commerce, Science, and Transportation Committee,
Washington, DC

Hon. DANIEL K. INOUYE,
Ranking Minority Member,
Commerce, Science, and Transportation Committee,
Washington, DC

Dear Sirs:

Thank you, again, for the opportunity to testify last week on S. 50 and the evolution of an effective U.S. tsunami warning and preparedness program. As I mentioned at the hearing, I am honored to be able to contribute in some small way to your efforts to build more disaster-resilient coastal communities in the U.S. and around the world. During the hearing, you asked me to provide you with some written suggestions to strengthen S. 50, including an outline of the elements of regional pilot projects focused on building the resilience of coastal communities. By way of this letter, I am pleased to respond to that request for additional information.

First, I would like to reinforce the importance of setting tsunami warning and preparedness programs in a multi-hazard, risk management context as mentioned in Section 2(a)(10) of S. 50. As we discussed during the hearing, many of the elements of a program designed to improve warnings and enhance resilience in the face of low-frequency, high impact events such as tsunamis will also make important contributions to enhancing the resilience of coastal communities in the face of other natural hazards such as extreme weather events (floods, hurricanes, high wind and wave events) as well as the consequences of climate variability and change. I would encourage the Committee to respond to Section 2(a)(10) with a new title/section authorizing NOAA to work with other federal partners, state governments, academia, the extramural research community, and the private sector to implement a Disaster-Resilient Coastal Communities Vulnerability and Adaptation Program. Such a program would complement and build on the tsunami-specific hazard mitigation program called for in Section 4 of S. 50 but would provide a broader context in which to support various activities that can help coastal communities respond to a variety of hazards/threats. Pursuant to your request, I have included a description of the key components of such an integrated program as Appendix A to this letter.

As we discussed briefly last week, this kind of integrated vulnerability assessment and adaptation program is perhaps best implemented on a regional scale since one size does not fit all when it comes to understanding vulnerability, providing useful and usable risk assessment information or developing effective risk management strategies. I would like to strongly endorse the idea of initiating this program through one or more regional pilot projects that would both demonstrate the value of the integrated programmatic approach described above and move quickly to reduce the vulnerability—enhance the resilience—of coastal communities particularly at risk to tsunamis and other natural hazards such as weather and climate-related extreme events.

As I mentioned last week, I believe that the Pacific might be one such region based on its vulnerability to tsunamis, a dependence on climate-sensitive resources and sectors such as fisheries, tourism and agriculture; ongoing work in tsunami, weather and climate forecasting and assessment; and the institutional partnerships reflected in the Pacific Risk Management Ohana (PRiMO). Based on the testimony of my colleague from the University of Alaska, I believe that Alaska would be another high-priority candidate for a regional pilot program for many of the same reasons. I might suggest that a third regional program might be considered for the Atlantic seaboard with its vulnerability to coastal flooding and hurricanes. I would encourage consideration of at least three years for a regional pilot project along the lines described above with an eye toward sustaining the partnerships established during the pilot phase.

My review of S. 50 identified a few additional specific suggestions for strengthening the bill. I have included those suggestions in Appendix B to this letter.

Mahalo nui loa for the opportunity to provide this additional information as you continue your deliberations on S. 50.

Aloha pumehana,

EILEEN L. SHEA,
East-West Center

APPENDIX A

Key Components of a Disaster-Resilient Coastal Communities Vulnerability and Adaptation Program

Such a program would complement and build on the tsunami-specific hazard mitigation program called for in Section 4 of S. 50 but would provide a broader context in which to support various activities that can help coastal communities respond to a variety of hazards/threats. Such an integrated program might include:

- The *development of multi-hazard vulnerability maps* that help governments, businesses and communities characterize and assess their current risks in the face of a variety of natural hazards and provide a baseline for assessing future risks;
- *Multi-disciplinary vulnerability assessment research and dialogue* to improve understanding of a coastal community's exposure and sensitivity to hazards as well as providing insights into adaptation options (policies, engineering, resource management) that would either reduce exposure and sensitivity or enhance resilience. The ultimate focus of this component of the program would be the integration of risk management considerations in the context of economic development and community development planning and policies. As I mentioned last week, this will involve more than a few, isolated studies of the socioeconomic impacts of hazards/natural disasters. Such a program will be most effective when it incorporates a collaborative, participatory approach that effectively engages scientific and technical experts as well as policy officials and decision-makers in government, businesses, academia, NGOs and community leaders in a process of shared learning and joint problem solving.
- *Risk management education programs,* including: (a) technical training on recent scientific developments in key hazard areas (e.g., tsunamis, weather extremes, climate variability and change) and new technologies; (b) leadership training to enhance the cadre of individuals and institutions responsible for risk assessment and risk management programs; and (c) formal and informal education programs and materials including public awareness brochures and campaigns as well as curriculum development;
- *Risk assessment technology development* including (but not limited to) developing practical applications of the insights gained from risk perception and risk communication research as well as the provision and application of new tools and technologies such as high resolution imagery and modeling, remote sensing and *in situ* observations and imagery, geospatial (GIS) technology, innovative uses of current and planned observing systems and model-based decision support tools;

- *Risk management data and information services* including: (a) access to observational data and derived products from relevant observing systems including, but not limited to the tsunami observing system of buoys and tide gauges authorized in S. 50 as well as the weather, climate and hazard/risk management components of regional and global observing systems (e.g., the Integrated Ocean Observing System, the Global Climate Observing System and the Global Environmental Observations System of Systems); (b) developing and maintaining multidisciplinary data sets on the nature and consequences of key hazards; and (c) development and provision of new, integrated data products that support risk assessment and risk management programs; and
- *Risk communication systems* that build on existing warning and forecast systems such as the expanded tsunami warning system called for in S. 50 as well as ongoing weather, climate and ocean monitoring and forecasting systems. This component of the program would also provide a focus for exploring the applicability of a variety of communications tools and technologies as well as the development of the social network of individuals and institutions involved in risk/hazard warning, response and recovery.

This kind of integrated vulnerability assessment and adaptation program is perhaps best implemented on a regional scale since one size does not fit all when it comes to understanding vulnerability, providing useful and usable risk assessment information or developing effective risk management strategies. Criteria for identifying appropriate regional pilot projects in the context of S. 50 might include:

- Vulnerability to tsunamis as well as weather, climate and other coastal hazards;
- Dependence on economic sectors and natural resources that are particularly sensitive to coastal hazards such as coastal inundation as well as weather and climate-related extreme events such as hurricanes, floods, and high wave events;
- Opportunities to link to and leverage related ongoing regional risk observation, research, forecasting, assessment, education and risk management programs such as: the Pacific Risk Management Ohana (PRiMO) and/or the Alaska Tsunami Preparedness Program discussed during the February 2 hearing; NOAA's Regional Integrated Science and Assessment (RISA) program which focuses on climate-related risk management; regional coastal ocean observing system programs in support of the U.S. Integrated Ocean Observing System (IOOS); and state coastal zone management programs with strong hazards/risk reduction components;
- Evidence of strong, interagency collaboration in the area of risk management; and
- Access to NOAA and other federal agency programs, facilities and infrastructure in tsunami and other coastal hazards monitoring, warning, forecasting, research, assessment and data management.

I would encourage the Committee to consider funding such regional pilot programs for a three-to-five year period with annual funding levels reaching approximately $1M.

Appendix B

Additional Specific Suggestions to Strengthen S. 50

The following specific suggestions to further strengthen S. 50 are also offered for your consideration:

- Add to the end of Section 2(a)(l0) "and a sustained program of education and risk assessment to support the development of effective response strategies;
- In Section 7, Global Tsunami Warning and Mitigation Network, explicitly identify and authorize expanded support for the International Tsunami Information Center which NOAA hosts as part of the UNESCO/IOC tsunami program;
- Also in Section 7, I would encourage you to authorize NOAA to contribute to international tsunami education and vulnerability and adaptation programs as well as the detection equipment and technical advice already included in S. 50;
- Consider combining the discussion of "Transfer of Technology, Maintenance and Upgrades" that currently comprises Section 3(d) with the "Tsunami System Upgrade and Modernization" provisions of Section 6 under Section 3;
- More explicitly call out the importance of engaging state coastal zone management programs in the implementation of S. 50; and

- Include a section on data management to authorize expanded support for efforts by NOAA to support the data management requirements associated with the expanded observing system called for in S. 50.

In the context of this latter item, I might suggest inclusion of a new subsection—possibly under Section 3, Tsunami Detection and Warning Systems—that would authorize and direct NOAA to support the data management requirements associated with the Tsunami Detection and Warning System called for in S. 50. From my perspective, these requirements would include:

- Quality control and quality assurance for the ocean observation and geophysical data from the tsunami detection and monitoring system;
- Archiving and maintaining ocean observation data from the tsunami detection and monitoring system;
- Supporting the integration of ocean observations from the tsunami detection and monitoring system with other national and international water level measurements such as the Global Sea Level Monitoring System (GLOSS);
- Supporting the integration of ocean observations from the tsunami detection and monitoring system with other elements of the global and coastal components of the Integrated Ocean Observing System (IOOS) and the Global Environmental Observing System of Systems (GEOSS); and
- Supporting the development of and access to data sets and integrated data products designed to support multi-hazard regional vulnerability assessment and adaptation programs such as those called for in Title____.

In addition to national data centers such as NODC, NGDC and NCDC, NOAA should look to regional data centers like the NOAA Integrated Environmental Applications and Information Center (NIEAIC) in Honolulu, HI to fulfill the requirements described in this section.

Senator INOUYE. Dr. Cox, this Committee has heard that Japan has already developed buildings, in place and operational, for tsunami purposes. Have you heard about them?

Dr. COX. Yes, sir.

Senator INOUYE. Are they working?

Dr. COX. To my knowledge, they're working. But I think that—if I could just continue that—I think the—how many people you could put into the building versus, you know, getting people to higher ground, I—I mean, I can't speak for the United States, but I think we have to consider whether or not we have a—sort of, a high concentration of people in a particular area, let's say at a resort community or something like that, then I think such a building might make sense. I think other times we have to consider just evacuating everybody to higher ground. I think we heard earlier that we can't have, sort of, a one-size-fits-all policy, but I think sometimes it may make sense to build tsunami-resistant structures in high-density places like a resort community.

Senator INOUYE. Dr. Hansen, I think statistics indicate that the State of Alaska is more prone than any other state to earthquakes and tsunamis. Are you satisfied that the warning system we have today is sufficient?

Dr. HANSEN. No, I'm not. I believe that it's insufficient in ways of getting the information out to the local communities. We're——

Senator INOUYE. How would you——

Dr. HANSEN.—in need of improving that.

Senator INOUYE.—improve that?

Dr. HANSEN. Right now, we're trying to establish—we're trying to exercise our established partnership to get out education and outreach programs. We visit communities. We've put together videos to help educate the populations of Alaska about the tsunami in our state. In addition, we're trying to work with leveraged moneys from the National Hazard Program and the university program to get sirens put out that have been developed under this—the National Program. Sirens then need to be triggered somehow, and so, we're working with the NOAA Tsunami Warning Center to put together the infrastructure we'll need to get out to communities where, say, NOAA Weather Wire doesn't work, or it doesn't work very well, and improve that infrastructure to get information out beyond just the local manager, but to the people that are in danger.

Senator INOUYE. Ever since the end of World War II, the State of Hawaii has maintained an air-raid siren system, and it blows off once a month, and some of the tourists go berserk, not knowing whether it's a bombing attack or tsunami, but it serves a little purpose.

Ms. Shea, do you think it works?

Ms. SHEA. Oh, absolutely. I think that for low-frequency events, like tsunamis, I think we tend to forget—the population tends to forget, in the long period of time. But I think it's useful in the sense that when we hear it, in Hawaii, and we know that what it means is, if it's the first Monday of the month, we know it's a test. And if it's not the first Monday of the month, then we know there's something to be concerned about, and then we do turn to the television, the radio, call the local agencies, call the State Civil Defense. So it absolutely does work. Those low-technology but high-impact systems are really quite effective.

Senator INOUYE. Oftentimes, when we venture into something that's complex and new, we set up pilot programs. Do you think a pilot program would work in this situation?

Ms. SHEA. I think it would. I think pilot programs would be, in fact, very useful. And I think—again, look for those opportunities where you have areas at high risk—Alaska, the Pacific comes to mind in the case of tsunami—and also those areas where you're built—where these partnerships of other—of agencies working together already exist. And I think—so I think that—I think we've heard enough testimony today to suggest that there are probably a couple of places, at least, where a pilot project could demonstrate that partnership, demonstrate the different kinds of technology, and demonstrate the value of building this comprehensive risk-management information system.

Senator INOUYE. See, we have no idea what the costs will be, and a pilot program might be helpful.

Ms. SHEA. Yes.

Senator INOUYE. Can members of the panel provide us with your ideas of what, if any, the pilot program should look like?

Ms. SHEA. Absolutely.

Senator INOUYE. I would appreciate that.

Dr. COX. Yes, thank you.

Senator INOUYE. Thank you very much, Mr. Chairman.

The CHAIRMAN. Thank you.

And, Dr. Hansen, I think I'm indebted to you for this, a copy of "Ocean Fury: Tsunamis in Alaska." Let me read to the Senator, what this says. It says, "Future tsunamis will hit Alaska. Taking its cue from the survivors of 1964, this program explains how scientists, local officials, and emergency responders are working together to reduce the loss of life and property when tsunamis assault Alaska's coast again. With the aid of 3D computer graphics, scientists describe how different kinds of tsunamis form, how they can travel at jetliner speeds, sometimes striking shorelines with little or no time to escape. More important, this program describes what you should do to improve your chances of surviving the next tsunami."

I hope, Dr. Hansen, you've provided a copy of this to every school in the state.

Dr. HANSEN. The emergency management group is doing that kind of thing, that's exactly right.

The CHAIRMAN. That should be a program that all young people should look at so they can understand there's something out there to prepare for.

We thank you very much. You demonstrate that this a issue of substantial concern to where we come from, the two of us, and we appreciate you—have you got another copy? I'll give that to Senator Inouye.

Dr. HANSEN. I don't with me, but I can get you one.

The CHAIRMAN. One of those graduate students will mail me one.

[Laughter.]

The CHAIRMAN. We do thank you very much for taking the time to come here. It's very important. This is our first hearing. The two of us, as Co–Chairmen of this Commerce Committee, we wanted everyone to understand this is going to be one of our number-one targets, to really deal with prevention and detection of disasters.

Thank you very much.

[Whereupon, at 12:15 p.m., the hearing was adjourned.]

A P P E N D I X

PREPARED STATEMENT OF HON. BARBARA BOXER, U.S. SENATOR FROM CALIFORNIA

Mr. Chairman, thank you for holding this hearing today. The December 26th Indian Ocean Tsunami was a terrible tragedy.

The sheer devastation inflicted by the tsunami reminds us all how vulnerable our coastlines are to widespread damage. In California, this is a serious threat because we are home to miles of beautiful coastal communities, well within reach of potential damage caused by tsunamis.

Californians have confronted tsunamis in the past. On March 28, 1964, a tsunami originating from an earthquake near Alaska hit the Northern California community of Crescent City, killing 10 people, and damaging 91 homes and 197 businesses. The power of this tsunami was so intense, large buildings in Crescent City were uplifted by the force of the waves.

The Cape Mendocino earthquake in 1992 created a tsunami that wreaked havoc along California's northern coastline. Thankfully, there were no deaths, but the 1992 tsunami highlights the need for notification of a tsunami as well as public outreach efforts.

One of the many lessons learned from the 1964 and 1992 tsunamis was that proper warning and evacuation truly saves lives. First, we need to ensure there are enough buoys to protect the California coast from tsunamis. Currently, only three out of the six buoys deployed in the Pacific Ocean are functional.

Second, coastal communities need adequate funding so that they can become tsunami ready. Since the time of the 1964 tsunami, Crescent City has made tremendous strides to protect its residents by implementing tsunami emergency plans, installing warning sirens, and creating a tsunami education program. As a result, Crescent City has been honored by NOAA as a *TsunamiReady* community.

However, much more is needed to make sure all of our coastal communities are as well prepared as Crescent City is today.

After consulting with the California Office of Emergency Services (OES), my staff has been informed that California is in dire need of *more* funding that will help map potential inundation zones, and that will help educate the public.

According to OES, only $88,000 in federal funding is given annually for tsunami evaluation and preparation in California's 15 coastal communities, and only two are *TsunamiReady* by NOAA standards. Tsunami taskforces in California have said they need more money to erect warning signs on county beaches, plan evacuation routes, and conduct public outreach efforts.

Mr. Chairman, we must do more to ensure that our citizens living near the coast are well-educated and better prepared to deal with a tsunami, and our emergency officials have the necessary funding to achieve this goal.

Thank you, Mr. Chairman.

PREPARED STATEMENT OF DOUG CARLSON, HONOLULU, HAWAII

Mr. Chairman, it is highly probable that tens of thousands of people died around the Indian Ocean rim on December 26, 2004 because an agency of the United States Government was unprepared to issue an effective tsunami warning to the region's population. This inference can be made with great certainty based on the public record and the statements of numerous Federal Government employees.

The warning failure occurred even though Pacific Tsunami Warning Center (PTWC) scientists first suspected the existence of the tsunami as much as two-thirds of an hour before the first waves struck Sri Lanka, India and Thailand. That is clearly established in the tsunami timeline by the National Oceanic and Atmospheric Administration. (Ref: http://www.noaanews.noaa.gov/stories2004/s2358.htm)

It's true that scientists did not initially know that a 9.0 magnitude earthquake had struck near Indonesia. They first calculated the magnitude at 8.0, which they felt would have triggered only a localized tsunami or no tsunami at all.

Others may wish to investigate the too-low estimate of the earthquake's strength with a goal of improving early forecasting techniques. The intent of my testimony, however, is to demonstrate that the communications protocols that existed on December 26 were inadequate to issue an effective warning and that U.S. officials may not have been sufficiently trained or sensitized to the importance of calling on the news media for assistance.

We know from numerous media interviews with the scientists that about an hour after the earthquake they felt a need to alert people in the Indian Ocean region about a possible tsunami. We also know that they felt handicapped by the absence of a high-tech tsunami detection and alert-dissemination system in the region. Nothing around the Indian Ocean approximates the sophistication of the Pacific Rim tsunami warning network.

To their credit, the Center's personnel wanted to take some kind of action to alert the region. According to the Center's director, as quoted in The International Herald Tribune: *"We wanted to try to do something, but without a plan in place then, it was not an effective way to issue a warning, or to have it acted upon."* (Ref: http://www.iht.com/articles/2004/12/28/news/warning.html)

Without a notification plan, the scientists resorted to telephoning their colleagues in south Asia, with virtually no success. What they did *not* do was telephone the major international news media, such as the Associated Press, CNN, the BBC, Reuters or any other news organization with world-wide communications capabilities.

In other words, in the 41 minutes between issuing a bulletin that mentioned a possible tsunami and when the first waves are now thought to have reached Sri Lanka, the scientists used the telephone to call one person at a time rather than call the mass media to help issue a warning through their broadcast and cable networks.

A NOAA spokesperson later gave what may be the most telling comment about the PTWC's crisis communications preparedness: *"Not only was the center focused on warning agencies, it does not have an official list of media contacts."* (Ref: http://www.washtimes.com/upi-breaking/20050107–050909–7208r.htm)

Would alerting the news media in those first critical minutes have made a difference in how many people died in south Asia? With proper planning and coordination of media protocols, I'm certain lives could have been saved.

And I'm not alone. Many others around the world have questioned the lack of an effective warning. A woman in Sri Lanka who lost her father, sister and niece was interviewed by National Public Radio: *"Why didn't we receive warning? We had two hours after Indonesian quake, and at least five minutes warning would have helped. Five minutes would have saved my father's life."* (Ref: http://www.npr.org/templates/story/story.php?storyId=4277/95)

On January 11, the day NOAA's administrator visited the PTWC and met with the Honolulu news media, I posted questions on my web log site that I felt might well be directed to him. They are still relevant today:

- Will NOAA release the PTWC's crisis communications plan? (If not, why not?)
- What liaison did NOAA accomplish with the major media (Associated Press, CNN, BBC, etc.) before 12/26 to ensure emergency phone calls to these media would produce timely warnings to their audiences?
- Are PTWC scientists trained to telephone the media to issue life-saving warnings?
- Is the PTWC too high-tech oriented? Do you think low-tech telephone calls have a place in your pre-crisis planning and emergency warning protocols?
- Have you ordered changes in the PTWC warning protocols since the tsunami?
- Does NOAA accept responsibility for an internal procedural failure that might have cost the lives of tens of thousands of people in South Asia?
- What is NOAA telling south Asia nations about its performance on 12/26?
- What are your personal feelings about NOAA's performance on 12/26?

The administrator did answer many media questions that day, including a variation of the last one. According to the Honolulu Star-Bulletin, he called the PTWC staff's actions "excellent" and faithful to the warning procedures in place. *"This is a group that believes in saving lives and protecting property at all costs,"* he said. (Ref: http://starbulletin.com/2005/01/12/news/index1.html)

The sad fact is the "warning procedures in place" on December 26 saved no lives and protected no property. Nothing PTWC scientists knew or did that day helped people in the tsunami danger zone.

I respectfully submit to this Committee that the PTWC's apparent inability to issue effective warnings is unacceptable. I have proposed a five-point program that would help NOAA shift its thinking and its culture to include meaningful media notification after future tsunami-generating earthquakes:

- NOAA should accept constructive criticism—rather than deny—that actions it could have undertaken likely would have saved lives in south Asia.
- NOAA should resolve to change its communications culture to include reevaluating the scope of its information-disseminating mission—i.e., whether its mission extends beyond the Pacific Rim.
- NOAA should rewrite its communications protocols to include early telephone calls to news organizations that have the capability of sending worldwide tsunami warnings.
- NOAA should accomplish high-level coordination with the management of these news agencies to ensure proper execution of the alerts when received by the media.
- NOAA should train its personnel to respond to suspected tsunamis by making direct person-to-person contact with major news outlets based on prior planning.

The media can be an efficient way to send warnings to threatened populations when time is of the essence, and NOAA would do well to integrate them into its crisis communications planning. Thank you for the opportunity to contribute to your deliberations on this important matter.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. DANIEL K. INOUYE TO BRIGADIER GENERAL JOHN J. KELLY

Failure of DART Buoys and Long Term Tsunami Funding Needs

General Kelly, in your testimony, you noted the failure of three of the six Deep-Ocean Assessment and Reporting of Tsunami (DART) buoys used to detect tsunami in the event of an earthquake. As you know, these buoys are extremely important to our coastal communities, both in detecting tsunami that pose a threat to these communities, and in preventing expensive evacuations by detecting false alarms. I am concerned that these problems have existed for over 15 months and Congress is just now learning of this situation.

Had there been a devastating tsunami in the Pacific this December, instead of in the Indian Ocean, and we found out 3 of the DART buoys were down, this hearing would have a very different tone. We would like to avoid ever having such a situation arise.

Question 1. What are NOAA's plans for instituting better oversight procedures to ensure that contractors are meeting the specifications of the system?

Answer. NOAA has existing procedures in place to ensure contractor performance meets the specifications of the DART station. The quality of work by the contractors is not a reason for buoy failure. Buoys can fail for a variety of reasons related to technology, mechanical or mooring systems.

Question 1a. When can we expect all six DART buoys to be operational again?

Answer. One of the three buoys is now operational, and once the weather permits, NOAA is ready to repair the other two. We expect all 6 DART stations to be operational by summer 2005, and we will follow our maintenance schedule to ensure they remain functional. While it is not possible to guarantee that these prototype stations will be operational 100 percent of the time, NOAA is focused on making the DART network more robust.

Question 1b. Will you notify Congress in a timely fashion if other failures occur?

Answer. For any outages of longer than 60 days, NOAA will notify the Committee of the status of the network. Additionally, the Committee can visit the National Data Buoy Center website for up-to-date information on the status of the DART buoys (http://www.ndbc.noaa.gov/dart.shtml).

Question 1c. How will you ensure these buoys—and the new buoys—are serviced regularly and stay in operational condition?

Answer. NOAA will ensure all DART stations are serviced regularly to ensure operational condition to the greatest extent possible. NOAA plans for the network to meet operational requirements, even with occasional DART station outages. NOAA will develop capabilities to address network coverage and redundancy to ensure, as best we can, that single DART station failures will not impact the integrity of the entire network. Planned redundancy and hardening of the infrastructure, combined with the addition of a two-way communication capability, will mitigate risk from system-wide failures. In addition to these measures, NOAA is also procuring three redundant DART buoys for the Alaska DART buoy array and will acquire 10 spare DART buoys as part of expansion of the tsunami warning system in FY 2005 and FY 2006. These spare buoys will ensure that NOAA can rapidly respond to buoy failure. As the expanded network is transitioned from a prototype to a fully operational network, NOAA will inform Congress of any outages impacting the integrity of the network as a whole.

Question 2. Funding. The President has committed $37.5 million over the next two years (through the end of Fiscal Year 2006) to expand the tsunami warning system. Of that funding, how much will go towards (1) inundation mapping for all coastal communities; (2) continued technology research and development for next generation equipment and forecasting; and (3) public education to ensure our communities are prepared?

Answer. Of the $24M scheduled for NOAA use, approximately $4.75M will be spent on inundation mapping and modeling, as well as education and outreach (e.g., community preparedness activities including TsunamiReady). Of this $4.75M, approximately $2.25M will be spent on inundation mapping and modeling and $2.5M will go towards public education activities. Following the current plan, inundation mapping for the major population centers will be complete in 2015. Of the $24M scheduled for NOAA use, approximately $1.0M will be directed to support Deep-ocean Assessment and Reporting of Tsunamis (DART) buoy research and development activities.

Question 2a. What are the out-year costs (beyond Fiscal Year 2006) of maintaining *in working order* the entire expanded detection system, and the associated tsunami programs?

Answer. By the middle of calendar year 2007, NOAA expects to fully deploy the new suite of DART stations, to continue accelerated inundation mapping and modeling activities, and to continue accelerated community preparedness activities. NOAA anticipates additional operation and maintenance (O&M) costs to maintain the expanded detection network in working order, as well as continued costs for efforts in tsunami inundation mapping and education/outreach programs. The level of funding required beyond FY 2006 will be determined through the budget process.

Agency Participation in the National Tsunami Hazard Mitigation Program

Question 3. Both you and Ms. Shea have provided testimony about the importance of interagency cooperation in the National Tsunami Hazard Mitigation Program, specifically cooperation among the National Oceanic and Atmospheric Administration (NOAA), the United States Geological Survey (USGS), the National Science Foundation (NSF), and the Federal Emergency Management Agency (FEMA). I have some questions about FEMA's role in the program.

In 1996, the Tsunami Hazard Mitigation Federal/State Working Group presented its Tsunami Hazard Mitigation Implementation Plan to the Senate Appropriations Committee. In this plan, FEMA was given responsibilities to produce inundation and evacuation maps, and to implement state and local tsunami mitigation programs. The Implementation Plan called for over $2.2 million in funding from FEMA to carry out these responsibilities—including mapping and mitigation.

How much funding or in-kind work has FEMA contributed to this interagency program since 1996? How does this compare with the other federal and state agency contributions?

Answer. Under the original National Tsunami Hazard Mitigation Program (NTHMP), FEMA responsibilities were limited to the mitigation and implementation of the mapping. While the original plan may have called for FEMA funding, under the NTHMP there was no funding made available for FEMA.

Up until last year, FEMA contribution to the NTHMP has primarily been in-kind support. This includes the support of two FEMA Regional staff members who have been members of the NTHMP Mitigation committee since its inception. At least one regional staff person has spent 25 percent of her time on the tsunami hazard over a 10-year period. A rough estimate of staff time and travel over this time is approximately $200,000. In addition, one FEMA Headquarters scientist has also been involved in this committee as a technical liaison for several years.

As described in further detail in question 3b, for the first three years of the NTHMP, FEMA was the distribution agency for the NOAA state grant funding. This was done since NOAA did not have a mechanism to transfer funds to the states, while FEMA did. While the actual funds came from NOAA, this activity did require significant staff resources on the part of FEMA.

Also described in further detail in question 3a, FEMA jointly co-funded a $400,000 project with NOAA to study and develop tsunami shelter design guidance. This project builds on a first phase, which involved a five-state engineer concept feasibility workshop funded by NOAA and led by the State of Washington and the identification of existing guidance material. The project will work with the engineering community and the states to research and produce the construction design guidance for a tsunami shelter structure capable of withstanding both the severe ground shaking expected during a design earthquake and specific velocities and water pressure that a tsunami will bring to bear on structures. The product will be especially useful to low-lying communities that lack evacuation access to high ground following a local great earthquake and that may have to rely on vertical evacuation in existing buildings.

FEMA has also jointly funded 66 percent of a $412,000 pilot project through its National Flood Insurance Program (NFIP) with NOAA and the USGS to develop risk identification products that will help communities understand their actual level of risk from tsunami in a way that could be conveyed on FEMA's existing flood hazard maps. The goal of the project is to develop techniques that can be used to determine the probability and magnitude of tsunami in other communities along the west coast of the United States. The location of the pilot project is Seaside, Oregon. FEMA's NFIP is involved because FEMA is responsible for mapping areas subject to flooding in order to properly rate flood insurance policies and provide risk assessment information to states and local communities.

In addition, it should be noted that FEMA's NFIP has considered tsunami wave heights during the development of its Flood Insurance Rate Maps since the late 1970's for areas of Hawaii and the West Coast where tsunami was considered a significantly probable flood threat. The NFIP flood maps still reflect tsunami wave heights for areas such as Hawaii where inundation heights from that hazard are considered that most probable form of flooding.

Other federal agencies that participate in the National Tsunami Hazard Mitigation Program (NTHMP) include NOAA, which has contributed approximately $27M, and USGS. The five states participating in the NTHMP (Alaska, Hawaii, Washington, Oregon, and California) have contributed a total of $5.0M in in-kind contributions since FY 1997.

Question 3a. Has NOAA transferred funds to FEMA in order for the agency to perform any work for the program? Please explain.

Answer. There are two instances of NOAA transferring funds to FEMA to perform work under the program. First, as mentioned above, was that for the first three years NOAA transferred the state grant funds to FEMA, who then distributed those funds through our existing State Emergency Management Preparedness Grant program. FEMA did not receive any compensation for managing this activity. NOAA subsequently took over this function and has been distributing the state grants directly.

Second, also mentioned above, FEMA and NOAA jointly funded a project to determine if it is possible to design and build a structure to withstand specific tsunami loads and, if so, to develop technical design and construction guidance for special shelter facilities that would allow for vertical evacuation. Funding for this two-year $400,000 effort is equally divided between FEMA, through the National Earthquake Hazards Reduction Program (NEHRP), and NOAA, through the NTHMP. The project will produce construction design guidance for a tsunami shelter structure capable of withstanding both the severe ground shaking expected during a design earthquake and specific velocities and water pressure from a tsunami that would impact structures. This is a significant challenge since current design practice takes into account earthquake or coastal storm surge but does not address stronger forces that a tsunami would generate. The project, which is being done under contract, was initiated last fall and is just getting underway.

A potential future phase of this project may include developing information for states and local communities on how this tsunami shelter design guidance can be utilized. This information would especially be critical for low-lying communities that lack evacuation access to high ground following a local earthquake and that may have to rely on vertical evacuation. Future funding would be equally divided between NOAA and FEMA.

Question 3b. Given that FEMA's priorities have shifted from natural disaster mitigation to preparing and responding to terror attacks, how much funding and effort can FEMA reasonably be expected to contribute in the post-9/11 environment?

Answer. Although the Department of Homeland Security (DHS) is focused on terrorism and protecting the homeland, it is also committed to an all-hazards approach of preparedness for, response to, recovery from, and mitigation against all events, including natural disasters. Recent efforts to improve response to and recovery from a terrorism event does not diminish FEMA's commitment to dealing with the destruction of a natural disaster—just the opposite. FEMA has enjoyed a long history of focusing on an all-hazards approach, and being part of DHS has strengthened that approach. FEMA has successfully continued to respond to and recover from a multitude of natural disasters in the past year. At the same time, these efforts provide FEMA with opportunities not only to better prepare for terrorism events, but also for catastrophic events, whether they are natural or caused by terrorism.

Question 3c. What financial burden does this place on NOAA, as the primary federal partner, as well as on the states?

Answer. FEMA's participation has not placed any financial burdens on NOAA. NOAA is not in a position to comment on financial burden placed on the states.

Tsunami and Earthquake Program Compatability

Question 4. As you may know, Congress recently enacted this Committee's reauthorization of the multi-agency National Earthquake Hazards Reduction Program (NEHRP), which is aimed at both improving earthquake detection and community resilience to earthquakes—including building construction and planning guidelines. Similarly, S. 50, would authorize NOAA's National Tsunami Hazard Mitigation Program (NTHMP), another multi-agency program involving many of the witnesses here today.

Looking at these two programs together, are the activities of the Earthquake program consistent with the goals of the Tsunami program? For instance, is a building designed to be earthquake resilient also designed to be resilient against tsunami?

Answer. The National Earthquake Hazard Reduction Program (NEHRP) activities, under the leadership of the National Institute of Standards and Technology (NIST), are consistent with those of the National Tsunami Hazard Mitigation Program. NEHRP operates the Global Seismographic Network and the National Earthquake Information Center, which provide data essential to the tsunami warning system. Currently, buildings designed to be earthquake resilient are not also designed to be resilient against tsunamis. NEHRP has a nascent effort to develop tsunami hazard maps and design criteria for shelters and critical facilities in cooperation with the Tsunami program. While it would not be economically feasible to build a typical structure to withstand a tsunami, NEHRP believes that structures could be designed to withstand at least some specific level of tsunami without collapse. This is especially important for buildings such as community shelters or critical facilities (e.g., hospitals).

Question 4a. Does the Earthquake Program have any programs or approaches that should be adopted by the Tsunami program? For example, should we expand programs regarding construction and planning?

Answer. The Administration has recently proposed significant expansion of the National Tsunami Hazard Mitigation Program. The primary goal of this proposed expansion is to develop and maintain a fully operational tsunami warning system. While construction practices may be of interest, our efforts are currently focused on improving our Nation's tsunami warning capabilities.

Question 4b. Has the Federal Emergency Management Agency (FEMA) participated meaningfully or financially in either program? Are there limitations that we should know about?

Answer. FEMA has the opportunity to play an important role as a participant in the National Tsunami Hazard Mitigation Program (NTHMP). The NTHMP receives strong regional level support from FEMA Region X, whose staff attends all NTHMP meetings. FEMA Region X also supports including tsunamis as part of the FEMA National Flood Insurance Program, and has funded a pilot project being conducted by NOAA to evaluate this inclusion. NOAA does not participate in the National Earthquake Hazard Reduction Program (NEHRP), and therefore cannot speak to FEMA's contributions to that program. Our federal partners, such as NSF, NIST, and USGS, are better suited to address FEMA's participation in the NEHRP.

Question 4c. How can we improve coordination and better define agency roles in our legislation?

Answer. An effective National Tsunami Hazard Mitigation Program requires active participation of key federal and state partners. NOAA believes this can be accomplished within the existing NTHMP.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO BRIGADIER GENERAL JOHN J. KELLY

Question 1. I recently visited the Pacific Marine Environmental Laboratory (PMEL) in Seattle, which, as you know, provides research support for all aspects of the U.S. tsunami program. I was extremely impressed by their work and dedication and I thank you for your support of this critical facility. As I'm sure you know, PMEL developed the DART buoys, which are, and will be, a critical component of our Nation's tsunami warning system. These technologies have greatly reduced the number of false tsunami alerts, which helps people take real alarms seriously. However, I was troubled to learn that three out of the six buoys in the Pacific Ocean, including the one off Washington's coastline, are currently not functioning properly. An emergency repair last month only lasted four days, and then a few days ago the buoy started working again. What this situation illustrates, I believe, is the need for more reliable buoys and a more redundant system. When I visited PMEL, I learned they were working on developing a new generation of buoys that would be more reliable, have a longer working life, have improved two-way communications, and hopefully be less expensive to produce than the older models. Can you please explain how you feel passage of this legislation will accelerate the timeline for completion of these buoys? Will the buoys deployed under the Administration's plan be more reliable?

Answer. NOAA agrees that we need a reliable and redundant tsunami-warning system, and we have accounted for some redundancy in our plan. It is important to note that the current DART network (DART I) is a research system that was only recently (October 2003) transitioned into operations. As you mentioned, the DART stations are being redesigned to include redundant features so that they will better withstand the harsh conditions in the northern Pacific. The redundant capabilities built into the stations will increase the life span of the DART systems, as will routine maintenance of the stations. NOAA will also maintain three redundant in-water backup stations in the Gulf of Alaska, where sea conditions are particularly harsh and servicing buoys can be difficult.

The Administration's plan was developed in response to the Indian Ocean Tsunami, and is designed to improve and expand coverage for the United States. This plan represents an accelerated version of NOAA's current efforts through the National Tsunami Hazard Mitigation Program (NTHMP), and has accelerated the timeline for completion of the full network of DART stations. The U.S. Tsunami Warning System, as described in the Administration's plan, will use the funds over the next two years to expand U.S. tsunami detection and monitoring capabilities. The complete network of 39 DART stations is planned to be fully operational by mid-2007. These measures will provide the United States with nearly 100 percent detection capability for a U.S. coastal tsunami, allowing response within minutes.

The buoys that will be deployed in the Administration's plan are those you describe—capable of two way communications and we expect this next generation DART system, DART II, to be more reliable. As there is always room for improvement, the Administration's 2-year plan also provides $1M for research and development for future innovation of the DART network.

Question 2. I understand the next major tsunami to hit the Washington coast could originate from an earthquake along the Cascadia plate rather than a deep ocean earthquake. However, the buoy-based warning system would be largely useless detecting a near-shore tsunami. Are there ways to make our current tsunami warning system more effective for mitigating near-shore hazards? For example, the NSF's NEPTUNE program to wire the Juan de Fuca plate with fiber optic lines seems to be supportive of these efforts. Do you feel that there are other technologies or approaches Congress should consider funding that might produce more timely warning for near-shore generated tsunamis?

Answer. Near-shore generated tsunamis present a difficult challenge. NOAA and federal, state and local emergency managers have ensured warning dissemination capabilities are in place for people to receive tsunami warnings. With response time for these events measured in "minutes" rather than "hours," education and outreach are critical, as with tornadoes, to enable people to understand their vulnerabilities and take appropriate action immediately. The Administration's plan includes $2.5M for education and outreach efforts, including NOAA's TsunamiReady program.

Question 3. On my recent visit to PMEL, I learned that Washington State is vulnerable not only to tsunamis generated by distant earthquakes in the North Pacific Ocean or the closer Cascadia subduction zone, but also from faults within the Puget Sound. In fact, there is a fault line that goes right across Puget Sound and downtown Seattle. While the last major earthquake event happened in the year 1100, scientists believe another event could happen at any time. Although a Puget Sound generated tsunami would provide almost no time to effectively evacuate citizens to higher ground, the vulnerability assessments and inundation mapping authorized by this bill is critical to inform city planners on future siting and permitting considerations. Can you tell me the current plans to analyze the tsunami risk for inland bodies of water like the Puget Sound?

Answer. The impact of tsunamis on inland bodies of water, such as the Puget Sound, is being researched by NOAA through inundation mapping and computer modeling efforts. The analysis of risks to areas such as these is included in NOAA's inundation mapping efforts.

Question 4. Considering the short warning time for earthquake-derived tsunamis within the Puget Sound, are there other technologies that you think could provide more timely warning to these inland areas?

Answer. Issuing improved local tsunami warnings due to near-shore earthquakes requires enhanced earthquake detection capabilities. The U.S. Geological Survey (USGS), which operates the Advanced National Seismic System to detect domestic earthquakes and jointly operates the Global Seismographic Network (GSN) with the National Science Foundation, is best suited to answer this question. However, the Administration's plan includes funding for upgraded seismometers used to improve tsunami detection and includes funding for improvements to the GSN. Most tsunamis are triggered by seismic events, and improvements to the GSN are critical to (1) quickly determine the precise location of the seismic event (2) its precise magnitude and (3) quickly disseminate this information to the USGS National Earthquake Information Center and the NOAA Tsunami Warning Centers. Prior planning and rapid response are the most effective means of minimizing casualties in any local tsunami event. People must be educated to move to higher ground if they are in tsunami threatened area and can feel a strong ground shaking. Until we are able to forecast earthquakes, we are limited in how well we can forecast local tsunami events.

Question 5. I am grateful for NOAA's work through the TsunamiReady program preparing coastal communities for tsunami hazards. However, you yourself noted in your testimony that very few coastal communities currently meet NOAA's standards of tsunami preparedness. In fact, only three Washington State communities qualify as "tsunami ready" under NOAA's program. How do you plan to work with communities and local emergency response agencies to improve and develop emergency response strategies?

Answer. NOAA is committed to accelerating and expanding its TsunamiReady community program to all at-risk communities. The Administration's plan provides $2.5M to NOAA over two years to support public education activities, including community preparedness activities such as the TsunamiReady Program. While NOAA recognizes achieving TsunamiReady status requires significant state and local support, NOAA will continue working with local communities to leverage existing assets and community warning preparedness programs, which provide the foundation for allowing a community to become "TsunamiReady." NOAA will also continue to work with communities and local emergency response agencies interested in developing or improving emergency response strategies, through our participation in the National Tsunami Hazard Mitigation Program (NTHMP).

Question 6. Although I am very concerned about the threat of a tsunami to a coastal or Puget Sound community, I would also like to state for the record that I remain concerned about all hazards. Therefore, it is important to me that related threats be considered when investing resources in tsunami preparedness. Do you see ways in which earthquake preparedness can be combined with tsunami preparedness with the passage of this bill? Please explain if you see opportunities to maximize hazard preparedness by preparing for both earthquake and tsunami threats.

Answer. The National Earthquake Hazard Reduction Program (NEHRP) activities, under the leadership of the National Institute of Standards and Technology (NIST) and other experts, are consistent with those of the National Tsunami Hazard Mitigation Program.

Question 7. Like Senator Stevens, I am concerned about coordination of agency efforts to ensure effective use of resources and efficient warning systems. I understand that the National Earthquake Information Center of the USGS is the recognized worldwide authority for rapid earthquake detection and location and already has most of the technological resources to provide earthquake information rapidly to anyone globally. I would like to know specifically how the NOAA tsunami warning centers and the USGS NEIC can coordinate to make sure that we create the best warning system possible without duplication of effort.

Answer. NOAA and the U.S. Geological Survey (USGS) National Earthquake Information Center (NEIC) currently coordinate to make sure that we have the best, and most efficient, tsunami warning system possible. The USGS operates the Advanced National Seismic System domestically and jointly operates the Global Seismographic Network (GSN) with the National Science Foundation. These networks provide data in real time to NOAA's tsunami warning centers through the USGS NEIC. The NEIC has a direct link into the NOAA dissemination network, which immediately transmits earthquake information to the NOAA tsunami warning centers. NOAA, USGS, and FEMA are members of the NTHMP and as such, have worked together to ensure coordination. Installation of the Consolidated Reporting of Earthquakes and Tsunamis (CREST) system is an example of coordination between NOAA and USGS to strengthen the ability to rapidly detect tsunamigenic earthquakes.

Question 8. I understand that the conditions in which the DART buoys operate can be dangerous and that a certain rate of equipment failure may be unavoidable. However, I'm concerned that 3 of 6 DART buoys are currently unreliable, including the buoy off the Washington coast. In your estimation, what is the failure rate of these buoys and the new buoys that might succeed the current generation of DART buoys? Given that failure rate, what is your estimation of the average effectiveness of this system?

Answer. While it is true that, at the time of the hearing, 2 of the 6 DART stations were offline, this does not indicate that these buoys are unreliable in general. The reliability of the DART stations, since October 2003, the time when they were transitioned from a research program of NOAA Research to an operational program of NOAA's National Weather Service, has been 72 percent. This percentage represents the combined number of hours the stations have been operational, and indicates that the DART station array is a highly effective system overall. Our goal is to have a fully capable network of 29 DART stations in the Pacific, with 3 additional in-water backups on the Gulf of Alaska. While it is not possible to guarantee that these prototype stations will be operational 100 percent of the time, NOAA is focused making the DART I network more robust and deploying a DART II network with reliability built into the design. NOAA plans for the network to meet operational requirements, even with occasional DART station outages. NOAA will develop capabilities to address network coverage and redundancy to ensure, as best we can, that single DART station failures will not impact the integrity of the entire network. Planned redundancy and hardening of the infrastructure, combined with the addition of a two-way communication capability, will mitigate risk from system-wide failures.

Question 9. Confronted with a fresh reminder of the potential devastation of an off-shore, tsunami-causing earthquake, I share Senator Stevens' concern about ensuring sufficient warning systems are in place so that loss of human life can be minimized. Senator Stevens requested an estimation of what it would take to establish a comprehensive tsunami notification system. I am very interested in your response and ask that you please forward me a copy of your answer to Senator Stevens' question.

Answer. A copy of the NOAA response to Senators Stevens and Inouye (as well as the incoming letter from the Senators) was faxed to your staff (Amit Ronen) on Thursday, March 3, 2005.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK PRYOR TO BRIGADIER GENERAL JOHN J. KELLY

Voice Sirens for Effective, Reliable Tsunami Warning

Question 1. Effective tsunami warning should rely on a variety of redundant modes of communication. While there are several technologies for communicating tsunami warnings highlighted in the Tsunami Preparedness Act of 2005 (S. 50), it is a concern that voice capable sirens are not among the technologies mentioned. Emergency managers have long depended on sirens to warn the public of emergency and civil defense situations including tsunamis, tornados, floods, hurricanes, hazardous material accidents, and of a potential nuclear attack.

Sirens have a number of significant advantages: they insure that all residents and visitors to a particular area can be informed without regard to the cell phone or pager technology platform or provider they may have, when equipped with backup power supplies they will work even when the electricity or phone lines are out; when equipped with live public address or pre-recorded messages they can be used BEFORE and AFTER the incident to communicate important public safety information.

Without the use of/installation of voice sirens as part of a preparedness plan, how do you warn people on the ground? Are there other effective warning systems available for this purpose? What criteria are used to determine which warning system is reliable in case of tsunami?

Answer. The National Oceanic and Atmospheric Administration (NOAA) works with the emergency management community to ensure warnings are received by the public in as many ways as possible—including cell phones, pagers, Internet, NOAA Weather Radio All-Hazards, television, radio, and sirens. All of these methods are effective, and emergency managers must decide how to best warn the public. NOAA's dissemination systems are available for the emergency management community to use in broadcasting emergency messages. NOAA will continue working with federal, state and local emergency managers to ensure warnings are as widely distributed as possible. Some National Weather Service Offices also issue tsunami warnings via High Frequency (HF) and Very High Frequency (VHF) marine radio as well, as do other federal agencies. There are no unique criteria for determining which warning systems are reliable for tsunamis.

Question 1a. Should a preparedness plan include a warning mechanism for small fishing boats trawling near the coastline? National Oceanic and Atmospheric Administration (NOAA) weather radios can be used to inform these fishing boats at minimal cost (approximately $20).

Answer. A comprehensive preparedness plan must address how to get messages to people, whenever they need it, wherever they are. NOAA Weather Radio All-Hazards is an effective way to reach fishing boats near the coast. There are other alternatives available as well, including satellite based communications links (Internet and cell phone). We employ all possible methods of delivering warnings to those at risk.

Improving Tsunami Prediction and Preparedness

Question 2. NOAA's National Weather Service has been able to mark its progress in severe weather prediction and forecasting with a number of useful metrics. For example, they have substantially increased warning times for hurricanes and tornadoes, while at the same time increasing accuracy of forecasts. Unlike these events, tsunamis are caused by largely unpredictable tectonic events that can strike without warning, which makes improving prediction a bit harder. However, it is important that we use the same approach to improving out tsunami prediction and warnings. One way we have started to characterize our success is a 75 percent reduction in false alarms since 1996. This is indeed an accomplishment. But we also want to make sure that when a deadly tsunami is headed for our coasts, we have the best information possible for our communities on time, place and severity.

What kind of progress have we made in accuracy of forecasting and prediction since 1996? What is a good measure of such progress?

Answer. Tsunamis often result from unpredictable seismic events that strike without warning. It is a challenge to improving the prediction of tsunami-genesis. With each tornado or hurricane, NOAA collects a tremendous amount of data. We are able to learn new things about these natural disasters with every event; this information aids us in our efforts to improve prediction. Fortunately, tsunamis are relatively infrequent. That means we record fewer events and have much we can learn when it comes to tsunami generation and propagation. Understanding how these natural disasters develop is key to determining how we can predict these destructive events.

The Administration's plan calls for NOAA to have a network of 39 advanced-technology Deep-Ocean Assessment and Reporting of Tsunamis (DART) buoys for a fully operational enhanced tsunami warning system by mid–2007. With a complete network of DART stations, we will have the opportunity to detect more tsunami events, and we have the opportunity to learn from each one. In November 2003, a large earthquake occurred in the Aleutian Islands and generated a tsunami. The DART stations recorded this event, confirming only a small tsunami. During post analysis of the event, DART data were used for a model simulation and the output from the simulation accurately predicted the 2 cm tsunami recorded at Hilo, Hawaii. With each tsunami-event recorded by the DART stations, we have the opportunity to fine-tune our models used to predict tsunami impacts. The DART data combined with forecast models promise to significantly reduce false alarm rates as well as provide a better measure of the severity of destructive tsunamis for Hawaii and all other parts of the Pacific. The accurate forecasting of a non-destructive tsunami in November 2003 saved Hawaii an estimated $68M in projected evacuation costs. With the additional DART stations, we expect to substantially reduce false alarm rate for distant tsunamis from 75 percent to less than 25 percent over the next 4 years. Little change is expected in reducing false alarms for local tsunamis (those generated from near-shore causes). A reduction in the rate of false alarms, and the associated cost-savings for our states and territories, is an appropriate measure of our progress in tsunami detection.

Question 2a. What other metrics will be important to pay attention to? For example, only 30 percent of our communities at risk have inundation maps—shouldn't this percentage improve? How much will this metric improve with the funds proposed under the President's plan?

Answer. NOAA agrees that the percentage of at-risk communities with complete inundation maps is an important metric, and we are working to increase the number of areas covered by inundation maps. Another important metric is the number of at-risk communities that are "TsunamiReady." NOAA's TsunamiReady program promotes tsunami hazard preparedness as an active collaboration among federal, state and local emergency management agencies, the public, and the National Weather Service tsunami warning system. The Administration's plan provides funding to allow NOAA to increase the number of mapped and TsunamiReady communities. Of the $24M scheduled for NOAA use, approximately $4.75M will be spent on inundation mapping and modeling, as well as education and outreach (e.g., community preparedness activities, including TsunamiReady). Of this $4.75M, approximately $2.25M will be spent on inundation mapping and modeling and $2.5M will go towards public education activities. Following the current plan, inundation mapping for the major population centers will be complete in 2015.

Question 2b. Since we have experienced a 50 percent decline in buoy service in the past 2 years, wouldn't this be another metric to focus on? What will be your goal?

Answer. It is not accurate to say that we have experienced a 50 percent decline in buoy service in the past 2 years. We believe you are referring to technical malfunctions of 3 of the 6 DART buoys in the weeks preceding the hearing. While it is true that at the time of the hearing, 2 of the 6 DART stations were offline, this does not indicate a 50 percent decline in performance over the last 2 years. The reliability of the DART stations since October 2003, the time when they were transitioned from a research program of the Office of Oceanic and Atmospheric Research to an operational program of the National Weather Service, has been 72 percent. This percentage represents the combined number of hours the stations have been operational, and is an appropriate metric to use in evaluating the reliability of the DART system. Further, this percentage indicates that the DART station array is a highly effective system overall.

Our goal is to have a fully capable network of 29 DART stations in the Pacific, with 3 additional in-water backups in the Gulf of Alaska, where sea conditions are particularly harsh. While it is not possible to guarantee that these stations will be operational 100 percent of the time given the demanding environmental conditions in which these stations operate, NOAA is focused on making the current DART network (DART I) more robust and deploying a next generation DART network (DART II) with reliability built into the design. NOAA plans for the network to meet operational requirements, even with occasional DART station outages. NOAA will develop capabilities to address network coverage and redundancy to ensure, as best we can, that single DART station failures will not impact the integrity of the entire network. Planned redundancy and hardening of the infrastructure, combined with the addition of a two-way communication capability, will mitigate risk from system-wide failures.

Funding for Tsunami Mitigation and Response

Question 3. The Administration recently released its plan to expand and modernize its tsunami detection and warning system. This plan includes the expansion of the system into areas such as the Atlantic Ocean, Caribbean, and Gulf of Mexico. I applaud the Administration's timely response, however, I am concerned that while the plan addresses the issue of tsunami detection, it does not completely address the issue of response to tsunami, as well as community preparation.

Which agency will be taking the lead for mitigation, mapping, and response?

Answer. NOAA, the Federal Emergency Management Agency (FEMA), and the United States Geologic Survey (USGS), through the National Tsunami Hazard Mitigation Program, coordinate inundation mapping efforts with state and local emergency management officials. FEMA is the lead agency for mitigation and response, with NOAA assisting any way possible. NOAA's role is to assist in identifying the tsunami hazard (required inundation mapping), providing tsunami warning guidance (including site-specific tsunami forecast models) and providing tsunami mitigation program support through community-based preparedness programs and education outreach—including the TsunamiReady Program.

Question 3a. Does the funding proposed by the Administration include funding for tsunami response? How much?

Answer. The two-year plan proposed by the Administration includes funding for NOAA and USGS for an improved tsunami detection and warning system. FEMA is the lead federal agency in the response area and is best suited to answer questions regarding response funding.

Question 3b. Will these amounts be adequate given the plans for expanded areas of coverage for the tsunami program?

Answer. The new NOAA funding for mitigation includes $2.5M for education and outreach and $2.25M for inundation mapping. This is a significant increase from the base funding levels managed through the National Tsunami Hazard Mitigation Program. FEMA is the lead federal agency in the response area and is best suited to answer questions regarding response funding.

RESPONSE TO LETTER DATED FEBRUARY 7, 2005 FROM CHAIRMAN STEVENS AND CO-CHAIRMAN INOUYE TO VICE ADMIRAL CONRAD C. LAUTENBACHER, JR.

In response to a letter, dated February 7, 2005 from Chairman Ted Stevens and Co-Chairman Daniel K. Inouye, asking to:

Please explain what information or resources your agency requires before it can issue a public warning notification of a natural hazard or disaster. In addition, we would like to know which entities or organizations receive warnings from, or through, your agency, such as the appropriate federal and local disaster response entities, first responders/911, and local and national media outlets. To the extent possible, your report should also demonstrate which communications technologies are currently used to deliver these public warnings, such as automatic alert televisions and radios, telephones, wireless and satellite technology, including cellular telephones, pagers, personal digital assistants (PDAs), and the internet. If such communications technologies are not being used, we would like to know what the impediments are, and the status of any discussions to expand the warning system's capability to do so.

Your report should also specify a process by which your agency, either on its own, or in conjunction with other relevant agencies, can maximize effective dissemination of public warning notifications. Lastly, we would be interested to know how your agency interacts with the Department of Homeland Security (including the Federal Emergency Management Agency), the Federal Communications Commission, the Department of Commerce, or other relevant agencies with respect to warning systems.

Response

Thank you for your letter regarding General John J. Kelly's testimony at the February 2, 2005, hearing of the Senate Committee on Commerce, Science and Transportation on the U.S. tsunami warning system and the Tsunami Preparedness Act of 2005. At the hearing, you asked us to tell the Committee how the National Oceanic and Atmospheric Administration (NOAA) could improve public notification of impending natural hazards and disasters.

NOAA's National Weather Service (NWS) is acknowledged as the premier agency in government for disseminating warning information. We are efficient at disseminating weather and natural hazard information through our vast communication network. We currently provide public notification of weather warnings as well as other natural hazards and disasters, such as earthquakes, tsunamis, and civil emergency messages, e.g., hazardous materials spills. These warnings can be received and transmitted by a myriad of other users providing access to virtually all of the people across the Nation. We can provide access, but we cannot ensure the message is received.

While our system is effective, we can still make improvements. We can make our systems more reliable and improve public education. We can work with the private sector to utilize new technology to make warnings available, and develop other methods to increase accessibility of warnings.

NOAA Weather, Alert, and Readiness Network (NOAA WARN), includes all NOAA's National Weather Service warning dissemination systems (see attachment). This includes the NOAA Weather Radio All Hazards (NWR) program, which consists of over 900 radio transmitters covering nearly 97 percent of the nation's population. The President's FY06 Budget request includes funds to modernize 64 of 400 remaining vintage 1970's NWR transmitters. These improvements will make them more robust by including backup power supply, and make them easier to maintain. Backup power is critical during major weather events, such as hurricanes, when commercial power is out.

Our assessment and decision-making equipment, the Advanced Weather Interactive Processing System (AWIPS), is the initial generation point for all NWS disseminated warnings. We are working to ensure AWIPS has appropriate software capabilities, capable of disseminating new information technology standard formats, to effectively support the new technologies such as Geophysical Information Systems (GIS) and Personal Digital Assistants (PDAs).

Issuing weather and water related warnings (including tsunamis) are the culmination of a complex process, beginning with observations, analysis, and interpretation, and culminating with disseminating the warning. NOAA's NWS maintains a complex infrastructure of people and technology to create, and then issue those warnings. It is our mission. It is what we do.

Issuing civil emergency warnings or earthquake warnings has a different process. NWS serves as a dissemination service for these warnings. We rely on communication processing, which is automated for earthquake warnings, and is being automated for federal, state and local civil emergency messages. For these civil emergency messages to be disseminated, we need to ensure agreements are in place to allow access to NOAA dissemination systems. In June 2004, the Department of Homeland Security (DHS) and NOAA signed a Memorandum of Agreement allowing DHS to use the NOAA Weather Radio All Hazards network to disseminate civil emergency messages.

Once warnings are in NOAA WARN, they are automatically transmitted to the Emergency Alert System (EAS; for wide distribution in real and near-real time), the NWS dissemination network, and through other private and public dissemination systems. NOAA WARN systems include NWR, NOAA Weather Wire, NOAAPort, Emergency Managers Weather Information Network (EMWIN), and the Internet. Most local and all national media outlets have links to NOAA's NWS dissemination network to receive warning information.

Warning messages from NOAA's NWS activate the EAS and also reach the private sector, which rebroadcast the emergency information via television, radio, internet (e.g., e-mail warnings), pagers, and in some cases PDAs and cell phones. Through this warning system, all appropriate federal and local emergency officials have access to the warning information and can receive warnings.

Newer technology (e.g., cell phones, reverse 911, PDA's, pagers) can receive warning information, but most are set up to do so only when requested by the user or as a subscription service. There is no federal, state or local policy in place to mandate redistribution of warning information. While there are some technical challenges to alert, for example, every cell phone within a certain area, it is possible. The difficulty with broadcast cell phone warnings is there are no national standards. NOAA will continue to work with appropriate public and private entities to ensure warning information is available in industry standard formats for ease of interoperability.

NOAA and DHS have ongoing discussions with satellite communications operators, such as XM Satellite Radio, who already have a channel devoted to emergency messages. This method to deliver warnings shows promise, with the only reservation at this point the limited number of users.

Effective dissemination of public warning notification requires using existing systems and infrastructure where possible and public education and outreach to recommend what actions to take once the warnings are issued. For example, USGS uses the NWS infrastructure to disseminate earthquake messages and, as stated above, DHS also has access to NWR to disseminate warnings. This is an efficient use of government infrastructure. All federal agencies involved in warning the public need to continue to work together to leverage available assets. NOAA has been working with DHS, the Federal Communications Commission (FCC), and other agencies within the Department of Commerce to help coordinate the federal effort on a consolidated warning system to ensure the public is able to receive emergency messages. This dialogue will continue.

For example, NWS is working with the Federal Emergency Management Agency (FEMA) on a system to streamline the ability of pre-approved and authenticated officials at federal, state, and local levels to submit messages for broadcast over NWS systems. The NWS received funds in the FY 2004 Omnibus Appropriations Act to streamline and automate the current manual creation, authentication, and collection of all types of non-weather emergency messages in a quick and secure fashion for subsequent alert, warning, and notification purposes. HazCollect, as the new system is known, will function through FEMA's Disaster Management Interoperability Service (DMIS). All weather and non-weather emergency messages will be available on the DMIS backbone network for national, state and local dissemination through myriad public and private sector systems.

Essential to any effective warning system is education and outreach. NOAA's NWS has two programs to help ensure local communities can receive warning information they need—StormReady and TsunamiReady. These programs focus on preparedness and education activities to make sure local communities can take appropriate steps once the warning information is received. One of the criteria for a community to be certified as StormReady is to have in place alternate and redundant ways to receive warnings. For example, an emergency operations center may have Internet notification as well as NWR as their methods to receive warnings. Receiving warnings through multiple systems reduces the possibility of missing critical information.

NOAA is working with DHS and other federal, state and local agencies to increase usage of NWR and expand the use of new and emerging technology to deliver warnings. Timeliness is always a factor, but existing NWS dissemination systems transmit warnings usually within seconds. Redistribution through EAS is also quick. However, the Nation needs a federal lead agency for a nationwide warning system, using a common message standard. We believe DHS/FEMA is the appropriate agency to lead such an effort, and must build on existing warning systems, such as NOAA WARN, to create a warning "system of systems."

American territories, such as American Samoa, do not have an extensive communications infrastructure. NOAA is working with these communities and our international partners to ensure warning information is communicated to government officials. Much communication is done through the Emergency Managers Weather Information Network (EMWIN) and Radio and Internet (RANET) systems.

Enclosed is a brief summary of existing NOAA/NWS and related federal dissemination systems. We would be pleased to meet with you and your staff to provide more detailed information about NOAA warning dissemination methods and processes.

An Integrated Public Alert and Warning System is an important element to help keep the people of this Nation safe. Public safety is a fundamental responsibility of federal, state and local governments. Public alert and warning systems save lives by informing, reducing fear, and assisting emergency managers. NOAA will continue to work with DHS, FCC and other government agencies to continue to integrate these systems.

ENCLOSURE

NOAA Weather Radio All Hazards

NOAA Weather Radio All Hazards (NWR) is a nationwide network of transmitters broadcasting continuous weather information directly from a National Weather Service office. NWR broadcasts National Weather Service warnings, watches, forecasts, and other hazard information 24-hours per day. Known as the "voice of NOAA's National Weather Service," NWR is provided as a public service by the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA). NWR includes more than 925 transmitters, covering more than 97 percent of the United States, Puerto Rico, the U.S. Virgin Islands, and the U.S. Pacific Territories. NWR requires a special radio receiver or scanner capable of picking up the signal. Broadcasts are found in the public service band on seven frequencies.

Currently, about 17 percent of the U.S. population owns a NOAA Weather Radio, though the actual percentage of the population reached may be greater due to the promulgation of receivers in public places such as schools, hospitals, fire stations, and malls. NOAA Weather Radio receivers can be purchased at many retail stores selling electronic merchandise. Some televisions are now equipped with AlertGuard™, which is essentially an embedded NWR receiver with alert capability. NOAA Weather Radio All Hazards receivers are often sold in boat and marine accessory businesses, as they are popular in the marine community. These are just some of the places NOAA Weather Radio receivers can be purchased.

A survey on *Weather Radio Interests and Awareness* conducted in August 2002 by eBrain Market Research (a service of the Consumer Electronics Association) identified the following key points:

- The most common type of the NOAA Weather Radio owned is a hand-held model (50 percent). Additionally, 32 percent of owners possess a desktop weather radio, 19 percent own a marine weather radio that picks up NOAA Weather Radio, 11 percent have a clock-radio equipped to receive NOAA alerts, and 10 percent can pick up NOAA announcements on their CB.
- Given the right product offerings and marketing campaigns to promote awareness of weather radios, it is possible manufacturers can sell 7.4 million weather radios over the next year.

Emergency Alert System

The Emergency Alert System serves two functions:

- It provides a last resort method for the President to address the Nation in times of national attack or major crisis (National Alert).

- When not in use by the President, it can be used to issue warning messages of imminent or ongoing hazards at the state and local levels by radio, television, and cable systems in selected regions. (NOAA Weather Alert, State and Local Alerts). [1]

During a national alert, all radio and television stations and cable television systems must either broadcast Presidential alerts immediately or cease transmission during the message. Broadcasting of state and local alerts is not mandatory, and stations/systems can postpone broadcasting a given warning or alert still in force until there is a programming pause. National alerts are issued through the Primary Entry Point (PEP) system via dialup telephone lines (with High Frequency (HF) radio backups) to 34 continental U.S. and territorial radio stations. For national alert and warning, the 34 PEP stations would then serve as relay points for the Presidential message to automatically seize the broadcasts of all U.S. radio and TV and cable stations monitoring the PEP stations. The direct PEP radio station broadcasts cover approximately 95 percent of the continental U.S. and Hawaii and the seized broadcast would cover well over 95 percent of the American public.

State and local alerts generally originate in the State Emergency Operations Center or other similar official location. Because there is no standard in the country for EAS plans, some states have more robust systems than others. For example, Florida and Pennsylvania use satellite technology to get out emergency messages from the Governor reaching the entire state. Most other states rely on the cascade system used for typical EAS messages where stations monitor "up stream" stations for a signal until the entire state is covered. "Amber Alerts" are also sent out over the system; these may originate from a law enforcement agency within the state. The only thing states using the system have in common is that they all must enter the system at some point from an authorized official.

All non-PEP broadcast stations and cable systems are required to follow their state EAS plans. [2] Integral to all state plans is they must specify monitoring assignments for all broadcast stations and cable systems in the state. All broadcast stations and cable systems are required to monitor at least two EAS sources according to their state EAS plan. At least one PEP station should be monitored by a state's EAS network so national level EAS messages can be distributed in the state. In an effort to bring order to the system, all broadcast stations and cable systems have EAS designations. PEP stations have an EAS designation of National Primary (NP), since they are the source of national level messages. State level sources have designations of State Primary (SP) and State Relay (SR) and local sources are designated Local Primary (LP).

There is also one national network, National Public Radio (NPR), which has voluntarily agreed to distribute national level messages to its affiliates via satellite. The NPR directly monitors a PEP/NP station and will relay a national level EAS message as soon as it is received.

The National Weather Service (NWS) originates about 90 percent of all EAS alerts. Many participating EAS entities voluntarily monitor the National Weather Service's NOAA Weather Radio (NWR) transmitting alerts. NWR supplies local EAS encoded alerts to broadcast and cable entry points as described in each approved state and local EAS plan. In many localities, emergency managers can originate EAS alerts through NWS, through a broadcaster or cable operator, or through their own equipment if they have made prior arrangements documented in EAS plans. Proper operation of the EAS depends on those state and local plans specifying how stations are linked together in monitoring webs; how State Primary (SP), State Relay (SR) and Local Primary (LP) EAS sources get EAS warnings; how EAS testing is accomplished; and which EAS messages may be relayed.

National Warning System

FEMA maintains and operates the National Warning System (NAWAS), which was developed and installed during the 1950s, as the primary national emergency communication system among federal, state, and local emergency operations centers. NAWAS is a dedicated, 24-hour, specialized party telephone line with 1,850 terminals at state and local emergency operations centers, 911 centers, and police and fire stations to all be activated at the same time. The system is used to relay national and local information within states. It also has direct links to the command center at the North American Aerospace Defense Command. Every NWS forecast office has connectivity to NAWAS.

[1] Plan for the Operation of the Emergency Alert System (EAS) during a National Emergency (FEMA EAS OPLAN), dated September 1995.

[2] There is no requirement from the FCC for states to have an EAS plan, but regulations require states choosing to develop an EAS plan to have it reviewed by the FCC.

NOAA Weather Wire System

The NOAA Weather Wire Service (NWWS) also plays a role in getting weather warnings to the public. NWWS is a satellite data collection and dissemination system. NWWS broadcasts can be received anywhere in the United States and Puerto Rico. NWWS disseminates warnings in less than 10 seconds. The warnings have embedded digital information identifying specific threats and specific geographic areas at risk. Satellite receivers are commercially available. At least one emergency management or law enforcement agency in each state has NWWS. These agencies rebroadcast the information to other state and local emergency managers and also provide local hazard information to the NWS for broadcast, when appropriate.

Negotiations are underway to add the National Law Enforcement Telecommunications System to NWWS. This would permit several thousand law enforcement agencies around the country to exchange all-hazard warnings.

Emergency Managers Weather Information Network

The Emergency Managers Weather Information Network (EMWIN) transmits real time weather and emergency information. The EMWIN signal is available anywhere within the NOAA's Geostationary Operational Environmental Satellites (GOES) footprint, which covers most of the western hemisphere as well as the central and eastern Pacific Ocean. The National Weather Service gathers real time weather and emergency information from sources across the globe and broadcasts the information via EMWIN. Emergency management groups and municipal agencies receive EMWIN data from the satellite and retransmit it on local radio frequencies. State and local agencies select the information to fit their specific area. The EMWIN datastream is rebroadcast by the University of Hawaii over the PEACESAT satellite covering much of the Pacific Ocean including remote Pacific islands. In some small island countries, it is the most reliable way to get forecasts and warnings and information. Commercial software is available to allow local computers to be configured to trigger alarms for specific hazards.

RANET

Advancement of communication and dissemination capacities in developing countries for purposes of tsunami and other hazards warning is being addressed in part through the NOAA and USAID Office of Foreign Disaster Assistance supported Radio and Internet (RANET) program. RANET works to develop dissemination capacities for distribution of critical weather and climate information to rural and remote populations in developing countries. This program is active throughout Africa and the Pacific, and activities are expected to begin in late spring and early summer in Asia. The RANET program utilizes WorldSpace digital satellite broadcast capacity, provided through the not-for-profit First Voice International, to deliver a variety of graphic and text based information to national weather services and remote field offices anywhere in Africa, Central Asia, South Asia, Southeast Asia, and the Pacific. The broadcast on the AsiaStar and AfriStar WorldSpace satellites is a comprehensive suite of weather forecasts, observations, bulletins, and related information. RANET ties this broadcast capacity to traditional FM and HF radio broadcasts, as well as other networks. In response to the December 26, 2004, tsunami disaster, RANET is working with the Pacific Tsunami Warning Center to develop a 'global' cell phone based SMS/text messaging service. Technical development of the system was completed on February 14, 2005, and it is now undergoing a series of tests before being formally announced. The service will provide notification to foreign government officials and those appointed by a country point-of-contact when bulletins from the Pacific Tsunami Warning Center and other centers are released. Similarly, RANET is developing a web-based alert notification system. While receiving activity support and coordination, RANET is not currently provided operational resources.

Dissemination of Tsunami Warning Information to the Public

The NOAA National Weather Service (NWS) Richard H. Hagemeyer Pacific Tsunami Warning Center (PTWC) disseminates bulletins by a variety of methods to (1) eliminate single points of failure, and (2) to reach all of its clients. PTWC relies heavily on the established communications infrastructure used by the weather side of the NWS. Bulletins are sent via a dedicated circuit to the NWS Telecommunications Gateway (NWSTG) in Silver Springs, Maryland, and from there they are forwarded into the Advanced Weather Information Processing System and delivered to NWS Forecast Offices. From NWS Forecast Offices tsunami information is relayed into the NOAA Weather Radio (NWR) and Emergency Alert System (EAS) when necessary. Bulletins are also forwarded from the National Weather Service Telecommunications Gateway (NWSTG) into the World Meteorological Organization's Global Telecommunications System for delivery to weather offices worldwide. Bulletins are also forwarded from the NWSTG into the Emergency Managers Weather Information Network (EMWIN) for delivery over the GOES and PEACESAT satellites to many places including remote Pacific islands. PTWC bulletins are also sent to the NWSTG over the NOAA Weather Wire System (NWWS), a satellite based system with a 2-way dish at PTWC. In addition to providing a redundant path from PTWC to the NWSTG, the NWWS provides NWS products including tsunami bulletins to a variety of customers, including the media, via an NWS program called the Family of Services (FOS). Television stations in Hawaii, for example, subscribe to an Associated Press (AP) feed over which they receive PTWC bulletins. The AP receives its weather information from multiple NWS forecast and warning dissemination systems to help ensure high reliability. PTWC sends tsunami information to the U.S. Armed Forces via a legacy dial-out GateGuard terminal delivering the bulletins via the AUTODIN system to approximately 200 commands. PTWC also informs the Pacific Command of U.S. Forces and the Navy Command Center for the Hawaii Region by telephone. PTWC also sends its bulletins to approximately 30 airfields and other locations in the Pacific over the Aeronautical Fixed Telecommunications Network. In addition, bulletins are sent via e-mail to about 100 addresses and via fax to about 20 offices.

The procedure PTWC has always operated under is it only provides tsunami warning guidance to national and local authorities. This is no different than for other natural disasters, such as hurricanes, floods, etc. NWS provides the information to decision-makers. Those authorities are then responsible for making decisions about whether or not to issue an evacuation order, and for disseminating such orders to the public. In some cases, such as an urgent local tsunami warning in Hawaii, the issuance of evacuation orders with sirens sounding and an activation of the EAS and NWR (by the NWS Honolulu Forecast Office in response to a PTWC bulletin) is pre-approved by State Civil Defense (SCD) in the interest of time when minutes and seconds count. But in other cases such as a distant tsunami approaching Hawaii, SCD may consult with its own tsunami advisors and control the issuance and timing of any evacuation. Local authority for evacuations is critical since PTWC warnings to various parts of the Pacific, being based initially on only the seismic data, have a high false alarm rate. It could be very confusing to the public if PTWC issued evacuation guidance to a region, but local authorities in that region had decided not to evacuate.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO DR. JOHN H. MARBURGER, III

Question. What actions are being taken by the U.S. in response to the health threats that continue to exist in the affected countries?

Answer. My office, the Office of Science and Technology Policy, is not coordinating the U.S. response to health threats in the affected countries. However, I have asked the U.S. Agency for International Development (USAID), the Department of Defense (DoD), and the Department of Health and Human Services (HHS) to provide detailed information on their response to health threats, which are described below. In addition, I have asked NASA to summarize its less direct, but nevertheless important, contributions through satellite imaging.

USAID

USAID/Office of U.S. Foreign Disaster Assistance (OFDA) has provided over $30 million to non-governmental organizations (NGOs) and international organizations to provide assistance in health, water/sanitation, and psychological and social activities. OFDA has provided $8 million to NGOs and international organizations for health sector programs (excluding psychological and social activities, and water/sanitation). OFDA funded partners have provided mobile health clinics and field hospitals, rehabilitated primary health care clinics and hospitals, and provided medicines and emergency health care supplies. In addition, OFDA-funded international organizations are tracking patterns of life-threatening diseases, and assisting in the control of communicable diseases through surveillance and early warning systems, immunization, distribution of hygiene kits, and health/hygiene education.

USAID/OFDA has provided $17 million to organizations for water and sanitation activities to ensure sanitary conditions and access to potable drinking water for affected populations. Partner activities include construction of latrines, provision of containers for transportation of water and water storage bladders, disinfection of water sources, water purification and treatment, hygiene education, and distribution of hygiene kits.

In addition to the traditional emergency health activities, OFDA is supporting organizations that are carrying out interventions to mitigate the psychological trauma of the tsunami. OFDA is providing funding in India, Sri Lanka, and Indonesia for programs that provide psychological and social support for survivors of the tsunami. Total support for these activities totals approximately $5.2 million. We have given particular attention to the needs of children and are supporting several organizations that are facilitating structured activities for children and adolescents, often through child-centered spaces. These activities are being implemented in internally displaced persons (IDP) program settlements and tsunami-affected communities alike.

OFDA is currently funding the following organizations to implement Health, Psychological and Social, and Water/Sanitation programs benefiting tsunami-affected populations:

Action Contre la Faim
American Center for International Labor
The Asia Foundation
CARE
Catholic Relief Services
Christian Children's Fund
Church World Services
Cooperative Housing Foundation International
GOAL
International Medical Corps
International Organization for Migration
International Rescue Committee
International Relief and Development
Johns Hopkins Program for International Education in Gynecology and Obstetrics
Project Concern International
Sarvodaya
Save the Children/US
Save the Children/UK
Shelter for Life
Sri Lanka Red Cross
United Nations Children's Fund
World Health Organization

USAID is also considering proposals from NGOs and others and working to respond to the needs assessments being developed for the region. For additional details, see the INDIAN OCEAN—Earthquake and Tsunamis Fact Sheet, available on the USAID website (http://www.usaid.gov/locations/asia__near__east/tsunami).

DoD

The Defense Department has dispatched the medical ship USNS Mercy off the coast of Banda Aceh Indonesia. This medical ship is staffed by a unique combination of military personnel and American volunteers from the medical community coordinated by the NGO Project HOPE. In coordination with the Government of Indonesia, the military staff and volunteers are providing state of the art medical services to those patients that cannot be treated by the hospitals on shore. They are also providing consultation services, limited training, and bioengineering repair services in hospitals on shore.

HHS

HHS has deployed 54 employees to the region, including four people assigned to the U.S. Disaster Assistance Response Teams, as well as Centers for Disease Control and Prevention (CDC) epidemiologists and field staff in Indonesia, Thailand, and Sri Lanka. They are assisting with activities related to vaccine-preventable diseases, childhood injuries and trauma, malaria control, health and nutrition, mental health, rapid needs assessment, and response coordination. Among the diseases that are being monitored are cholera, dysentery, malaria and typhoid fever. In addition, HHS staff are assisting the Department of Defense aboard the USNS Mercy.

Since late December, CDC staff in Thailand and India, where HHS has ongoing programs, have been assisting local health and other officials, under the direction of the respective U.S. embassies. Their activities include assessing health needs, monitoring for diseases, and documenting the dead and missing. HHS scientists are assisting teams led by Department of Defense, the State Department and international organizations. HHS officials in the United States are in daily contact with American, international and local officials involved in the tsunami response.

HHS is working with other agencies of the U.S. government planning for the recovery and reconstruction phase of the tsunami response.

NASA

NASA satellite observations and predictions of Earth processes are being used to support human health aid programs in the tsunami affected regions and elsewhere in the world. Health factors that are measurable from NASA research instruments include, air and water contaminants, ambient temperature extremes, ultra-violet radiation and a myriad of other factors that contribute to our knowledge of public health challenges. NASA collaborates to expand the use of Earth observing instruments, advanced communication technology, high speed computing capabilities, data products, and predictive models associated with the occurrence of disease to assist partners in enhancing their surveillance systems.

For example, NASA's Socioeconomic Data and Applications Center (SEDAC) is working with the Geographic Information Support Team (GIST), which includes representatives from the U.S. Office of Foreign Disaster Assistance (OFDA), the UN Office for the Coordination of Humanitarian Affairs (OCHA), the World Bank, the World Food Programme (WFP), the UK Department for International Development (DFID), the World Health Organization (WHO), and others. This group is providing access to key geospatial data needed by working teams in the field.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO DR. JOHN H. MARBURGER, III

Question. Dr. Marburger, confronted with a fresh reminder of the potential devastation of an off-shore, tsunami-causing earthquake, I share Senator Stevens' concern about ensuring sufficient warning systems are in place so that loss of human life can be minimized. Thank you for the outline you provided in your written testimony of the generic components for a successful disaster detection, warning, and reduction system. Senator Stevens requested an estimation of what it would take to establish a comprehensive tsunami notification system, such as the one you outlined in your testimony. I am very interested in your response and ask that you please forward me a copy of your answer to Senator Stevens' question.

Answer. I share your concern that the citizens of the U.S. have sufficient warning of any tsunami event on our shores. In fact, tsunami warnings are a part of a larger effort to provide warnings for all natural and human-caused disasters within the U.S.

The responses to Senator Stevens' question come mostly from the agencies charged with the development of a comprehensive tsunami notification system. The U.S. already has significant warning capabilities for a variety of severe weather events and other emergencies. For example, I have attached an extended excerpt from a letter submitted by NOAA Administrator Lautenbacher in response to questions by Senators Stevens and Inouye in which the current warning capabilities of the U.S. are summarized nicely. We believe that the efforts of the Department of Commerce (NOAA), the U.S. Geological Survey (USGS), the National Science Foundation (NSF), and the Department of Homeland Security (FEMA) are effective and should continue their development. The next steps in this process are outlined in the fact sheet that the Office of Science and Technology Policy released (copy attached) describing the Administration's immediate steps to strengthen the U.S. tsunami detection and warning capabilities in the Pacific Ocean, Atlantic Ocean, and Caribbean Sea. Furthermore we have assembled an interagency working group under the National Science and Technology Council to provide the detailed planning and identification of responsibilities to implement these improvements. This group will issue a detailed plan by mid-summer.

In addition, the evolving emergency notification situations following the events of September 11, 2001 have motivated us to create an interagency effort to coordinate the activities with the Federal Government that deal with emergency warnings. This new group is now being formed under the National Science and Technology Council and will be called the Task Force on Effective Warnings. This Task Force will be charged with examining both natural disaster warnings and homeland security warnings, and to will examine and make recommendations about disaster warning/communication systems, networks or facilities to provide effective disaster warning systems for the Nation. We believe that the integration of warning systems for natural hazards should be combined with warning associated with homeland security into a single "all hazards" warning system for the people of the U.S.

Excerpt from letter to Senators Stevens and Inouye from Vice Admiral Conrad C. Lautenbacher on February 22, 2005:

NOAA's National Weather Service (NWS) is acknowledged as the premier agency in government for disseminating warning information. We are efficient at disseminating weather and natural hazard information through our vast communication network. We currently provide public notification of weather warnings as well as other natural hazards and disasters, such as earthquakes, tsunamis, and civil emergency messages, e.g., hazardous materials spills. These warnings can be received and transmitted by a myriad of other users providing access to virtually all of the people across the Nation. We can provide access, but we cannot ensure the message is received.

While our system is effective, we can still make improvements. We can make our systems more reliable and improve public education. We can work with the private sector to utilize new technology to make warnings available, and develop other methods to increase accessibility of warnings.

NOAA Weather, Alert, and Readiness Network (NOAA WARN), includes all NOAA's National Weather Service warning dissemination systems (see attachment). This includes the NOAA Weather Radio All Hazards (NWR) program, which consists of over 900 radio transmitters covering nearly 97 percent of the nation's population. The President's FY06 Budget request includes funds to modernize 64 of 400 remaining vintage 1970's NWR transmitters. These improvements will make them more robust by including backup power supply, and make them easier to maintain. Backup power is critical during major weather events, such as hurricanes, when commercial power is out.

Our assessment and decision-making equipment, the Advanced Weather Interactive Processing System (AWIPS), is the initial generation point for all NWS disseminated warnings. We are working to ensure AWIPS has appropriate software capabilities, capable of disseminating new information technology standard formats, to effectively support the new technologies such as Geophysical Information Systems (GIS) and Personal Digital Assistants (PDAs).

Issuing weather and water related warnings (including tsunamis) are the culmination of a complex process, beginning with observations, analysis, and interpretation, and culminating with disseminating the warning. NOAA's NWS maintains a complex infrastructure of people and technology to create, and then issue those warnings. It is our mission. It is what we do.

Issuing civil emergency warnings or earthquake warnings has a different process. NWS serves as a dissemination service for these warnings. We rely on communication processing, which is automated for earthquake warnings, and is being automated for federal, state and local civil emergency messages. For these civil emergency messages to be disseminated, we need to ensure agreements are in place to allow access to NOAA dissemination systems. In June 2004, the Department of Homeland Security (DHS) and NOAA signed a Memorandum of Agreement allowing DHS to use the NOAA Weather Radio All Hazards network to disseminate civil emergency messages.

Once warnings are in NOAA WARN, they are automatically transmitted to the Emergency Alert System (EAS; for wide distribution in real and near-real time), the NWS dissemination network, and through other private and public dissemination systems. NOAA WARN systems include NWR, NOAA Weather Wire, NOAAPort, Emergency Managers Weather Information Network (EMWIN), and the Internet. Most local and all national media outlets have links to NOAA's NWS dissemination network to receive warning information.

Warning messages from NOAA's NWS activate the EAS and also reach the private sector, which rebroadcast the emergency information via television, radio, internet (e.g., email warnings), pagers, and in some cases PDAs and cell phones. Through this warning system, all appropriate federal and local emergency officials have access to the warning information and can receive warnings.

Newer technology (e.g., cell phones, reverse 911, PDA's, pagers) can receive warning information, but most are set up to do so only when requested by the user or as a subscription service. There is no federal, state or local policy in place to mandate redistribution of warning information. While there are some technical challenges to alert, for example, every cell phone within a certain area, it is possible. The difficulty with broadcast cell phone warnings is there are no national standards. NOAA will continue to work with appropriate public and private entities to ensure warning information is available in industry standard formats for ease of interoperability.

NOAA and DHS have ongoing discussions with satellite communications operators, such as XM Satellite Radio, who already have a channel devoted to emergency messages. This method to deliver warnings shows promise, with the only reservation at this point the limited number of users.

Effective dissemination of public warning notification requires using existing systems and infrastructure where possible and public education and outreach to recommend what actions to take once the warnings are issued. For example, USGS uses the NWS infrastructure to disseminate earthquake messages and, as stated above, DHS also has access to NWR to disseminate warnings. This is an efficient use of government infrastructure. All federal agencies involved in warning the public need to continue to work together to leverage available assets. NOAA has been working with DHS, the Federal Communications Commission (FCC), and other agencies within the Department of Commerce to help coordinate the federal effort on a consolidated warning system to ensure the public is able to receive emergency messages. This dialogue will continue.

For example, NWS is working with the Federal Emergency Management Agency (FEMA) on a system to streamline the ability of pre-approved and authenticated officials at federal, state, and local levels to submit messages for broadcast over NWS systems. The NWS received funds in the FY 2004 Omnibus Appropriations Act to streamline and automate the current manual creation, authentication, and collection of all types of non-weather emergency messages in a quick and secure fashion for subsequent alert, warning, and notification purposes. HazCollect, as the new system is known, will function through FEMA's Disaster Management Interoperability Service (DMIS). All weather and non-weather emergency messages will be available on the DMIS backbone network for national, state and local dissemination through myriad public and private sector systems.

Essential to any effective warning system is education and outreach. NOAA's NWS has two programs to help ensure local communities can receive warning information they need—StormReady and TsunamiReady. These programs focus on preparedness and education activities to make sure local communities can take appropriate steps once the warning information is received. One of the criteria for a community to be certified as Storm Ready is to have in place alternate and redundant ways to receive warnings. For example, an emergency operations center may have Internet notification as well as NWR as their methods to receive warnings. Receiving warnings through multiple systems reduces the possibility of missing critical information.

NOAA is working with DHS and other federal, state and local agencies to increase usage of NWR and expand the use of new and emerging technology to deliver warnings. Timeliness is always a factor, but existing NWS dissemination systems transmit warnings usually within seconds. Redistribution through EAS is also quick. However, the Nation needs a federal lead agency for a nationwide warning system, using a common message standard. We believe DHS/FEMA is the appropriate agency to lead such an effort, and must build on existing warning systems, such as NOAA WARN, to create a warning "system of systems."

American territories, such as American Samoa, do not have an extensive communications infrastructure. NOAA is working with these communities and our international partners to ensure warning information is communicated to government officials. Much communication is done through the Emergency Managers Weather Information Network (EMWIN) and Radio and Internet (RANET) systems.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK PRYOR TO DR. JOHN H. MARBURGER, III

The questions voiced by Senator Pryor reflect concern and interest in the success and effectiveness of existing warning mechanisms and the likelihood that these systems will get better in the future. I share those concerns and have assembled an interagency working group under the National Science and Technology Council to gather together the agencies working on tsunami warning systems to provide the detailed planning and identification of responsibilities to implement these improvements. This group will issue a detailed plan by mid-summer and we will follow up with the agencies to ensure effective implementation.

The specific questions submitted by Senator Pryor are identical to the questions submitted to NOAA. Since NOAA is the agency responsible for managing the TsunamiReady Program and is primarily responsible for instituting any needed changes in the U.S. tsunami warning system, I will defer to NOAA's detailed responses to these questions, listed here.

Voice Sirens for Effective, Reliable Tsunami Warning

Question 1. Effective tsunami warning should rely on a variety of redundant modes of communication. While there are several technologies for communicating tsunami warnings highlighted in the Tsunami Preparedness Act of 2005 (S. 50), it is a concern that voice capable sirens are not among the technologies mentioned. Emergency managers have long depended on sirens to warn the public of emergency and civil defense situations including tsunamis, tornados, floods, hurricanes, hazardous material accidents, and of a potential nuclear attack.

Sirens have a number of significant advantages: they insure that all residents and visitors to a particular area can be informed without regard to the cell phone or pager technology platform or provider they may have, when equipped with backup power supplies they will work even when the electricity or phone lines are out; when equipped with live public address or pre-recorded messages they can be used BEFORE and AFTER the incident to communicate important public safety information.

Without the use of/installation of voice sirens as part of a preparedness plan, how do you warn people on the ground? Are there other effective warning systems available for this purpose? What criteria are used to determine which warning system is reliable in case of tsunami?

Answer. NOAA works with the emergency management community to ensure warnings are received by the public in as many ways as possible—including cell phones, pagers, Internet, NOAA Weather Radio All-Hazards, television, radio, and sirens. All of these methods are effective, and emergency managers must decide how to best warn the public. NOAA's dissemination systems are available for the emergency management community to use in broadcasting emergency messages. NOAA will continue working with federal, state and local emergency managers to ensure warnings are as widely distributed as possible. Some National Weather Service Offices also issue tsunami warnings via High Frequency (HF) and Very High Frequency (VHF) marine radio as well, as do other federal agencies. There are no unique criteria for determining which warning systems are reliable for tsunamis.

Question 1a. Should a preparedness plan include a warning mechanism for small fishing boats trawling near the coastline? National Oceanic and Atmospheric Administration (NOAA) weather radios can be used to inform these fishing boats at minimal cost (approximately $20).

Answer. A comprehensive preparedness plan must address how to get messages to people, whenever they need it, wherever they are. NOAA Weather Radio All-Hazards is an effective way to reach fishing boats near the coast. There are other alternatives available as well, including satellite based communications links (Internet and cell phone). We employ all possible methods of delivering warnings to those at risk.

Improving Tsunami Prediction and Preparedness

Question 2. NOAA's National Weather Service has been able to mark its progress in severe weather prediction and forecasting with a number of useful metrics. For example, they have substantially increased warning times for hurricanes and tornadoes, while at the same time increasing accuracy of forecasts. Unlike these events, tsunamis are caused by largely unpredictable tectonic events that can strike without warning, which makes improving prediction a bit harder. However, it is important that we use the same approach to improving out tsunami prediction and warnings. One way we have started to characterize our success is a 75 percent reduction in false alarms since 1996. This is indeed an accomplishment. But we also want to make sure that when a deadly tsunami is headed for our coasts, we have the best information possible for our communities on time, place and severity.

What kind of progress have we made in accuracy of forecasting and prediction since 1996? What is a good measure of such progress?

Answer. Tsunamis often result from unpredictable seismic events that strike without warning. It is a challenge to improving the prediction of tsunami-genesis. With each tornado or hurricane, the National Oceanic and Atmospheric Administration (NOAA) collects a tremendous amount of data. We are able to learn new things about these natural disasters with every event; this information aids us in our efforts to improve prediction. Fortunately, tsunamis are relatively infrequent. That means we record fewer events and have much we can learn when it comes to tsunami generation and propagation. Understanding how these natural disasters develop is key to determining how we can predict these destructive events.

The Administration's plan calls for NOAA to have a network of 39 advanced-technology Deep-Ocean Assessment and Reporting of Tsunamis (DART) buoys for a fully operational enhanced tsunami warning system by mid-2007. With a complete network of DART stations, we will have the opportunity to detect more tsunami events, and we have the opportunity to learn from each one. In November 2003, a large earthquake occurred in the Aleutian Islands and generated a tsunami. The DART stations recorded this event, confirming only a small tsunami. During post analysis of the event, DART data were used for a model simulation and the output from the simulation accurately predicted the 2 cm tsunami recorded at Hilo, Hawaii. With each tsunami-event recorded by the DART stations, we have the opportunity to fine-tune our models used to predict tsunami impacts. The DART data combined with forecast models promise to significantly reduce false alarm rates as well as provide a better measure of the severity of destructive tsunamis for Hawaii and all other parts of the Pacific. The accurate forecasting of a non-destructive tsunami in November 2003 saved Hawaii an estimated $68M in projected evacuation costs. With the additional DART stations, we expect to substantially reduce false alarm rate for distant tsunamis from 75 percent to less than 25 percent over the next 4 years. Little change is expected in reducing false alarms for local tsunamis (those generated from near-shore causes). A reduction in the rate of false alarms, and the associated cost-savings for our states and territories, is an appropriate measure of our progress in tsunami detection.

Question 2a. What other metrics will be important to pay attention to? For example, only 30 percent of our communities at risk have inundation maps—shouldn't this percentage improve? How much will this metric improve with the funds proposed under the President's plan?

Answer. NOAA agrees that the percentage of at-risk communities with complete inundation maps is an important metric, and we are working to increase the number of areas covered by inundation maps. Another important metric is the number of at-risk communities that are "TsunamiReady." NOAA's TsunamiReady program promotes tsunami hazard preparedness as an active collaboration among federal, state and local emergency management agencies, the public, and NOAA's National Weather Service tsunami warning system. The Administration's plan provides funding to allow NOAA to increase the number of mapped and TsunamiReady communities. Of the $24M scheduled for NOAA use, approximately $4.75M will be spent on inundation mapping and modeling, as well as education and outreach (e.g., community preparedness activities, including TsunamiReady). Of this $4.75M, approximately $2.25M will be spent on inundation mapping and modeling and $2.5M will go towards public education activities. Following the current plan, inundation mapping for the major population centers will be complete in 2015.

Question 2b. Since we have experienced a 50 percent decline in buoy service in the past 2 years, wouldn't this be another metric to focus on? What will be your goal?

Answer. It is not accurate to say that we have experienced a 50 percent decline in buoy service in the past 2 years. We believe you are referring to technical malfunctions of 3 of the 6 DART buoys in the weeks preceding the hearing. While it is true that at the time of the hearing, 2 of the 6 DART stations were offline, this does not indicate a 50 percent decline in performance over the last 2 years. The reliability of the DART stations, since October 2003, the time when they were transitioned from being operated by NOAA Research to NOAA's National Weather Service, has been 72 percent. This percentage represents the combined number of hours the stations have been operational, and is an appropriate metric to use in evaluating the reliability of the DART system. Further, this percentage indicates that the DART station array is a highly effective system overall.

Our goal is to have a fully capable network of 29 DART stations in the Pacific, with 3 additional in-water backups in the Gulf of Alaska, where sea conditions are particularly harsh. While it is not possible to guarantee that these prototype stations will be operational 100 percent of the time given the demanding environmental conditions in which these stations operate, NOAA is focused making the DART I network more robust and deploying a DART II network with reliability built into the design. NOAA plans for the network to meet operational requirements, even with occasional DART station outages. NOAA will develop capabilities to address network coverage and redundancy to ensure, as best we can, that single DART station failures will not impact the integrity of the entire network. Planned redundancy and hardening of the infrastructure, combined with the addition of a two-way communication capability, will mitigate risk from system-wide failures.

Funding for Tsunami Mitigation and Response

Question 3. The Administration recently released its plan to expand and modernize its tsunami detection and warning system. This plan includes the expansion of the system into areas such as the Atlantic Ocean, Caribbean, and Gulf of Mexico. I applaud the Administration's timely response, however, I am concerned that while the plan addresses the issue of tsunami detection, it does not completely address the issue of response to tsunami, as well as community preparation.

Which agency will be taking the lead for mitigation, mapping, and response?

Answer. NOAA, FEMA and USGS, through the National Tsunami Hazard Mitigation Program, coordinate inundation mapping efforts with state and local emergency management officials. FEMA is the lead agency for mitigation and response, with NOAA assisting any way possible. NOAA's role is to assist in identifying the tsunami hazard (required inundation mapping), providing tsunami warning guidance (including site-specific tsunami forecast models) and providing tsunami mitigation program support though community-based preparedness programs and education outreach—including the TsunamiReady Program.

Question 3a. Does the funding proposed by the Administration include funding for tsunami response? How much?

Answer. FEMA is the lead federal agency in the response area and is best suited to answer this question.

Question 3b. Will these amounts be adequate given the plans for expanded areas of coverage for the tsunami program?

Answer. NOAA funding for mitigation includes $2.5 million for education and outreach and $2.25M for inundation mapping. This is a significant increase from prior year funding levels managed through the National Tsunami Hazard Mitigation Program. FEMA is the primary federal agency in the response area and is best suited to answer that portion of this question.

U.S. PLAN FOR AN IMPROVED TSUNAMI DETECTION AND WARNING SYSTEM
FACT SHEET

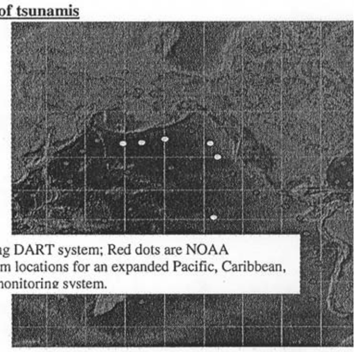
Key Components to an ideal Tsunami Warning/Response System:
1. Risk Assessment
2. Detection
3. Warning
4. Response Plan
5. Ready Public
6. Situational Awareness
7. Lessons Learned

President Bush is committed to improving protection for the United States

- Additional deep-sea tsunami detection buoys and other sensors to provide more accurate/earlier detection along more of the US coast; monitor the Pacific, Atlantic, Caribbean and Gulf of Mexico.
- Improve availability of real-time seismic sensor data and upgrade infrastructure for better earthquake detection and warning including instrumentation in the Caribbean.
- Expanded research on seismic, tsunami processes to improve forecasting.
- Improve response capacity with enhanced emergency warning systems, community response plans and public education.

Making the U.S. safe from the threat of tsunamis

- The Administration will commit $37.5 million over the next two years to expand U.S. tsunami detection and monitoring capabilities
- This investment will enable the National Oceanic and Atmospheric Administration (NOAA) to begin deployment of 32 new advanced technology (Deep-ocean Assessment and Reporting of Tsunami (DART) buoys for a fully operational tsunami warning system by mid 2007.
- The United States Geologic Survey (USGS) will invest in improved seismic monitoring and information delivery from the Global Seismic Network.
- This will provide the United States with nearly 100% detection capability for a U.S. coastal tsunami allowing response within seconds.
- Expanded monitoring capabilities throughout the entire Pacific and Caribbean basins and significant portions of the mid-Atlantic will provide tsunami warning capability for regions bordering half of the world's oceans.



Yellow dots are existing DART system; Red dots are NOAA estimated DART system locations for an expanded Pacific, Caribbean, and Atlantic tsunami monitoring system.

- Improved coastal topography and ocean floor bathymetry will lead to real-time reporting of tide gauges across the globe and enhance communications systems, regional warnings and information dissemination.

How will the United States improve protection around the world?

- The United States is providing leadership in the Global Earth Observation System of Systems (GEOSS), the international effort to develop a comprehensive, sustained and integrated Earth observation system.
  - 54 participating nations, including India, Indonesia and Thailand
- The GEOSS implementation plan for this new system is scheduled to be adopted at the Third Earth Observation Summit that will be held in Brussels this February.
- In parallel, the United States has developed a *Strategic Plan for the U.S. Integrated Earth Observation System*, which, like the GEOSS plan, focuses around nine societal benefit areas, including "Reduce loss of life and property from disasters" and "Protect and monitor our ocean resources."
- The United States will work with its GEOSS partners and other international bodies to develop a global tsunami warning system.
- A global system of comprehensive, sustained and integrated Earth observations will enable better tsunami monitoring in the Indian Ocean and other areas of the world presently without protection.

RESPONSE TO LETTER DATED FEBRUARY 7, 2005 FROM CHAIRMAN STEVENS AND CO-CHAIRMAN INOUYE TO DR. ARDEN L. BEMENT, JR.

In response to a letter, dated February 7, 2005 from Chairman Ted Stevens and Co-Chairman Daniel K. Inouye, asking to:

Please explain what information or resources your agency requires before it can issue a public warning notification of a natural hazard or disaster. In addition, we would like to know which entities or organizations receive warnings from, or through, your agency, such as the appropriate federal and local disaster response entities, first responders/911, and local and national media outlets. To the extent possible, your report should also demonstrate which communications technologies are currently used to deliver these public warnings, such as automatic alert televisions and radios, telephones, wireless and satellite technology, including cellular telephones, pagers, personal digital assistants (PDAs), and the internet. If such communications technologies are not being used, we would like to know what the impediments are, and the status of any discussions to expand the warning system's capability to do so.

Your report should also specify a process by which your agency, either on its own, or in conjunction with other relevant agencies, can maximize effective dissemination of public warning notifications. Lastly, we would be interested to know how your agency interacts with the Department of Homeland Security (including the Federal Emergency Management Agency), the Federal Communications Commission, the Department of Commerce, or other relevant agencies with respect to warning systems.

POTENTIAL ENHANCEMENTS TO THE GLOBAL SEISMOGRAPHIC NETWORK (GSN)

Background

Over the past 20 years, the National Science Foundation (NSF), through funding to the Incorporated Research Institutions for Seismology (IRIS) Consortium, has established the 137-station Global Seismographic Network (GSN). This network serves as the primary international source of data for earthquake location and tsunami warning. Although the establishment of the GSN is an NSF-supported function and the acquisition of GSN equipment is solely supported through the NSF, the GSN-station operation is shared with the U.S. Geological Survey (USGS), which supports the maintenance of approximately 2/3 of the network. The GSN infrastructure includes not only the *in situ* observing stations, but also global telemetry, and data collection and distribution through the IRIS Data Management System. The Data Management System, in addition to being the primary world repository for seismic data, analysis tools, and visualization software, provides an essential quality-control function for the GSN hardware and communication links that are so vital to real-time hazard warning functions related to earthquakes.

Real-time GSN data formed the critical core of the early warning of the December 26, 2004 Sumatran Earthquake. Within 8 minutes of the initial rupture of the M=9.0 earthquake, GSN data flashed electronically via satellite and the Internet to the GSN Data Collection Center and then to the Pacific Tsunami Warning Center (PTWC/NOAA) and the National Earthquake Information Center (NEIC/USGS). GSN seismometers recorded with full-fidelity the ultra-long period energy radiated by the earthquake's 1000 km long rupture. The unique long-period response of the GSN is the key factor in providing an accurate measure of the size, character, and tsunami-potential of such mega-events.

Potential Enhancements

Although the GSN system is working very well, there is much that can be improved. Some of the enhancements that might be possible with the appropriate resources, over the next five years are:

(1) Telemetry and Information Technology—Expansion and Reliability

The rapid collection of GSN data and distribution of earthquake information is at the heart of an earthquake/tsunami warning system. Over 80 percent of the GSN now has real-time telemetry links. However, the means of telemetry are very heterogeneous. These include local Internet and telemetry links supported by local host organizations; Internet infrastructure supported by IRIS and USGS; satellite telemetry links supported by IRIS, USGS, National Weather Service, and NSF; and global satellite infrastructure shared by the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO). To complete GSN telemetry to 100 percent coverage and to enhance low-bandwidth links, 40 telemetry links need to be established and maintained.

(2) Expanding Coverage—International and National Cooperation

Under NSF supervision, the GSN and the IRIS Data Management System are prepared to work with the international community (in particular Australia, Japan, France, India, and China) and U.S. agencies, such as NOAA and USGS, to enhance the GSN capabilities. This includes the installation of much-needed stations on the ocean floor to augment and complement the land-based GSN. As new seismic stations are proposed and installed in the Indian Ocean region and elsewhere, arrangements need to be made to ensure that these stations will contribute to the GSN system. IRIS successfully worked with international organizations and governments to establish similar networks in Kyrghizstan and Africa. The GSN's success is predicated on its close relationship with the many local organizations that host the seismic stations. The international Federation of Digital Seismograph Networks (FDSN) and the Global Earth Observing System of Systems (GEOSS) provide appropriate pathways for international collaboration. Needs include data and information exchange, shared telemetry, joint stations, coordination of infrastructure and the development of local capacity for seismological observations and research. Portable seismic systems provided through IRIS offer a basis for collaborative research projects between U.S. Earth scientists and specialists in South Asia on the structure, dynamics, and seismic hazard of the region.

(3) Long-term Viability of the GSN—Operation and Maintenance

The Sumatran earthquake once again points to the importance of diligence in maintaining a highly reliable and fully operational system at all times. Relationships must be nurtured to improve local help for GSN maintenance and interagency support by the NSF and the USGS must be provided on an ongoing basis.

With the resources at its disposal, the GSN currently operates at about 90 percent data availability. About 10 percent of the network (~14 stations) is down at any given time, awaiting repair. Increasing station uptime requires more field engineer FTE's and travel support. The GSN equipment is currently spared and refreshed at a yearly rate equal to 5 percent of the total installed equipment base. Increasing station uptime will deplete spares more rapidly, requiring an increased rate of equipment sparing.

(4) Sensor Development—Next Generation Ultra-long Period Seismometers

The Streckeisen STS–1, the premier seismometer used by the GSN for recording ultra-long period Earth motions, is no longer manufactured or available. The information provided by this unique sensor is the single key component in determining the size, and tsunami potential, of great earthquakes. As these sensors age and fail, the prospect of a decline in network quality looms very real. That there is no comparable replacement for the STS–1 is an internationally recognized problem. Given the small market (<1000) for such exquisite seismic sensors, there is no financial motivation for the private sector to undertake such a development. This a potential area for collaboration among groups at NSF involved in sensor design. The United States has an opportunity to take the lead in developing the next generation ultra-long period sensor, which serves both tsunami warning and scientific purposes.

The NSF Division of Earth Sciences has an ongoing Memorandum of Understanding (MOU) with the USGS regarding joint operation and maintenance of the Global Seismographic Network, joint support of the Southern California Earthquake Center (SCEC), and participation of the USGS in the EarthScope project. The NSF also participates in the National Earthquake Hazard Reduction Program (NEHRP) with the USGS, FEMA, and the National Institute of Standards and Technology (NIST). NEHRP fosters cooperative activities with respect to the nation's vulnerability to earthquake hazards, and fosters knowledge transfer efforts related to earthquake hazards. It should be noted that in addition to earthquake/tsunami research, the NSF also maintains a broad research portfolio relevant to potential hazards from volcanic eruptions, landslides, and hydrological hazards such as floods, droughts, and ground-water contamination. We look forward to continuing these interagency activities. It is certainly in the public interest that efforts in ameliorating the effects of natural hazards are improved by our activities in fundamental research.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO DR. ARDEN L. BEMENT, JR.

Question 1. Please describe how you expect the Ocean Observatories Initiative to cooperate with other seismic research projects within the Foundation and other agencies.

Answer. The National Science Foundation (NSF) supports basic subsea research to understand fundamental earth processes, including those that generate earthquakes with tsunami potential. The Ocean Observatory Initiative (OOI) will add to understanding and monitoring of large submarine fault zones. Sites constructed through the OOI will contribute to the seismometer arrays of the Ocean Seismic Network (OSN), as well as provide other research tools such as undersea pressure sensors. Both these efforts will enable the research and technological advancements that will enhance the warning system for earthquakes and tsunamis.

NSF is committed to cooperation and coordination between all environmental observing networks, including those that are part of the tsunami warning system. Program managers from each of the NSF observing systems and geophysical facilities (e.g., EarthScope, OOI, Incorporated Research Institutions for Seismology—IRIS, Network for Earthquake Engineering Simulation Research (NEES), and UNAVCO) promote interactions and synergies between the observing systems and work together to respond to common needs for measurement tools, data management and cyberinfrastructure, as well as to develop novel approaches to interactions across disciplines. For example, studies by the Integrated Ocean Drilling Program (IODP) drill ship *Joides Resolution* include instrumented subsea boreholes linked to seafloor observatory networks. These are similar to those proposed for the OOI and provide excellent prototype information for the future OOI system.

Further coordination and cooperation between the OOI and other seismic research projects within the Foundation and other agencies also occurs through shared facility support as well as use of common data management systems such as that funded by NSF through the IRIS consortium. Program officers for the NSF, USGS, NASA, and NOAA work together to coordinate scientific projects and share support for geophysical facilities. This ensures the full capacity and cost effective use of these facilities.

Question 2. Could you please detail how you anticipate OOI, and particularly the NEPTUNE project, could contribute to the science that will lead to a better understanding of tsunami?

Answer. The Regional Cabled Observatory (NEPTUNE) that is part of NSF's Ocean Observatories Initiative will be constructed off the Washington and Oregon coasts. This ocean observing network will be equipped with an array of seismic and acoustic sensors that will provide data that will complement the Deep-ocean Assessment and Reporting of Tsunamis (DART) buoy array for effective warning of tsunami generation and will also enable researchers to investigate processes leading to creation of large tsunamis. Information collected by NEPTUNE will flow instantly to shore where it will be relayed via the Internet to the Tsunami Warning Center, researchers, educational institutions, science centers and the public.

The oceanic region off the coasts of Washington and Oregon is an ideal location to create an undersea laboratory to investigate the processes leading to tsunami generation. This area is home to a variety of active environments each of which will be instrumented with seismic and pressure sensors. This will enable researchers to better understand how differences in tectonic regimes can lead to variations in the amplitude and direction of tsunamis. In addition, this region has areas of gas hydrate generation that will be instrumented and their evolution studied as part of the NEPTUNE array. Therefore, the effects of gas hydrate release on submarine slides and their influence on tsunami generation can be studied in detail. Another significant benefit will be the ability to investigate all of the processes leading to tsunami generation in one location at the scales at which these processes occur so that the outcomes of these combined influences can be quantified.

Question 3. Senator Stevens requested an estimation of what it would take to establish a comprehensive tsunami notification system. I am very interested in your response and ask that you please forward a copy of your answer to Senator Stevens' question.

Answer. We have attached a discussion of "Potential Enhancements to the Global Seismic Network" (GSN). This paper describes NSF's role in the GSN, a system that provides real-time information on location and tsunami potential of great earthquakes, and also suggests some improvements to the system that could be made over the next few years. NSF has supported acquisition of equipment for the GSN, and shares operation of the GSN with the U.S. Geological Survey (USGS). Immediate notification of significant earthquake events is made to the National Earthquake Information Center (NEIC), operated by the USGS.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK PRYOR TO DR. ARDEN L. BEMENT, JR.

Question 1. Without the use of/installation of voice sirens as part of a preparedness plan, how do you warn people on the ground? Are there other effective warning systems available for this purpose? What criteria are used to determine which warning system is reliable in case of tsunami?

Question 1a. Should a preparedness plan include a warning mechanism for small fishing boats trawling near the coastline? National Oceanic and Atmospheric Administration (NOAA) weather radios can be used to inform these fishing boats at minimal cost (approximately $20).

Answer. We have attached a discussion of "Potential Enhancements to the Global Seismic Network"(GSN). This paper describes NSF's role in the GSN, a system that provides real-time information on location and tsunami potential of great earthquakes. NSF has supported acquisition of equipment for the GSN, and shares operation of the GSN with the U.S. Geological Survey (USGS). Immediate notification of significant earthquake events is made to the National Earthquake Information Center (NEIC), operated by the USGS. Although NSF participates in the interagency National Earthquake Hazard Reduction Program (NEHRP), agencies other than NSF have primary responsibility for issuing public disaster warnings and NSF defers to them to provide detailed responses concerning warning mechanisms.

RESPONSE TO LETTER DATED FEBRUARY 7, 2005 FROM CHAIRMAN STEVENS AND CO-CHAIRMAN INOUYE TO U.S. GEOLOGICAL SURVEY

In response to a letter, dated February 7, 2005 from Chairman Ted Stevens and Co-Chairman Daniel K. Inouye:

Explain what information or resources your agency requires before it can issue a public warning notification of a natural hazard or disaster.

The U.S. Geological Survey (USGS) has responsibility under the Stafford Act to issue forecasts and warnings for earthquakes, volcanoes, and landslides. For tsunamis, wildfire, flood and hurricane hazards, USGS provides critical support to the National Oceanic and Atmospheric Administration (NOAA) and other agencies tasked with warning responsibility. In order to carry out these mandates, USGS requires a monitoring infrastructure that includes local, national and global networks; reliable and redundant telecommunications; modem computing centers for data analysis and dissemination; and a skilled staff of analysts, technicians, scientists, and network support people. To ensure that publicly funded monitoring networks and education programs are targeted to regions at highest risk, USGS performs assessments of the distribution and extent of each natural hazard listed above at various scales—from national to, in high-hazard urban areas, local. To improve the accuracy and timeliness of warnings and to minimize false alarms, we perform (and fund university and State partners to perform) targeted research to understand the underlying processes and their predictability. To maximize the extent to which hazard information is received and acted upon by appropriate individuals when disasters strike, we actively pursue and foster links with local governments, emergency management agencies and the media. The USGS targets these capabilities to areas with the highest hazard and the greatest risk.

Volcanoes

Impending volcanic eruptions can be forecast and warnings issued in time for communities to take preparatory actions. Eruption forecasts and warnings depend on telemetered, real-time data streams from diverse suites of monitoring instruments on volcanoes, including reliable data streams transmitted by other agencies (e.g., GOES satellite data from NOAA, seismic data from key university cooperators). Observatory-based scientists are necessary to interpret monitoring data, as eruptions are too complex for the fully automatic generation of alerts directly from machine signals. Automatic warnings of large volcanic debris flows (lahars) based on signals from acoustic-flow-monitor arrays may be the exception. These capabilities are currently deployed at the highest-priority volcanoes. The USGS has closely monitored the eruption of Mount St. Helens since September 2004, correctly forecasting the style of eruption, and remaining in daily communication with the Washington State Emergency Management Division and the U.S. Forest Service (USFS) who rely on USGS information to restrict public access to potentially threatened areas surrounding the volcano.

Landslides

Landslides, whether induced by rainfall or earthquakes, involve complicated physical processes that are not sufficiently well understood to permit reliable predictions, but the capability to provide advanced warning of increased landslide danger now exists. Doing so requires accurate landslide thresholds to monitor the hazard and travel distances to gauge possible impact. The first step is a detailed study of susceptible geographic regions having the requisite geology and topography. Probable landslide paths and travel distances are analyzed to identify possible landslide hazards, for example, by specifying areas where landslides have a high probability of impacting roads and buildings. Within different regions, the timing of landslides needs to be observed during storms and correlated with the rainfall intensity and duration in order to develop the criteria of rainfall thresholds for triggering landslides. Advanced weather forecasts can be combined with the threshold models to evaluate whether landslides are likely to occur within regions susceptible to landsliding. Real-time monitoring of rainfall and site measurements of rising groundwater and initial slope movements near landslide sources can provide critical information for issuing immediate public warning of landslide hazards. Numerous rainstorms in southern California this winter have resulted in serious landslides and debris flows. USGS scientists have issued advisories of potential landslides to the National Weather Service, California Office of Emergency Services (OES), other state and federal agencies, and the public—as recently as February 15, 2005. The San Bernardino County Sun and other local newspapers have used these advisories in crafting news articles alerting their readers to the possibility of landslide occurrence and instructing their readers on ways to protect themselves.

The USGS and NOAA recently signed an MOA to develop a joint watch/warning system for rainfall-generated landslides (debris flows). The MOA calls for NOAA-generated precipitation observations and forecasts to be forwarded to the USGS, where they will be compared with the threshold models. When a watch/warning is warranted, the USGS will forward the pertinent information to NOAA for NOAA to disseminate a joint message using its standard watch/warning communication procedures. The prototype of this system will be fielded by September 2005 in the area of operation of NOAA's Weather Forecasting Offices of Oxnard (CA) and San Diego (CA), and will cover a number of counties, including San Bernardino and Ventura counties.

Earthquakes

For earthquakes, it is not yet possible to predict the time and location of damaging events, but it is possible to predict their impacts and deliver rapid post-event information to emergency responders. First, USGS delivers long-term forecasts of earthquake shaking in the form of hazard maps that underlie most building codes used in the United States. Second, within minutes after a domestic earthquake, USGS and its regional network partners issue an alert with location and magnitude. In five urban areas where dense arrays of strong-motion instruments have been deployed through the Advanced National Seismic System (ANSS), Internet-distributed *ShakeMaps* showing the intensity of ground shaking are available to prioritize response efforts. Following the December 22, 2003, magnitude 6.5 San Simeon earthquake, the California OES was automatically notified within five minutes, and the first ShakeMap was pushed to OES and other users in less than nine minutes. Third, in the time scale of hours to days following large earthquakes, USGS provides short-term predictions for the likelihood of aftershocks in California.

Which entities or organizations receive warnings from, or through, your agency (such as federal and local disaster response entities, first responders/911, and local and national media outlets).

Earthquakes

The USGS provides hazard alerts to a broad suite of federal, state and local government agencies, and private-sector entities, including the media. The scope of the USGS notification process depends on the severity, extent, location, and possible impact of the hazard at hand. For damaging domestic earthquakes, USGS notifies by telephone, fax, e-mail and/or pager:

White House, The Situation Room
Federal Emergency Management Agency (FEMA)
Department of the Interior (DOI) Watch office
Dam and power plant operators (including U.S. Army Corps of Engineers (USACE, Bureau of Reclamation, Nuclear Regulatory Commission and some public and private utilities)
Pipeline operators
Railroads
Insurance companies
Department of Defense (DoD) offices with domestic civil defense responsibilities
State and local offices of emergency services
State geological surveys
Veterans Administration
Department of Agriculture
Department of Transportation including the Federal Aviation Administration (FAA)
Department of Homeland Security (DHS) Transportation Security Administration
NOAA
The Weather Channel
National Science Foundation (NSF)
National Institute of Standards and Technology

For both domestic and international damaging earthquakes, USGS also e-mails earthquake notifications to over 40,000 subscribers including many print and broadcast media companies. For public and news media, notices are automatically posted to the Web. In the first few days after the Sumatra disaster, USGS earthquake Web sites received over 120 million hits. The ANSS regional networks also have e-mail/pager notification lists that reach further into affected States and communities. Depending on the location and severity of the earthquake, targeted distribution also proceeds to key users that can include the Department of Health and Human Services, U.S. Environmental Protection Agency, NOAA Pacific and Alaska/West Coast

Tsunami Warning Centers, state and local emergency managers, and 200 foreign agencies.

For damaging international earthquakes, USGS notifies by telephone, fax, e-mail and/or pager:

White House, The Situation Room
Department of State
U.S. Embassies and consulates in affected countries
U.S. Agency for International Development
United Nations Office of Coordinator of Humanitarian Affairs
Department of Defense
Federal Aviation Administration
Federal Emergency Management Agency
Earthquake Engineering Research Institute
Humanitarian groups (Red Cross, Red Crescent)
International Atomic Energy Commission
Private sector and government search-and-rescue groups

Volcanoes

For volcanic alerts, each of the five U.S. volcano observatories has developed communication protocols tailored to the appropriate hazard and region. For notifications of explosive eruptions that can send volcanic particles ("ash") into the atmosphere, USGS eruption alerts are sent to

FAA air traffic control centers
NOAA meteorological watch offices and Volcanic Ash Advisory Centers Air Force Weather Agency
U.S. Coast Guard
Military bases
Airports

For volcanic ground hazards (such as lava flows and debris flows), USGS relies on the interagency incident command system (ICS), operated either by state emergency or federal land managers (like the one established by the U.S. Forest Service in 2004 for the eruption of Mt. St. Helens). In the absence of an operating ICS, the protocol for ground hazards is to alert State emergency and land managers (e.g., National Park Service, U.S. Forest Service, and Washington Emergency Management Department), who in turn alert county emergency managers and other federal agencies. When an eruption is expected or underway, USGS also makes ash fall forecast graphics and sends them to appropriate FEMA regional offices and may have a FEMA representative on-site at an observatory. To communicate with the local and national media—before, during, and after an eruption or episode of unrest—each observatory commits experienced staff to talk directly with media representatives.

Landslides

Landslide advisories and warnings are sent to the appropriate State Offices of Emergency Management and the National Weather Service. Notice is also provided (through the DOI Watch Office) to the White House, DOI land management agencies, DHS (including FEMA), and Military Commands. To communicate with local and national media prior to, during, and after landslide events, Landslide Hazard Program scientists are available to respond to media inquiries. The Landslide Hazard Program also posts detailed information and maps on its Web site, which is available to the media, public officials, and the public.

Demonstrate which communications technologies are currently used to deliver these public warnings, such as automatic alert TVs and radios, telephones, digital assistants (PDAs), and the Internet. If such communications technologies are not being used, we would like to know what the impediments are, and the status of any discussions to expand the warning system's capability to do so.

The USGS uses a broad range of technologies to distribute alerts and notifications, including the public Internet, private/government Internet, text messaging, pager, phone, fax, NOAA Weather Wire, and briefings to local and national media. Currently, over 40,000 e-mails will be sent following a large earthquake. Users have the choice of a full message by e-mail or a shorter message suitable for a cell phone or PDA. Several improved distribution programs are in development under the ANSS, including a replacement for the current e-mail notification system that will allow users to customize which earthquake sizes and locations will generate alerts. In the Pacific Northwest, the National Tsunami Hazard Mitigation Program—a partnership that includes NOAA, FEMA, NSF, USGS and five Pacific States—is deploying all-hazards warning system technology to coastal communities in that region, providing tsunami, earthquake and mudflow warnings. The pole-mounted All Hazard Alert Broadcast system has a blue warning light to cut through fog, a siren warning, and a voice warning that is keyed by NOAA Weather Radio or local emergency managers. Washington Emergency Management is developing this warning system as part of the National Tsunami Hazard Mitigation Program. This Program is a model for how federal agencies and their State partners can work together to reduce risk.

The USGS relies on FAA and NOAA communications systems to relay notifications of volcanic activity to enroute aircraft and airline dispatchers. For other groups, USGS primarily uses brief phone calls, followed by fax and e-mail, to provide more detailed information. During both the premonitory and eruptive phases of a volcanic crisis, PDAs and text messaging are used to notify off-duty scientists automatically of changes in monitoring parameters.

Specify a process by which your agency, either on its own, or in conjunction with other relevant agencies, can maximize effective dissemination of public warning notifications.

The USGS hazard/disaster notification process relies on a "notification tree" or infrastructure, in which federal and state agencies alerted by USGS take responsibility for disseminating USGS information to emergency responders and other critical users. This system contributes to an all-hazards approach to public warning. This process is supplemented regionally and locally by direct (and in many cases automated) alerting to critical users (e.g., earthquake *ShakeMap* delivery to utilities, state transportation departments, homeland security command centers, and regional pager/text-messaging to emergency managers). We believe this is an effective strategy for USGS, and it is appropriate to our mission. The USGS is continually honing its disaster response strategy.

As part of the President's plan for an improved tsunami warning system, USGS proposes to deploy software developed by the California Integrated Seismic Network (a USGS, university and State partnership) to speed USGS-generated earthquake information directly to local emergency managers with a dual use capability to also provide NOAA tsunami warnings.

Tsunamis are not solely produced by earthquakes. Approximately five percent of tsunamis in the past 250 years were produced by volcanoes, and some of these are among the most destructive tsunami events known. Volcano induced tsunamis are generated in various ways; the largest, most destructive tsunamis have been caused by large explosive eruptions and flank collapse events on island and coastal volcanoes. There is a demonstrated volcanic tsunami hazard in Alaska and Hawaii and a likely one in the Commonwealth of the Northern Mariana Islands. Improved volcano monitoring systems and response planning at volcanoes that have a potential tsunami hazard would help provide better mitigation concerning an important natural hazard.

The USGS will continue its broad-based public awareness activities, which are integral to effective use of warnings and other hazards information by the public and civil defense authorities. For example, USGS is working with the FAA, NOAA and others, to formulate a National Interagency Operational Plan for Volcanic Ash Episodes, and we continue to develop other inter-agency response plans for ground hazards. Such a plan is necessary for USGS to meet the aviation sector's stated need for notification of explosive ash-producing eruptions by a volcano observatory to the appropriate FAA air-traffic control center within 5 minutes of the event. The USGS offices in California and Washington provide training programs for local emergency managers and media on how to use *ShakeMap* and other earthquake notification and assessment products generated by the regional and national networks. The USGS is working with the American Planning Association to develop a best-practices manual on landslides that will become available to thousands of planners this spring.

The USGS is working with the National Weather Service to develop a protocol for issuing landslide warnings over NOAA Weather Radio All Hazards network. State and county emergency managers—the agencies most responsible for issuing instructions to citizens—rely on this communication network for timely warnings. Part of the protocol will allow real-time transmittal of current weather conditions to USGS landslide experts to better pinpoint the areas of greatest danger.

For improved delivery of flood warnings, USGS currently partners with other federal agencies, including the National Weather Service, Army Corps of Engineers, and Bureau of Reclamation. This includes efforts to raise public awareness about appropriate responses to flood watches and warnings. In addition, there are a number of proof-of-concept experiments underway to improve the timeliness and quality of USGS information used by public and private entities to reduce flood damages and loss of life.

To aid wildland fire suppression, USGS manages and hosts the Geospatial Multi-Agency Coordination Group or GeoMAC, an Internet-based tool that permits fire managers to access online maps of current fire locations and perimeters in the conterminous 48 States and Alaska using a standard Web browser. GeoMAC is a multi-agency group with technical and subject matter experts from the Department of the Interior's fire management agencies—the Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and the Bureau of Indian Affairs, and the United States Forest Service of the Department of Agriculture, as well as numerous other agencies and firms.

The USGS is working with the National Interagency Fire Center and the University of Alaska Fairbanks, specifically the Geographic Information Network of Alaska (GINA) to develop a process for analyzing satellite information to obtain daily updates of vegetation condition for Alaska to improve the sensitivity to fire weather conditions. A cooperative project called LANDFIRE is conducted by USGS and the Forest Service to provide regional and local scale geospatial data of vegetation, fuel, and fire regime. The project will enhance prediction of fire danger and understanding of fire behavior for incident commanders and a broad range of other users.

Specify how your agency interacts with the Department of Homeland Security (including FEMA), the Federal Communications Commission, the Department of Commerce, or other relevant agencies with respect to warning systems.

The USGS interacts with DHS, Department of Commerce, DoD and many other Federal agencies on matters related to hazard mitigation, preparedness and disaster alerting. Key among these are FEMA, National Weather Service and, for volcanic hazards, FAA. Notifications are either direct to the responding agency or coordinated through the Department of the Interior Watch Office, which operates around the clock to compile and disseminate information relevant to law enforcement, homeland security, and natural disasters impacting the Department's responsibilities across the United States. For earthquakes, USGS National Earthquake Information Center has a direct phone line to the DHS/FEMA operations center in Washington. The USGS and FEMA are partners in the National Earthquake Hazards Reduction Program and have developed and tested a coordinated earthquake response plan. For tsunami coordination, USGS exchanges telephone, e-mail, data, and Web products with the NOAA Tsunami Warning Centers (and with tsunami warning centers in Japan, Chile and Russia). The USGS also provides earthquake alerting through the NOAA Weather Wire, as previously noted.

For volcanic hazards, USGS works with FAA, NOAA, and DoD to disseminate notifications of explosive eruptions and associated ash clouds to the aviation sector (both military and commercial). For ground volcanic hazards, USGS relies on the interagency Incident Command System (ICS), operated either by state emergency or federal land managers (like the one established by USFS in 2004 for the eruption of Mt. St. Helens). In the absence of an operating ICS, the protocol for ground hazards is to alert state emergency and land managers (e.g., NPS, USFS), who in turn alert county emergency managers and other federal agencies. The USGS sends ash fall forecast graphics to appropriate FEMA regional offices.

To improve the effectiveness of flood warnings, USGS collaborates with many federal, state and local government agencies and the private sector. The FEMA, and state and local officials monitor flood watches and warnings and use USGS Internet sites to ascertain flood conditions for those rivers not serviced by the National Weather Service river forecast system.

Explain how your agency could improve public notification of impending natural hazards and disasters.

The USGS could improve public hazard notification and warning of natural hazards in three basic areas: (1) Modernization and expansion of monitoring networks; (2) increased robustness and redundancy of communication links; and, (3) accelerated development and deployment of capabilities to take full advantage of new data streams, research findings and communication technologies to improve the accuracy and timeliness of information we provide for emergency management.

(1) Modernization and expansion of monitoring networks

The President's proposal for improving tsunami warning systems would replace legacy hardware and software systems at the USGS National Earthquake Information Center (NEIC) and establish 24×7 operations, actions that will improve response time, benefiting both earthquake notification and tsunami warning. The proposal also includes support to improve station up-time in the Global Seismographic

Network (GSN)—a partnership of USGS, the National Science Foundation, the Incorporated Research Institutions for Seismology, and the University of California—and to install additional stations in the Caribbean region. The NEIC modernization is a key component of the Advanced National Seismic System (ANSS). As described in USGS Circular 1188, the ANSS plan includes both notification and early warning of earthquakes as fundamental goals.

Impending volcanic eruptions can be forecast and warnings issued in time for communities to take preparatory actions. To improve this warning capability, USGS is developing a plan for a National Volcano Early Warning System (NVEWS). This plan will outline priorities for monitoring instrumentation at our most threatening volcanoes, along with development of a new generation of information technology tools for sharing of data.

Fire danger information and specific information on fire fuels assessment depend on reliable timely satellite observations. It is important that USGS continue to provide remote sensing technology to the fire management agencies. It is, therefore, important to support the ongoing development of the Landsat Data Continuity Mission (LDCM) and the companion National Polar-orbiting Operational Environmental Satellite System (NPOESS), a satellite system used to monitor global environmental conditions, and collect and disseminate data related to: weather, atmosphere, oceans, land and near-space environment.

(2) Robust telemetry and communication links

For rapid-onset events like earthquakes, tsunamis, volcanic eruptions and landslides, only realtime systems can provide data in sufficient time to issue actionable notifications and warnings. The funding in the Emergency Supplemental for improved tsunami detection and warning system for the United States, along with the funding in the 2006 budget for the same purpose, will expand and improve telemetry connections to monitoring stations, so that the seismic stations in the Global Seismographic Network provide real-time data. This will contribute to decreasing the reporting time for global earthquakes from over one hour to about twenty minutes.

USGS data and products often travel across a web of communications links from the monitoring network to the public, typically involving satellite uplinks and downlinks, the Internet, and radio or television bands. Although some USGS systems employ redundant links (e.g., satellite, phone lines, and/or Internet communications), in many cases the communications channels are vulnerable to a single point of failure. Hardening of these telecommunication links is essential to ensure a reliable warning system is available with the appropriate level of redundancy.

As part of the NEIC upgrade, the President's proposal calls for 24×7 network operations and robust Internet serving of seismic data. It would also increase the number of USGS-operated GSN stations that provide real-time data to NEIC and the NOAA tsunami warning centers. Currently, only 80 percent of GSN stations have digital telemetry links that allow for real-time communication. Both for the GSN and the ANSS, a fully telemetered system with redundant communications links will improve response time for damaging earthquakes. For volcano hazards, establishing a local Internet portal in Alaska would strengthen the robustness and reliability of warnings.

(3) New capabilities

The USGS is testing dedicated ground-based Doppler radar at volcanoes in order to improve its ability to provide notification of explosive ash-producing eruption to the appropriate FAA air traffic control center within 5 minutes of the event, a need identified by the aviation sector. By adding such radar units to the suite of monitoring instruments in place at restless or erupting volcanoes, rapid detection and confirmation of eruptive ash plumes at night and in bad weather is greatly improved.

Increased use of new remote-sensing technologies such as airborne LiDAR and satellite-based InSAR would allow USGS to provide more accurate information for a number of hazards. In the case of landslides, LiDAR delivers highly detailed topography, which is critical for landslide susceptibility characterization and identification of past landslide scars. InSAR allows monitoring of large slow-moving landslides. These technologies have proven valuable for early detection of volcano re-activation as well as providing important insights on earthquake fault rupture characteristics.

Forecasting coastal hazards associated with hurricanes and other major storms is critically-dependent on the availability of accurate and up-to-date information on nearshore and coastal elevations. In cooperation with NASA, NOAA, and the USACE, USGS is developing a comprehensive national assessment of coastal hazards based on high-resolution LiDAR surveys of coastal and nearshore elevation. Data developed within this program have supported the development of models relating coastal response to storm surge and wave run-up and nearshore, beach, and dune elevations. Forecasts of coastal vulnerability to impending storm landfall are developed prior to landfall and made available to state and federal agencies to guide pre-storm evacuation and post-storm recovery planning. At present, forecasts rely on historic or "model" storm characteristics and USGS and NOAA are working collaboratively to develop vulnerability products that incorporate hurricane forecasts issued by the National Hurricane Center.

The USGS routinely acquires and distributes global satellite image data from its Landsat satellite system; receives and distributes data from several NASA earth-observing satellites; and obtains and redistributes data from U.S. commercial and international satellite systems. In support of tsunami disaster-response, USGS is distributing many types of tsunami-related satellite imagery, maps, and other geospatial data and working with commercial satellite data providers to support the needs of Federal Government agencies. For disaster situations such as these, where hundreds of thousands of digital files have already been distributed, USGS posts digital data on a server and users electronically "pull" what they need over the Internet. The President's budget request for USGS includes funds to ensure the continued operation of Landsat 7, along with NASA and NOAA, and to begin work on an upgraded ground-processing system to acquire, process, archive and distribute data from a new generation of satellite-based land image sensors. This Landsat Data Continuity Mission is expected to begin operations in 2009.

The President's proposal for upgrading NEIC will accelerate development of several rapid-response products, including the Prompt Assessment of Global Earthquakes for Response (PAGER) system, which uses information about an earthquake's source, combined with information regarding population and infrastructure in the affected region to estimate potential damage and loss of life in a major earthquake. The PAGER system is ideal for both domestic and international areas where a dense seismic network is not available, but where a rapid assessment is critical for estimating impact.

In several metropolitan areas, the ANSS *ShakeMap* System supports direct links to critical users. In California for example, *ShakeMap* is automatically sent by Internet to:

California Department of Transportation (DOT)
California Office of Emergency Services (OES)
Utilities (Southern California Edison, Pacific Gas & Electric, Southern California Gas, the Los Angeles Department of Water and Power, East Bay Municipal Utility District)
Bay Area Rapid Transit system
National media outlets
Communications companies
California Earthquake Authority
Los Angeles County Office of Emergency Services
Local media outlets
FEMA regional offices

Outside of California, *ShakeMap* is in various stages of development and integration. *ShakeMap* requires dense instrumentation. *ShakeMap* has been deployed in Salt Lake City, Utah, Anchorage, Alaska, and Seattle, Washington. In those cities, *ShakeMap* has been integrated into their emergency management and response procedures. The *ShakeCast* software, now under development at a pilot level, is designed to help users overcome Internet security barriers and effectively integrate USGS earthquake notifications into emergency procedures.

The USGS is exploring the feasibility of earthquake early warning, in which rapid computer analysis and communication links are used to provide seconds of warning before earthquake waves arrive. Such warning systems are in place in Japan, Mexico and Taiwan. The 2000 re-authorization of the National Earthquake Hazards Reduction Program (NEHRP) called for development of a U.S. early warning system for earthquakes. The USGS currently sponsors modest research and development in this area, including research on earthquake early warning feasibility and efforts to improve the numbers of seismic stations reporting in real time and the speed and reliability of earthquake reporting.

Building on current capabilities for issuing aftershock probabilities, USGS and its partners in the California Integrated Seismic Network will be releasing a public Web site this spring with the probability of strong earthquake shaking in the next 24 hours, based upon a background probability from our understanding of geology, modified by the probability that earthquakes that have just occurred will trigger other activity. In southern California, USGS is investigating what information from structural instrumentation can be used to provide rapid estimates of structural damage following earthquakes or explosions. An experimental instrumentation package is being installed in two buildings in the Los Angeles area and we are developing tools to analyze the structural health of the buildings from those data streams.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. MARIA CANTWELL TO ROGER A. HANSEN

Question. Dr. Hansen, thank you for your work to improve local communication systems for tsunami warnings in Alaska. Because of his strong interest in protecting coastal communities, Senator Stevens requested a written suggestion of what a pilot project for improving and expanding local tsunami warning systems would look like in your estimation. Because of Washington State's high risk for a tsunami disaster in the next 50 years, I'm very interested in your vision of a possible pilot project and request that you please also send me your suggestions.

Answer.

PILOT PROJECT FOR IMPROVING TSUNAMI SAFETY IN ALASKA

The Problem

The December 26, 2004 Sumatra Earthquake and Tsunami illustrated a fundamental failure: The inability to communicate a warning message to remote areas. This failure existed (both nationally and internationally) at all levels of observation, information dissemination, and local education and outreach.

- Lack of warning system contributed to deaths of 10s or 100s of thousands of people.
- All links in chain missing.
  Scientists—National Authorities—Local Authorities—Populace

A Secondary failure (scientific) comes from the inability to obtain a rapid and robust estimate of an earthquake magnitude using current instrumentation.

- The Magnitude of the earthquake was dramatically underestimated in real time.
- But we can do something about it. The combination of strong motion seismic stations and GPS data in the near regional area of a large earthquake can be shown to estimate magnitude rapidly within 0.1–0.2 magnitude units of the final estimate.

Forty years earlier on March 27, 1964 a magnitude 9.2 earthquake ripped through the Prince William Sound in southern Alaska, generating a devastating tsunami. Though the death toll in the 1964 Good Friday quake is miniscule compared to the Indian Ocean disaster, Alaska today is vastly different but still faces difficult challenges with warning its at-risk communities of the occurrence of tsunamis. These challenges come in part from the nature of our remote location, irregular coastlines with complex bathymetry and topography; the vast size of the state that we live in, one of the most seismically active regions of the world; the lack of infrastructure throughout the area for both operations and maintenance of monitoring systems; and consistent and timely communication of warning messages.

The Solution

As presented in my testimony to the Senate Committee on Commerce, Science, and Transportation, I will concentrate on addressing some of the needs for improving tsunami safety in Alaska by focusing this pilot project on combining warning guidance, hazard assessment, and mitigation in the very seismically active Alaska Peninsula and Aleutian Islands region.

The pilot project area has been recognized as the most seismically active area in the United States. The area generates large tsunamis that can affect not only the coastlines of Alaska, but also the rest of the Pacific Ocean. The goals of this project will be accomplished by engaging the partnerships that already exist in Alaska for addressing tsunami safety. This team of professionals from the University of Alaska, and state and federal agencies are already operating as a partnership within the Tsunami Warning and Environmental Observatory for Alaska (TWEAK) program coordinated out of the University of Alaska.

Warning Guidance

The region of Southern Alaska extending into the Aleutian Islands is severely lacking in modern earthquake instrumentation even though there have been more large earthquakes in the past 50 years than anywhere else in the United States.

First and foremost, we must be able to detect events that can trigger tsunamis. The primary method of event detection is accomplished using seismology and seismic networks. Sea level data (both tide gauges and deep ocean buoys) are also monitored to verify the existence of and danger posed by tsunamis. Our primary hazard (like that in Sumatra) comes from a "local" tsunami generated by nearby large earthquakes in or near the coast of Alaska. Therefore, we must rely on the rapid warnings that can be issued from the detection of large earthquakes by the seismic network.

Modern seismic recordings combined with GPS data can provide rapid information on earthquake location, size, and distribution of sea floor deformation that generates tsunamis. However, since much of the seismic network in Alaska has been in operation since the late 1960s, many stations are in need of modernization.

Over the past few years, AEIC was tasked through the National Tsunami Hazard Mitigation Program (NTHMP) to develop 18 of these modern stations for Alaska and to ensure timely delivery of this data to the warning centers. The University program has now increased the number of modern stations AEIC can provide to augment this sparse improvement, and provides enhanced information on local earthquakes through applied research efforts. However, even with the funding of both the NTHMP and the University TWEAK program, nearly 75 percent of the Alaska seismic network still relies on outdated equipment, leaving vast areas of Alaska (and in particular the very seismically active Aleutian Islands) still under-populated with modern seismic stations.

To improve this situation we propose to augment the network with:

- 20 Modern broad band seismic stations with high dynamic range and frequency bandwidth.
- 20 Modern strong motion seismic sensors that will stay on scale for even the large magnitude 9+ earthquakes that can occur in the region.
- 20 continuously reporting GPS sensors that can directly measure permanent deformation and robust earthquake size.
- Modern tide gauges.
- Modern satellite telemetry to record seismic and deformation signals in real time at the Alaska Earthquake Information Center and the Alaska Tsunami Warning Center.
- Near real time processing of the combined signals to rapidly estimate the earthquake size, and distribution of deformation. This gives direct and rapid estimates of tsunami potential.
- A prototype multi-observing deep ocean buoy system consisting of at least an ocean bottom pressure sensor and an ocean bottom seismometer giving lateral constraint to the land based seismic network.

Unique to this effort is the co-location of modern seismic and GPS instrumentation. The combined observations give rich information for the rapid determination of earthquake location, size, and distribution of sea floor deformation that generates tsunamis.

Hazard Assessment

Tsunami warning and safety procedures require an understanding of hazards and risks associated with tsunamis. Alaska researchers at UAF are evaluating the risk by constructing inundation maps for at-risk communities through super computer modeling of the tsunami water waves from scenario earthquakes and landslides. Reliable modeling results, however, require that we have accurate bathymetry to a resolution that is not generally available in Alaska. Much of the sea floor along the shallow waters off the coast of Alaska have not been mapped in many years. Some areas have not been mapped since before the 1964 Prince William Sound M9.2 earthquake (Note that large earthquakes can change bathymetry in local regions of the sea floor by tens of meters.). Collection of improved bathymetry is necessary along Alaska's coastal communities and should be a top priority for our pilot project area.

High resolution modeling and mapping is needed to identify potential areas for evacuation and lifeline infrastructure at risk. As a part of the pilot project at least one community at risk should be selected for acquisition of very high resolution bathymetry. This data will enable the construction of very detailed flooding maps for the community. Benefits of this process include the enhanced understanding of the local risk, construction of evacuation routes for the community, and an evaluation of the capabilities (and potential errors) of numerical modeling and forecasting of tsunamis with the highest quality data available. The models would then be hosted for evaluation by the research community as part of the Alaska Region Super Computer Center tsunami portal system developed as part of the TWEAK program. A candidate community for this evaluation is Akutan. Akutan has one of the largest communities in the Aleutian Islands, which supports the largest fishing industry in the United States. Other candidate communities could include Sand Point, Adak, Dutch Harbor, and a host of others among Alaska's 76 coastal communities.

Mitigation

Last, but not least, to tie together all the components of tsunami identification and warning with the hazard assessment, the pilot community needs a comprehensive public education program. It is important to recognize that tsunami warning systems must go beyond just the ability to detect a tsunami and send a warning message. The most important aspect of tsunami warning systems is the existence of a mechanism for disseminating warning information to the people on the shorelines, and for the recipient of the warning message to understand how to react. Tsunami hazard mitigation requires a long-term sustained effort of continuing public education, and responsible planning decisions in coastal communities.

The power of education is clear.

The State of Alaska partners' are well aware of our difficulties in reaching our 76 communities at risk to tsunamis. Enhancing the warning communication and outreach infrastructure at the state and local level for both emergency managers and the public represents the most important improvement to be made in Alaska for saving lives.

Among the pilot project community enhancements to be made include:

- Tsunami training for schools at all grade levels—Adult public education through media, community workshops, and other means.
- Exercises and drills for elected officials, schools, and the general public.
- Focus groups for mitigation, contingency and continuity planning workshops for essential services and tsunami-at-risk businesses.
- (Note that Public education could have saved thousands of lives around the Indian Ocean.)

Tied to this effort will be an enhanced technical communication infrastructure package that can ensure tsunami warnings are broadcast to people along the coastlines or in their homes, businesses, and boats. Within the pilot community, we will explore all possible communication possibilities, including but not limited to:

- Local alert and notification communication equipment such as the Emergency Management Weather Information Network, NOAA Weather Radios for indoor use, and All Hazard Alert Broadcasting (AHAB) Siren and Radio for outdoor use.
- Support from Alaska Division of Homeland Security and Emergency Management professionals for disseminating existing alert notification, and other enhanced communication protocols, to ensure tsunami warning and evacuation messages can be received by the public rapidly and effectively.

The key to success is developing a strong communications link from the Tsunami Warning Center to a hazard control center or emergency contact point that can be assured of receiving *and* relaying the warnings to the local people through the above considerations.

Summary

In summary, Alaska has partnerships in place to address the threat from tsunamis. Yet we still have continuing needs for improved monitoring with seismic and tide gauge networks, scientific infrastructure for numerical forecasting of tsunamis, and the civil infrastructure to educate and warn people.

This pilot will demonstrate the techniques and procedures necessary to enhance the delivery of hazard warnings to very remote areas of the world. It will focus on an integrated approach of improved monitoring, coupled with extensive hazard and risk assessment and quantification, tied together with a strong approach for education and outreach, and reliable information delivery. In addition, the enhanced monitoring with world class multi-use sensing stations will allow for rapid evaluation of earthquake size and characteristics, estimates of the deformation of the sea floor, and more accurate forecasting of tele-tsunamis that would potentially impact

Hawaii, the west coast of the United States, and other coastlines of the Pacific Ocean.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO CHARLES G. GROAT

Question 1. Dr. Groat, I understand that the Cascadia Subduction zone off the coast of Washington state is similar to the fault that produced the Indian Ocean tsunami. The last major Cascadia quake on January 26, 1700 caused 30-foot high tsunamis that inundated the Washington coastline. In your testimony, you stated that USGS scientists and others have estimated that there is a 10–14 percent chance of a repeat of the Cascadia magnitude 9 earthquake and tsunami event in the next 50 years. What is the basis for this estimate?

Answer. The 10–14 percent probability of having a magnitude–9 earthquake on the Cascadia subduction zone in the next 50 years was derived from the average recurrence time of these great earthquakes observed in studies of coastal subsidence. For example, at Willapa Bay, WA there are wetland soils that were buried during coastal subsidence that occurred during great Cascadia earthquakes. These buried soils are evidence that seven great earthquakes occurred along the Cascadia subduction zone during the past 3500 years. The dates of when these soils were buried are consistent with the dates of subsidence events found at other locations along the Pacific Northwest coast, further supporting the concept that these buried soils record the occurrence of great earthquakes along the coast. The ages of these buried soils indicate an average recurrence time of about 500 years for great Cascadia earthquakes. The USGS used this average recurrence time to get two probability estimates for the next 50 years: the 10 percent estimate is derived from a model that does not consider the time from the last earthquake and the 14 percent estimate is derived from a model that considers the time since the last great Cascadia earthquake (in 1700 A.D.) and the variability in the recurrence time of past great earthquakes as seen in the record of buried soils.

Question 1a. Please explain what makes this fault especially prone to generating a tsunami-causing earthquake.

Answer. Nearly all of the world's major tsunamis occur in subduction zones. The geometry between two adjacent tectonic plates in subduction zones gives rise to the possibility of tsunami generation in areas like Cascadia, where the offshore Juan de Fuca plate is moving landward about 1.5 inches per year. Because the rocks in the Juan de Fuca plate are more dense than the rocks in the North American plate, the Juan de Fuca plate begins to dip slightly into the earth just off the Pacific Coast. The contact between the two plates is the Cascadia fault. Unlike the San Andreas fault, which is nearly vertical, the Cascadia fault is nearly horizontal. This shallow, dipping, geometry establishes a very wide contact area—perhaps as much as 60–80 miles—between the two plates. The wide contact area combines with the 600-mile length of Cascadia to give a huge earthquake fault area. When an earthquake occurs on the Cascadia fault, there is as much as 30–60 feet of displacement of one plate against the other, and that motion can cause rapid changes in the level of the sea floor, resulting in tsunamis.

Not all subduction-zone earthquakes generate damaging tsunamis. If the fault displacement does not cause significant movement on the ocean floor, then only small waves are generated. In some cases, the initial earthquake ground shaking may generate huge underwater landslides that can either produce their own tsunamis or complicate a tsunami generated by displacement of the ocean floor. Although most tsunamis are generated in the world's active subduction zones such as Cascadia, occasionally large gravity-driven slumps have occurred elsewhere that produced significant waves.

One issue that needs more study in Cascadia is the effectiveness of existing warning systems in the event that only a portion of the subduction zone ruptures. In the case where the entire subduction zone from Vancouver Island to northern California ruptures, the immediate response of coastal residents must be keyed on the strong ground shaking. However, the geologic record shows that earthquakes are more frequent in the northern California-southern Oregon portion of Cascadia than off the Washington coast. If only a portion of the subduction zone breaks during an earthquake, then warning systems could be used to help guide initial response on the portion of the coast adjacent to the immediate earthquake area. The June 14, 2005, magnitude–7.1 earthquake off northern California highlighted the need for strengthening seismic warning systems to provide better guidance to state officials in the event of the next Cascadia earthquake rupturing along only a portion of the coast.

Question 2. Dr. Groat, I understand that a tsunami generated by an earthquake along the Cascadia fault could reach the coast of Washington state within 10–20 minutes. I'm concerned because only three Washington towns are considered prepared under the TsunamiReady program, meaning that many, many coastal residents would not have adequate time to escape a tsunami. Would the USGS earthquake notification system be able to notify coastal communities in time to allow for an orderly evacuation?

Answer. It is important to distinguish the roles of the USGS and NOAA with regard to notifying the public about tsunamis. The USGS supplies earthquake data to the NOAA West Coast/Alaska Tsunami Warning Center (WC/ATWC) in Palmer, AK, which is responsible for issuing warnings to coastal Washington. While the WC/ATWC receives USGS earthquake data within seconds, it takes their seismologists a few minutes to process the data and obtain a reliable earthquake location and magnitude and for the duty seismologist to execute the response procedures. Under optimal conditions the WC/ATWC can issue warnings as rapidly as two minutes after the earthquake.

The USGS is also supporting the development of software like California Integrated Seismic Network (CISN) Display that enable emergency managers to receive notification about earthquakes and tsunami warnings quickly as they are distributed by USGS and NOAA. This technology eliminates any delays in information distribution and portrays the earthquake data on maps that can be customized with local highways, hospital locations, and other geographic features. The President's tsunami warning initiative provides funding to enhance CISN Display and provide it to coastal emergency managers.

Even though the goal of the USGS is to put automated earthquake information into the hands of the emergency management community and the public within seconds, and likewise the WC/ATWC strives to issue tsunami warnings within a few minutes, it will be difficult, if not impossible, for many communities to successfully evacuate all citizens in inundation zones within 20 minutes. For that reason, education about tsunami hazards and proper evacuation procedures, land-use planning, and construction of structures that enable vertical evacuation will all be necessary to reduce the loss of life from a tsunami generated by a repeat of the 1700 Cascadia earthquake.

In an effort to further coordinate U.S. national response to the threat from tsunamis, USGS and NOAA co-led two separate task groups organized by the National Science and Technology Council Subcommittee on Disaster Reduction and U.S. Group on Earth Observations: "Tsunami Lessons Learned Interim Report" provides a first look at what lessons can be taken from the December 26, 2004 earthquake and tsunami, and "Tsunami Risk Reduction for the United States: A Framework for Action" provides a national plan to reduce future losses. These reports are expected to be released shortly.

Question 3. Dr. Groat, I understand that the goal of USGS's National Earthquake Information Center (NEIC) is to rapidly determine location and size of all destructive earthquakes and immediately disseminate that information to the public. I understand this to be critical because a person on the ground can't tell if the earthquake they just felt was a little one under their feet, or a huge one off the coast that may be followed by a tsunami. However, I understand that in previous instances, such as the Nisqually Earthquake that gave Seattle quite a shake in 2001, NEIC notification came in too late to inform and improve emergency response efforts. For this reason, I'm pleased to see that under the Administration's proposal, the NEIC would upgrade their operations and be able to provide 24 hour, 7 day a week notification. It is my understanding that a Cascadia fault generated earthquake would give Washington state coastal communities only 10 to 20 minutes of time to evacuate. Is it possible to reach a two minute performance standard for issuing tsunami warnings?

Answer. The speed at which seismic networks can report about an earthquake is governed by the number of seismic stations in the vicinity of the earthquake and the speed at which seismic monitoring systems can calculate earthquake location and magnitudes. For example, the coastal region of Washington is monitored by seismic stations of the Pacific Northwest Seismic Network (PNSN), operated by the University of Washington with funding from USGS. Data from the PNSN is continually transmitted to the WC/ATWC within seconds as a result of system upgrades funded by the National Tsunami Hazard Mitigation Program. As a result of this cooperative effort and because NOAA staff were on duty at the time of the earthquake, the WC/ATWC released the Nisqually earthquake location and magnitude within 2 minutes. It should be noted that the PNSN, like other U.S. seismic networks participating in the ANSS, typically releases automated earthquake information within 3–5 minutes.

Despite improvements in the speed in which USGS or NOAA systems can compute location and magnitude and rapid human response, the goal of reaching a two minute performance standard for issuing tsunami warnings is only possible if there are sufficient seismic stations in the epicentral area. For quakes that occur in remote areas of the planet where the nearest seismic stations are many hundreds of miles away, it can take 10 minutes for sufficient data to be available for a seismic network to release a reliable location and magnitude. Although 10 minutes may seem like a long time to locate a distant earthquake, the transit times for distant tsunamis to reach U.S. shores are on the order of hours.

Just as the PNSN provides seismic data to the ATWC , the NEIC also provides continuous transmission of data from seismic stations around the globe to the WC/ATWC in order for them to be able to issue tsunami warnings as fast as possible. With the planned upgrades for the NEIC with funding from the President's tsunami warning initiative, the NEIC is standing up 24×7 operations and upgrading their software and hardware systems. Like the WC/ATWC, it will then be possible for the ANSS to release authoritative and reviewed earthquake information at the same speed at which the WC/ATWC releases earthquake information.

We again want to emphasize that it is unlikely that a 2-minute performance standard would be sufficient to guarantee successful evacuation of all citizens in inundation zones. However, quick, reliable earthquake locations can be used to "turn off" initial activities that began with felt ground shaking. As noted above, the USGS is working to distribute these locations through such systems as CISN Display. The USGS is also working to provide a more complete description of the earthquake within minutes by automatically delivering ShakeMaps to emergency responders so that they can see the extent of strong shaking in their region. ShakeMaps also serve as input to the HAZUS program for rapidly calculating the expected losses from an earthquake.

Question 4. Dr. Groat, I've heard that coordination and cooperation between NOAA, NSF, and USGS is very poor leading to lots of inefficiencies. Given the possibility of only 10 to 20 minutes warning, it is very important to me that both USGS and NOAA work together to disseminate information as fast as possible. Please explain how current procedures could be improved to ensure communication and dissemination of critical information.

Answer. Since 1997, the USGS and NOAA have successfully partnered on tsunami warning efforts under the National Tsunami Hazard Mitigation Program (NTHMP) in cooperation with FEMA and the five Pacific states. The USGS installed dedicated data circuits connecting the two NOAA Tsunami Warning Centers to the ANSS to ensure reliable data exchange. USGS installed 53 new seismic stations in Alaska, California, Hawaii, Oregon and Washington to support improved earthquake detection for tsunami warnings and collaborated with NOAA staff in the installation of USGS seismological software in the Tsunami Warning Centers. As described above, the WC/ATWC also submits their calculations of earthquake location and magnitude into the ANSS earthquake information distribution system. The USGS and NOAA meet regularly under the auspices of the NTHMP to discuss how we could improve cooperation and coordination, and the level of cooperation between the ANSS operations and Tsunami Warning Center operations is excellent.

In addition, USGS scientists often are active collaborators with NOAA scientists in performing tsunami inundation modeling. USGS scientists are tasked with specifying the "source characteristics" (e.g., the dimensions, orientation, and the amount of fault movement) of anticipated earthquakes for the models. The USGS has an active research program to investigate the geologic evidence from historic tsunamis to gain a better understanding of the amount of wave run-up and frequency of occurrence. These studies guide the inundation modeling of NOAA scientists and form the basis for mitigation planning.

The USGS, NOAA, and FEMA all belong to the State-Local Tsunami Working group convened quarterly by Washington Emergency Management. The working group seeks to implement directions and programs developed by the NTHMP and provide guidance back to the national program. These meetings involve local emergency managers from all Washington coastal counties and outside experts as required by the items being discussed (e.g., a structural engineer, business continuity planner, etc.).

The key to coordination among agencies in the NTHMP is the twice-yearly meeting of the Steering Committee, made up of representatives from the three federal agencies and the five Pacific States. The NTHMP has used the steering committee structure to develop the priorities for the entire program, ensure a uniform message in tsunami-prone areas, and initiate new efforts such as the guidelines for construction in inundation zones. Washington State has been particularly aggressive in taking full advantage of this coordination by calling routinely on the federal partners to help improve public safety efforts in the state.

As a research granting agency, the National Science Foundation is not directly involved with NTHMP or tsunami response. However, USGS and NSF collaborate extensively on research activities that contribute to an improved understanding of Earth processes that lead to earthquake generation. An important aspect of that collaboration is NSF's EarthScope initiative, which is establishing a dense array of geodetic stations along the western boundary of the North American tectonic plate to better understand plate interactions. EarthScope also includes a drilling project into the San Andreas fault, and a moving array of seismic stations to image the crust and deep structure of the continent. In all three projects, USGS scientists are closely collaborating with their NSF and university counterparts. NSF and USGS are partners in the National Earthquake Hazard Reduction Program (along with FEMA and the National Institute of Standards and Technology). NEHRP is focused on translating research into on-the-ground earthquake loss reduction.

Question 5. Dr. Groat, on my recent visit to PMEL, I learned that Washington State is vulnerable not only to tsunamis generated by distant earthquakes in the North Pacific Ocean or the closer Cascadia subduction zone, but also from faults within the Puget Sound. In fact, there is a fault line that goes right across Puget Sound and downtown Seattle. Can you tell me the current plans to analyze the earthquake risk for this fault? Are there other technologies that could provide more timely warning to these inland areas?

Answer. Pacific Northwest earthquakes occur in three source zones: along the Cascadia subduction zone boundary, within the subducting Juan de Fuca plate and within the crust of the overlying North American plate. Earthquakes from all three zones threaten the Puget Sound and western Washington, but a large crustal earthquake would have very severe consequences in Seattle and other cities.

Crustal zone earthquakes, typically of small magnitudes and usually not felt, are the most common earthquakes in western Washington. Crustal earthquakes have been as large as magnitude 5.5 in the last 40 years but have produced little damage. The initiation points (hypocenters) of earthquakes located beneath Puget Sound form a dense cloud of locations in the crust and do not define linear fault zones as seen in California. For many years, the lack of clear trends in the located earthquakes, coupled with a lack of known surface evidence in the form of fault scarps, contributed to the uncertainty as to how best to account for the possibility of crustal earthquakes in hazard assessments.

There are three major fault zones—the Seattle, the Tacoma, and the Southern Whidbey Island—that cut through the heavily urbanized regions of central Puget Sound. Of these, the Seattle fault is the best studied and because of its proximity to so many people and infrastructure, is the most critical feature of regional hazard assessments. Although known for many years based on regional geology and geophysics, until 1992 there was no evidence that the Seattle fault was active. In that year, paleoseismologists showed that large changes in the elevation of prehistoric beaches, in some cases as much as 22 feet, occurred during a very large earthquake on the Seattle fault about a thousand years ago. This large displacement is consistent with an earthquake of about magnitude 7. However, even with these large vertical motions, the exact location of the Seattle fault was still poorly known. The portion of the fault thought to be responsible for the elevation changes has yet to be found.

Nevertheless, the discovery of the vertical land elevation changes sparked considerable research on the fault. In 1994 a basic model was developed linking the Seattle fault to the Seattle basin; the Seattle basin is a deep (5 miles in places) structural feature roughly centered beneath downtown Seattle and Bellevue. A regional aeromagnetic experiment suggested the location of three strands of the Seattle fault. These strands curve from southern Bainbridge Island through south Seattle before bending more northeastward and crossing Lake Washington to the greater Bellevue area.

The introduction of LIDAR flights—Lidar stands for *light detecting and ranging* similar to radar, which stands for *radio detecting and ranging*— over the Seattle fault on Bainbridge Island in 1998 allowed geologists to find the fault in the field for the first time. With a precision of about 20 centimeters, LIDAR can map very subtle changes in the surface topography, and allows scientists to organize features of the landscape. In particular, short linear features that might be missed with conventional topography are easily highlighted with LIDAR data. Field trenching very rapidly discovered several earthquakes on the Seattle fault on and near Bainbridge Island. USGS Geologists also found evidence for an active scarp near Vasa Park in southeastern Bellevue.

USGS has used LIDAR since 1998 to document at least eight faults from the southeastern Olympic Peninsula to Whidbey Island that have had large earthquakes of magnitude 6.5 or greater during the last few thousand years, and there are many additional faults that have now been identified that need thorough study. Ground motions from crustal earthquakes of moderate size, magnitude 6–6.7, produce strong shaking on hard rock that can have major effects on buildings and lifelines.

Fieldwork on various strands of the Seattle fault documents three or more large earthquakes in the last few thousand years. By modeling the expected ground motions from these earthquakes, seismologists can show that the ground and buildings will shake very hard when they next strike. The scientific and engineering understanding of the large crustal earthquakes on the Seattle fault is now well accepted and the USGS joined seven other agencies and organizations to develop a detailed scenario of the consequences of a major earthquake on the Seattle fault. The scenario, published in June 2005 by the Earthquake Engineering Research Institute and Washington Emergency Management, is being used to help the region develop a more aggressive strategy to lower losses from future events.

Unfortunately, for crustal earthquakes in urban areas, there is little prospect of providing warning of possible tsunamis, because the travel time of the first arriving wave will be a few minutes at most. Thus, as with the offshore Cascadia events, sustained public education is the best way to lower losses and save lives in the event of strong shaking in Puget Sound. It is also why the region puts such a high premium on completing a full inventory of possible active faults using LIDAR data. Without LIDAR, possible crustal faults that could be tsunami sources in northern Puget Sound will be almost impossible to evaluate.

Investigating the possibility of tsunamis in Puget Sound is a good example of USGS–NOAA cooperation. Under the NTHMP, Washington State asked USGS and NOAA to consider this issue. The USGS and NOAA jointly convened a panel of experts to discuss shallow earthquake faults in the inland waters and consider their potential to generate tsunamis. Washington State's request was built on the Seattle fault geologic history, which generated a tsunami about 1100 years ago. That tsunami overtopped the site of the current West Point Wastewater Treatment plant in Seattle and has been traced as far north as Whidbey Island.

The expert panel developed reasonable fault parameters for several major crustal faults that cross the inland waters. NOAA has completed modeling a worst-case scenario for the Seattle fault and is now beginning modeling on the Tacoma fault. Future modeling will likely include the Southern Whidbey Island fault and the Devils Mountain-Darrington fault. Modeling of the last fault is hindered by a lack of high-resolution topographic data from LIDAR along much of the fault trace.

Much of Seattle and the surrounding area is underlain by poorly consolidated glacial materials that may be prone to landslides during earthquakes in areas of steep slopes. In addition, the inland waters of Washington are subject to landslides that sometimes cause local tsunamis. Although not nearly as widespread as other types of tsunamis, landslide driven tsunamis may have very high local run-up. Again, at the request of Washington State, USGS and NOAA held a meeting to assess possible landslide tsunami sources in the inland waters. Using a series of maps showing steep, geologically unstable slopes and deep waters, the panel designated sections of the inland waters as more likely than others to generate tsunamis. NOAA is now studying the best way to use the source areas in developing models of possible tsunami inundation areas from landslides.

Question 6. Dr. Groat, I understand that it is most likely that a tsunami hitting the Washington coast would originate from an earthquake along the Cascadia plate rather than a deep ocean earthquake. I also understand that there may be several ways to make our current tsunami warning system more effective for mitigating hazards. For example, the NSF's NEPTUNE program to wire the Juan de Fuca plate with fiber optic lines seems to be supportive of these efforts. Do you feel that there are other technologies or approaches Congress should consider funding that might produce more timely warning for near shore generated tsunamis?

Answer. There are certainly many reasons to take advantage of collaborative opportunities in the region. Already, USGS and the University of Washington are collaborating with the NSF-sponsored Earthscope initiative that will improve deformation monitoring and seismic capabilities in the region. With respect to NEPTUNE, there have been discussions between the university departments responsible for NEPTUNE and the Pacific Northwest Seismic Network about studying possible deployment of offshore seismometers.

The greatest benefit of offshore seismometers would be more reliable earthquake locations for events occurring there. Some offshore seismometers might help resolve the forces producing the occasional offshore earthquake west of Oregon and Washington, and that would give seismologists a better understanding of these events.

However, improved locations would still be within the time constraints discussed in the above questions, meaning that ongoing, consistent education would remain their best hope for people on the beach of surviving a devastating Cascadia earthquake and tsunami.

Question 7. Dr. Groat, confronted with a fresh reminder of the potential devastation of an off-shore, tsunami-causing earthquake, I share Senator Stevens' concern about ensuring sufficient warning systems are in place so that loss of human life can be minimized. Senator Stevens requested an estimation of what it would take to establish a comprehensive tsunami notification system. I am very interested in your response and ask that you please forward me a copy of your answer to Senator Stevens' question.

Answer. Sen. Stevens and Sen. Inouye jointly asked USGS to explain how we could improve public notification of impending natural hazards and disasters. The components of the USGS answer related to earthquakes and tsunamis follow:

The USGS could improve public hazard notification and warning of natural hazards in three basic areas: (1) modernization and expansion of seismic monitoring networks; (2) increased robustness and redundancy of electronic communication links; and, (3) accelerated development and deployment of capabilities to take full advantage of new data streams, research findings and communication technologies to improve the accuracy and timeliness of information we provide for emergency response and management.

(1) Modernization and expansion of monitoring networks

The President's proposal for improving tsunami warning systems would replace legacy hardware and software systems at the USGS National Earthquake Information Center (NEIC) and establish 24×7 operations, actions that will improve response time, benefiting both earthquake notification and tsunami warning. The proposal also includes support to improve station up-time in the Global Seismographic Network (GSN)—a partnership of USGS, the National Science Foundation, the Incorporated Research Institutions for Seismology, and the University of California—and to install additional stations in the Caribbean region. The NEIC modernization is a key component of the Advanced National Seismic System (ANSS). As described in USGS Circular 1188, the ANSS plan includes both notification and early warning of earthquakes as fundamental goals.

(2) Robust telemetry and communication links

For rapid-onset events like earthquakes, tsunamis, volcanic eruptions and landslides, only real-time systems can provide data in sufficient time to issue actionable notifications and warnings. The funding in the FY 2005 Emergency Supplemental for improved tsunami detection and warning system for the United States, along with the funding in the 2006 budget for the same purpose, will expand and improve telemetry connections to monitoring stations, so that the seismic stations in the Global Seismographic Network provide real-time data. This will contribute to decreasing the reporting time for global earthquakes from over one hour to about twenty minutes.

USGS data and products often travel across a web of communications links from the monitoring network to the public, typically involving satellite uplinks and downlinks, the Internet, and radio or television bands. Although some USGS systems employ redundant links (e.g., satellite, phone lines, and/or Internet communications), in many cases the communications channels are vulnerable to a single point of failure. Hardening of these telecommunication links is essential to ensure a reliable warning system is available with the appropriate level of redundancy.

As part of the NEIC upgrade, the President's proposal calls for 24×7 network operations and robust Internet serving of seismic data. It would also increase the number of USGS-operated GSN stations that provide real-time data to NEIC and the NOAA tsunami warning centers. Currently, only 80% of GSN stations have digital telemetry links that allow for real-time communication. Both for the GSN and the ANSS, a fully telemetered system with redundant communications links will improve response time for damaging earthquakes.

(3) New capabilities

The President's proposal for upgrading NEIC will accelerate development of several rapid-response products, including the Prompt Assessment of Global Earthquakes for Response (PAGER) system, which uses information about an earthquake's source, combined with information regarding population and infrastructure in the affected region to estimate potential damage and loss of life in a major earthquake. The PAGER system is ideal for both domestic and international areas where a dense seismic network is not available, but where a rapid assessment is critical for estimating impact.

The USGS is exploring the feasibility of earthquake detection and early warning, in which rapid computer analysis and communication links are used to provide seconds of warning before earthquake waves arrive. Such warning systems are in place in Japan, Mexico and Taiwan. The 2000 reauthorization of the National Earthquake Hazards Reduction Program (NEHRP) called for development of a U.S. early warning system for earthquakes. The USGS currently sponsors modest research and development in this area, including research on earthquake early warning feasibility and efforts to improve the numbers of seismic stations reporting in real time and the speed and reliability of earthquake reporting.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. DANIEL K. INOUYE TO CHARLES G. GROAT

Tsunami and Earthquake Program Compatibility. As you may know, Congress recently enacted this Committee's reauthorization of the multi-agency National Earthquake Hazard Mitigation Program (NEHRP), which is aimed at both improving earthquake detection and community resilience to earthquakes—including building construction and planning guidelines. Similarly, S. 50, would authorize NOAA's National Tsunami Hazard Mitigation Program (NTHMP), another multi-agency program involving many of the witnesses here today.

Question 1. Looking at these two programs together, are the activities of the Earthquake Program consistent with the goals of the Tsunami program? For instance, is a building designed to be earthquake resilient also designed to be resilient against tsunami?

Answer. Because earthquakes are the triggering mechanism for most tsunamis, NEHRP activities aimed at improving seismic monitoring capabilities are directly relevant to improved tsunami warnings. The 2000 reauthorization of NEHRP authorized the development of the Advanced National Seismic System (ANSS). The data from ANSS stations is provided to the NOAA Tsunami Warning Centers. In addition, NSF's George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES) facility, authorized as part of NEHRP legislation, includes a tsunami-wave tank at Oregon State University that is making significant contribution to our understanding of tsunami phenomena.

With respect to the second part of this question, the forces generated by a tsunami wave are different from those generated by strong seismic shaking, and the building design for the earthquakes does not necessarily address the hydrodynamic forces generated by tsunamis. USGS is not directly involved in the issuance of model building codes, although USGS data provides a critical input to the process. This question would be best directed to our NEHRP partner agencies, NIST and FEMA. FEMA is in the process of developing model tsunami inundation zone vertical evacuation shelter construction guidance for coastal areas, a project that was initiated before the Sumatra earthquake and tsunami brought this issue to the forefront.

Question 2. Does the Earthquake Program have any programs or approaches that should be adopted by the Tsunami program? For example, should we expand programs regarding construction and planning?

Answer. The USGS operates seismic networks in order to record data from large earthquakes. We conduct extensive research on this data to document the amount of shaking that earthquakes can generate and to predict the probability of strong shaking for the entire nation. This information is utilized by engineers to make improvements to the International Building Code so that structures can withstand the shaking from strong earthquakes.

This collaboration between engineering seismologists in the USGS Earthquake Hazards Program and the engineers who are responsible for modifications of the building code serves as a model for developing structures that could withstand the forces of a tsunami. Hydrodynamicists can study and model these forces for input to engineers developing building codes for inundation areas.

Question 3. Has the Federal Emergency Management Agency (FEMA) participated meaningfully or financially in either program? Are there limitations that we should know about?

Answer. FEMA plays a crucial role in both programs, ensuring that fundamental and applied research activities are implemented into loss-reduction practice. FEMA's role in the NTHMP flexes according to the needs of the five Pacific states. During the first formative years of the program, the mitigation budget was divided between the five states and FEMA, with FEMA running a multi-state project. However, rather than transfer funds to FEMA for a multi-state project, a few years ago the Steering Committee decided to support these projects through a grant directly to one of the states. Currently, the NTHMP is funding the Guidelines for Construction in Tsunami Inundation Zones, a multi-state program effort, through Washington State. FEMA Headquarters has contributed about $250K to match the funding from NTHMP for this effort.

Question 4. How can we improve coordination and better define agency roles in our legislation?

Answer. The NTHMP program has provided the impetus for interagency coordination and cooperation. Under guidance of a federal-state steering committee, the need for reducing the hazard of future tsunamis has been foremost in guiding cooperative efforts by NOAA, FEMA, and USGS. Continued support for this program, with a strong interagency steering committee and active interaction at the working level, is in the best interest of furthering this work. No single federal agency has the resources or mission to address this complex hazard.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK PRYOR TO CHARLES G. GROAT

Voice Sirens for Effective, Reliable Tsunami Warning

Effective tsunami warning should rely on a variety of redundant modes of communication. While there are several technologies for communicating tsunami warnings highlighted in the Tsunami Preparedness Act of 2005 (S. 50), it is a concern that voice capable sirens are not among the technologies mentioned. Emergency managers have long depended on sirens to warn the public of emergency and civil defense situations including tsunamis, tornados, floods, hurricanes, hazardous material accidents, and of a potential nuclear attack.

Sirens have a number of significant advantages: they insure that all residents and visitors to a particular area can be informed without regard to the cell phone or pager technology platform or provider they may have, when equipped with backup power supplies they will work even when the electricity or phone lines are out; when equipped with live public address or pre-recorded messages they can be used BEFORE and AFTER the incident to communicate important public safety information.

Question 1. Without the use of/installation of voice sirens as part of a preparedness plan, how do you warn people on the ground? Are there other effective warning systems available for this purpose? What criteria are used to determine which warning system is reliable in case of tsunami?

Question 2. Should a preparedness plan include a warning mechanism for small fishing boats trawling near the coastline? National Oceanic and Atmospheric Administration (NOAA) weather radios can be used to inform these fishing boats at minimal cost (approximately $20).

Answer. USGS will defer to NOAA's responses to these questions.

○