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AMERICA'S NATURAL DISASTER PREPAREDNESS: ARE FEDERAL INVESTMENTS PAYING OFF?

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED TWELFTH CONGRESS

FIRST SESSION

MAY 3, 2011

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED TWELFTH CONGRESS

FIRST SESSION

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AMERICA'S NATURAL DISASTER PREPAREDNESS: ARE FEDERAL INVESTMENTS PAYING OFF?

TUESDAY, MAY 3, 2011

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

The Committee met, pursuant to notice, at 2:33 p.m. in room SR–253, Russell Senate Office Building, Hon. John D. Rockefeller IV, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. JOHN D. ROCKEFELLER IV, U.S. SENATOR FROM WEST VIRGINIA

The CHAIRMAN. I'm going to put my absolutely brilliant opening statement in the record, which pains me greatly. But, we have a vote at 3:20, and the whole idea of doing statements and then going to you and then going to vote, then coming back, doesn't make much sense. And what does make sense is to have all of you say what you're going to say. And then we'll probably, at the end of that time, have to go vote. And then we'll question you when we get back, if you can put up with that situation.

[The prepared statement of Senator Rockefeller follows:]

PREPARED STATEMENT OF HON. JOHN D. ROCKEFELLER IV, U.S. SENATOR FROM WEST VIRGINIA

Good afternoon. I want to welcome our distinguished panel of witnesses. Thank you for testifying before the Committee. And a special welcome to Bob Ryan, who so many in the Washington, D.C. region depend on for their weather news. Some may not know that his forecasts and alerts are critical to many in West Virginia's Eastern Panhandle. Thank you for being here today.

We are here today to examine our Nation's ability to prepare and respond to natural disasters. The weather-provoked tragedies and terrible loss of life just days ago make it clear that this hearing could not come at a more important time.

Two months ago, the world watched as a series of earthquakes and a massive tsunami roiled Japan: toppling cities, overturning buildings and killing thousands of people. It was a tragedy of epic proportions.

And now, an ocean away, America is experiencing its own destruction and devastation because of natural disasters. Tornadoes and severe storms have rocked the American South and Midwest. In Alabama, the death toll has jumped to more than 200, and continues to climb, as families and first responders search rubble and razed towns for missing loved ones.

At least 15 people have been killed in Georgia and 34 in Mississippi. It has been the deadliest outbreak of tornadoes in nearly 40 years. We've seen whole neighborhoods ruined, homes flattened, cars flipped onto their sides, tractor-trailers twisting in the air like rag dolls. The destruction is devastating, and the death toll, rising.

I want to extend my deepest condolences to friends and family who've lost loved ones to these disasters—and my deepest thanks to those who are working around-the-clock to respond to them. The destruction and loss of life has been absolutely heartbreaking.

These events underscore just how important it is to be prepared for disaster when it strikes, and to mitigate damage, destruction and loss of life. They underscore how important it is to make the necessary strategic investments now to save lives and property in the future. I have one major question for our witnesses today: how can our Nation best respond to, prepare for, and mitigate the effects of natural disasters—such as earthquakes, flash floods, tornadoes, hurricanes and wildfires—when they strike?

I find it extremely alarming that the American Society of Civil Engineers gave our Nation's infrastructure—our levees, bridges and roads—a "D" grade in 2009. We must do better.

Right now, this Committee has several bills under consideration that would help reduce our Nation's risk from natural disasters.

We know improved building codes can help reduce damage and fatalities when disasters strike. That is one of the aims of Senator Nelson's bill, the *National Hurricane Research Initiative Act of 2011* and Senator Boxer's bill, the *Natural Hazards Risk Reduction Act of 2011*.

We also know that when the unthinkable occurs, first responders must be able to communicate—seamlessly, across cities and states—with one another. That's what my bill, the *Public Safety Spectrum and Wireless Innovation Act,* will do.

And we know that agencies, like NOAA, which provide early warnings, weather prediction and forecasting, need support and resources to do their jobs. That's why I will continue to fight reckless attempts to slash funding for the important services they provide.

Natural disasters cannot be avoided, but their damages can be mitigated, and we must do everything we can toward that end.

I want to again thank our witnesses for being here today. I look forward to learning your views on the state of our Nation's disaster preparedness and what more we can do to prepare going forward.

The CHAIRMAN. Dr. William Hooke—we welcome you—Senior Policy Fellow and Director of the American Meteorological Society; Bob Ryan, Senior Meteorologist, ABC WJLA, covering five West Virginia counties—and you do warn us; and Dr. Anne Kiremidjian, who is Professor of the Department of Civil and Environmental Engineering at Stanford University; and Dr. Clinton Dawson, Professor, Institute of Computational Engineering and Science at the University of Texas at Austin.

And you all are extraordinary in what you know. And, without, sort of, getting into it, let's get into you.

So, Dr. Hooke, why don't we start with you. Give your testimony, please.

STATEMENT OF WILLIAM H. HOOKE, PH.D., SENOR POLICY FELLOW AND DIRECTOR, AMERICAN METEOROLOGICAL SOCIETY

Dr. HOOKE. Thank you, Mr. Chairman.

Today we grieve for those who suffered loss because of violent weather in recent weeks. And we can best honor their loss and suffering by working together to reduce the risks of further tragedy in coming years. So, thank you for convening this conversation on this topic. And thank you for letting us take part.

Now, because of its size and location, the United States bears a unique degree of risk from natural hazards. We suffer from as many winter storms as Russia or China. We have as many hurricanes as China or Japan. And our coasts are exposed not just to these storms, but also to earthquakes and tsunamis. Dust bowls and wildfires have shaped our history. And as we know too well, 70 percent of the world's tornados, and some 90 percent of the truly damaging ones, occur on our soil.

Also, because of our global reach, disasters a world away calls for a U.S. response. So, if you think of the earthquakes in Haiti and Chili, the tsunami in Japan, the floods in Pakistan, people are waiting to see what the U.S. will do.

Our current disaster preparedness, though good, and though improving, remains far from ideal. Warnings are more accurate and timely, but, in that last mile, where they struggle to reach those who are actually in harm's way, they are all too often lost or garbled or misunderstood. Compromises in land use and building codes mean that our homes aren't always as safe as we might hope. Eighty-five percent of the small businesses that close their doors because of disaster never reopen. And the dollar loss from property—the dollar amount of property loss and business disruption is growing faster than GDP. Virtually every disaster quickly becomes a public health emergency.

We can do better if we take the following steps. Number one, we must maintain our essential warning systems. That means funding for the day-to-day operations of those systems, but also funding for modernization. And it also means funding continuity from year to year. These are programs that cannot be shut down for a year and then restarted. The biggest gap right now is the—NOAA's JPSS satellite system, which needs an additional $800 million this Fiscal Year in order to avoid an unacceptable gap in satellite coverage beginning no later than 2017. That gap will throw back our warning capability to what we had 20 years ago.

It's not just enough to bring meteorology and engineering to the problem, we also have to bring social science. Pushing that warning the last mile, we need to hear from those who study communication in a disciplined way. We need to hear from sociologists.

Another example: The title of this hearing asks the question, "Are investments paying off?" And the answer is, "We think so, but we don't know how much." If they were really investments, we would have a much better idea of the return on those investments. That requires that we invest a little bit in economic analysis that we're not doing.

When it comes to natural disasters, we should also do better at learning from experience. We do this in aviation. When the wing falls off the airplane, we noodle around the wreckage site until we see what happens, and we go and we fix it. We lack an agency like the NTSB to perform that function for natural hazards. And the result is that we rebuild as before. Because we do that, we condemn future generations to a great deal of unnecessary pain and suffering.

All of this requires that government and the private sector work in partnership, they work collaboratively and effectively at all levels: NOAA with the aerospace firms that build those satellites and ground systems; the weather service with the broadcasters. I actually think that one's going quite well. At the local level, the private sector and local government need to work together to prepare communities. The Academy just issued a report on that subject, which is in your notes. We need to bring in the insurance industry to provide incentives for better land use and building codes. And finally, we need to support wonderful private-sector efforts like the Business Civic Leadership Council of the Chamber of Commerce and their work in hazard mitigation and disaster relief.

We—as we're blowing up levees in the Midwest, we need to explore no-adverse-impact policies for flood and other hazards. And we also need to track our progress and keep score.

I've got three concluding points and then I'm done. First, the Department of Commerce is a suitable agency home for many of these notions. Second, we shouldn't look at this just domestically. These measures can build international goodwill and international markets for U.S. products and services. And finally, we should not forget the impact of these measures on jobs, protecting jobs that Americans already hold by protecting their communities and their homes in the face of natural hazards, and creating new jobs to serve those emerging international markets.

Thank you, Mr. Chairman. Thank you, Senators.

[The prepared statement of Dr. Hooke follows:]

PREPARED STATEMENT OF WILLIAM H. HOOKE, PH.D., SENIOR POLICY FELLOW AND DIRECTOR, AMERICAN METEOROLOGICAL SOCIETY

Thank you, Mr. Chairman, Senators, Ladies and Gentlemen.

Today we grieve for those who were injured, lost their lives, families, homes, or jobs because of violent weather in recent days and weeks. We can never make them whole. But we can best honor their loss and suffering by working together to reduce risks of further tragedy in coming years. So thank you for taking time—in the midst of so many competing claims on your attention—to convene this conversation on disaster preparedness.

The United States, because of its size and its location, arguably bears a unique degree of risk from natural hazards. We suffer as many winter storms as Russia or China. As many hurricanes as China or Japan. Our coasts are exposed not just to storms but to earthquakes and tsunamis. Dust bowls and wildfire have shaped our history. *And, as this past week reminds us, 70 percent of the world's tornadoes, and some 90 percent of the truly damaging tornadoes, occur on our soil.*

In addition, because of our global reach, disasters a world away call for a U.S. response: earthquakes in Haiti and Chile, a tsunami in Japan, floods in Pakistan.

Our current disaster preparedness, though improving, remains far from ideal. Warnings are more accurate and timely, but too often are lost, or garbled, or misunderstood, in that "last mile," where they struggle to reach those actually in harm's way. Compromises in land use and building codes mean our homes aren't always the unassailable fortresses we might hope. 85 percent of the small businesses who close their doors as a result of disaster never reopen. The dollar amount of property loss and business disruption is growing faster than GDP. And virtually every disaster very quickly also becomes a public health emergency.

We can and should do better. We need to:

- *Step up funding and maintain the year-to-year continuity of funding*, for day-to-day operations, and continuing modernization of, essential warning systems. Today, most specifically and urgently, some $800M in additional funding is needed for NOAA's Joint Polar Satellite System (JPSS), *in this fiscal year* (FY 2011), to avoid an unacceptable gap in satellite coverage beginning no later than 2017.[1] To avoid a repetition of this oversight in future years, it would help if the Office of Science and Technology Policy would develop a policy with respect to long-term observations of and study of the Earth. We need this, because we will need to make short-term observations forever; and we need this because the Earth, the atmosphere, and the oceans vary on time scales of decades and centuries.
- *Bring to bear not just meteorology and engineering, but also social science.* Pushing that warning message the last mile? Helping those in danger to save themselves? Here's where we need advice from communication scientists and sociologists. The title of this hearing asks the question: *Are investments paying off?* We think so, but we don't know how much. Toward this end, more economic

[1] See, *e.g., http://www.aviationweek.com/aw/generic/story.jsp?id=news/asd/2011/04/07/07.xml&channel=space*.

analysis of benefits and value would sure be useful. And more funding support for the supporting social science (amounting to no more than "sales tax" on the much larger engineering and natural-science outlays) is needed to build our capacity for such analysis.

- *Learn from experience.* We do this in aviation. The National Transportation Safety Board plays a key role. Absent a similar agency to study loss of life, property, and economic activity to natural hazards, we do the opposite of learn from experience; we "rebuild as before." [2] This condemns future generations to pain and suffering down the road.
- *Exercise public-private partnerships*: To build America's disaster preparedness requires that government and the private sector collaborate effectively at all levels: (1) NOAA with the aerospace firms who build NOAA satellites and ground systems; (2) NWS with the broadcasters and private firms who deliver weather warnings (this is actually working rather well); [3] (3) at the local level to build community disaster resilience; [4] (4) bringing in insurers to provide incentives for better land use and building codes; and finally (5) with respect to private-sector role in hazard mitigation and disaster relief, as so well exemplified by organizations such as the Business Civic Leadership Council of the U.S. Chamber of Commerce.
- *Explore No-Adverse Impact Policies for flood [5] and other hazards,* [6] as propounded by the Association of State Floodplain Managers and the newly-formed Natural Hazard Mitigation Association. (This is timely given the legal battle developing on whether to blow up a two-mile section of levees on the Missouri side of the Mississippi River to reduce the threat of flooding on the Illinois side.) [7]
- *Track progress/keep score.* Over a decade ago, an NAS/NRC study recommended that the Department of Commerce maintain statistics on U.S. losses to natural hazards.[8] We give priority to what we measure. That proposal should be implemented.

Three concluding points:

First, as we consider these and similar policy options, we might contemplate the U.S. Department of Commerce as a suitable agency home. The Department already has many of the needed pieces in place. Second, in looking at the benefits of these measures we should keep in mind that they each embody potential for building international goodwill and international markets for U.S. products and services. And finally, we should not forget the impact of each of these measures on jobs—the preservation of jobs and our domestic economy in the face of natural hazards, and the creation of jobs to serve those emerging international markets.

Thank you, Mr. Chairman, Senators, Ladies and Gentlemen.

The CHAIRMAN. Thank you very much.

Mr. Ryan, we welcome you.

STATEMENT OF ROBERT RYAN, SENIOR METEOROLOGIST, ABC7/WJLA–TV

Mr. RYAN. Thank you very much, Mr. Chairman, for the opportunity—there we are——

The CHAIRMAN. You're meant to know that, Mr. Ryan.

Mr. RYAN. Thank you. Usually, it's done for me, so—[Laughter.]

Mr. RYAN. But, this is a nonunion shop, so I think——

[2] Eosco, Gina M., William H. Hooke, 2006: Coping With Hurricanes. *Bull. Amer. Meteor. Soc.*, 87, 751–753.

[3] Fair Weather: Effective partnerships in weather and climate services NAS/NRC BASC (2003) *http://www.nap.edu/openbook.php?isbn=0309087465*.

[4] Building Community Disaster Resilience through Private-Public Collaboration, NAS/NRC BESR (2010) *http://www.nap.edu/catalog.php?record_id=13028*.

[5] As suggested by the Association of State Floodplain Managers: *http://www.floods.org/index.asp?menuID=460&firstlevelmenuID=187&siteID=1*.

[6] Natural Hazard Mitigation Association: *http://www.nhma.info/*.

[7] *http://www.washingtonpost.com/national/mayor-orders-evacuation-of-ill-town-as-river-water-bubbles-up-behind-levee-rain-adds-to-woes/2011/05/01/AFOexTQF_story.html*.

[8] The Impacts of Natural Disasters: A framework for loss estimation. NAS/NRC CGER (1999) *http://www.nap.edu/openbook.php?isbn=0309063949&page=27*.

Thank you, Mr. Chairman, for the opportunity to present some views on the topic of Federal investments and disaster preparedness.

I'm speaking, first of all, only for myself and not my employer, Albritton Communications.

I've served as President of the American Meteorological Society, a distinct pleasure, as well as on two National Research Council committees, which wrote two reports to NOAA and the National Weather Service on effective partnerships, the *Fair Weather* report, which has advanced quite a bit of the entire enterprise, as well as the recent report, *Completing the Forecast,* characterizing and communicating uncertainty for better decisionmaking using weather and climate forecasts.

The short answer, I believe, is most definitely yes. Federal investments in disaster preparedness in paying—are paying off. And as we have so recently seen, the United States—and as Bill mentioned—has more severe weather and more weather-related disasters than any other country. As example, 90 percent of the strong and life-threatening tornados in the world occur in the United States. The science of meteorology has made remarkable advances in the last 50 years, thanks, in large part, due to the Federal investment in knowing that better forecasts and advanced warning before weather emergencies are of tremendous public and economic benefit to all of us.

And indeed, I would argue that if we all agree that one of the fundamental purposes of government is protection of the life and property of its citizens, few organizations do that each and every day more than our Nation's weather services, both public—NOAA and the National Weather Service—and private-sector companies and local broadcasters.

Many may ask: After all the investments that we have made in advancing the science of weather and weather forecasting—satellites, Doppler radars, supercomputers—how could so many lives be lost in the terrible tornado outbreak of last week? More than 90 percent of last week's tornados were warned on with an average lead time of 25 minutes—something impossible, years ago. But, more than—we had more than EF—11 EF4 tornados and 2 EF5 tornados in a single day, more than any day in history. And without proper protection in storm cellars, reinforced safe rooms, or protected areas in basements, it was impossible to survive tornados with winds of 160 to more than 200 miles an hour.

Jeff Masters, who is at the University of Michigan and has written a blog, estimated that if we had the same outbreak 50 years ago, before Doppler and before all of the investments, the loss of life would have been in the thousands from that event.

The current weather forecasting warning communications system is a shared enterprise. Sometimes the entire mix—Federal, public, private, nongovernmental organizations, emergency management, the community, and the media—they're called "the weather enterprise" sometimes some of us refer to it. And indeed, there are such early warnings and communication of these warnings and alerts to the public through every means, from NOAA Weather Radio to radio, new digital medium, and especially local news broadcasts, which were on the air continuously last week, tracking tornados with both National Weather Service and local TV station Dopplers. That allowed so many people as possible to survive what is probably once-in-a-100-year natural disaster. The system worked. And the shared partnership of Federal employees at the National Weather Service, local government officials, and emergency managers, and, critically, the broadcast community and local broadcast meteorologists, helped more than 99 percent of our fellow citizens in the path of killer tornados survive what everyone hopes is certainly a once-in-a-lifetime experience.

Today's forecasts are really an end-to-end process that every more—the ever more accurate weather forecasts and climate forecasts—the communication of the forecast information to the public and other users.

And finally, the decisionmaking using that information by the public and users. If we have a 100-percent accurate weather forecast which may not be effectively communicated and then results in a poor or bad decision, we have failed. The 100-percent-correct forecast is of little use if the wrong weather or climate-related decision is made. Effective communication is as essential as the correct weather forecast. And in the case of weather emergencies, the media and over-the-air broadcasters play a vital role in communication of weather forecasts and warnings.

My fellow broadcasters in Mississippi, Georgia, Texas, West Virginia, and Alabama, in the last few weeks, were on the air continuously to keep the public informed, communicating the warnings from our colleagues at the National Weather Service, helping the community watching and listening, to make the best life-saving decisions.

The last—however, the last stop on our end-to-end weather forecast process is the decision by the public end user in weather emergencies. And that's what I do. The local broadcaster, the local broadcast meteorologist, known in the community they serve, are still using traditional methods of communicating via over-the-air live radio, television broadcasts during local newscasts, and continuously, as we saw last week, during weather disasters, is the trusted source for the public to make a decision.

And just to wrap up, my Albritton colleague, James Spann, in Alabama, during this terrible, terrible outbreak, was on the air using all of the assets at his command, from the public radar to spotters and over-the-air continuously. And he has received hundreds and hundreds of thank-yous for those efforts in pinpointing the terrible outbreak of tornados, helping people make the proper decision that saved their lives. And that is where we are all heading.

Yes, the system is working. The way we communicate weather information and forecasts is expanding every day. The Federal investment in our weather enterprise is vital. Efforts to stop funding the new Joint Polar Satellite System, as we have just heard, will degrade our ability to adequately forecast and warn of the next potential weather disaster.

Certainly, we do need to bring social science expertise into our shared enterprise and learn how to better—how we can better use these expertise, in every new and old media, to better communicate what we know and what actions should be taken, and better help the public make the best life-saving decision, rather than life-risking decision, in the face of the next weather emergency.

With continuing Federal support for the core structure of this country's great weather enterprise, what we have accomplished together in the advance of the service of the science I love to the public, the country, and the world will continue, and continue to be a shining example of how government meets its key role of the protection of the lives and property of its citizens.

Thank you very much, Mr. Chairman. I'd be happy——

The CHAIRMAN. Thank you, sir.

Mr. RYAN.—to answer questions later.

[The prepared statement of Mr. Ryan follows:]

PREPARED STATEMENT OF ROBERT RYAN, SENIOR METEOROLOGIST, ABC7/WJLA–TV

Thank you, Chairman Rockefeller, for the opportunity to present my thoughts on the importance of accurate weather forecasting, information and services during emergencies. Examining the current state of how Federal agencies and Federal investments in weather and climate research, forecasting and communication are doing, is extremely timely after the tragic tornado outbreak last week. I have had a brief time to prepare this document so I will present my thoughts as a number of items.

1. The science of meteorology has made tremendous progress in the last 50 years in understanding, observing and forecasting weather events from the next 10 minutes to storms that may be days away to general patterns weeks and months away.

2. The investment in the hardware to observe weather and climate from traditional ground instruments to satellites and Doppler radars, coupled with the investment in fundamental research and understanding of weather and climate along with the investment in so-called super computers to make every more accurate forecasts has saved lives and been of tremendous economic benefit to the country.

3. The United States has more severe weather than any other country, 1200 tornadoes, 5000 floods, 10,000 thunderstorms each year and 14 Billion dollars in weather related losses.

4. The organization that might be called a "Weather Enterprise" of public, private and academic sectors has worked cooperatively with shared goals of creating an integrated weather and climate information, forecast and communication system that serves all sectors well. This shared observational, forecast, communication "enterprise" with Federal agencies as the lead, is unique to the United States and a great example to other countries of true government—private sector partnerships that benefit all citizens.

5. All providers and users of weather information whether to the public or to private sector clients or research institutions, depend on the Federal Government to be the open source and backbone of the information, data, model outputs, warnings and forecasts we all use. No meteorologist can make an accurate forecast, or deliver timely warnings to clients or emergency managers or the public without the core information, warnings, model data etc. openly provided by the National Weather Service, NOAA, NASA, FAA, EPA and other Federal agencies. *This partnership with NOAA and NWS being the lead Federal agencies of open operational weather information and data is vital and must continue for effective communication of warnings by traditional and new media to the public.*

6. Federal weather warning systems now in place such as NOAA Weather Radio are vital to broadcasters being able to communicate weather warnings to the public.

7. Cooperation between the National Weather Service and broadcasters during weather emergencies has been excellent. Federal agencies such as NOAA and the National Weather Service regularly reach out to broadcasters through workshops, various professional conferences and joint meetings with the emergency management community to solicit feedback and exchange ideas and information.

8. The recent tragic tornado outbreak (April 27, 2011) generated almost 300 tornadoes. About 90 percent of these tornadoes were correctly warned on. The average warning lead-time was 24 minutes but EF4-EF5 tornadoes, with winds speeds of 200 mph or higher are almost unsurviveable above ground. Preliminary estimates are that there may have been 4 or 5 EF4 or EF5 tornadoes on April 27, including the tornado that moved directly through Tuscaloosa, Alabama, a metropolitan area of more than 100,000.

9. The weather/climate prediction should be thought of as an end-to-end process. That is the actual forecast and or warning, the communication of the forecast and warning and the decision made by the user of that forecast or warning. *If a 100 percent correct forecast has been made and communicated, but the wrong decision has been made the forecast/warning process has failed.* A tragic example this link: *http://news.yahoo.com/s//nm/20110430/us_nm/us_usa_weather_shelter*.

Suggestions for Improvements to Federal Services and Programs

10. Items to improvements in Federal programs to support "timely and accurate forecast" include immediately restoring funding for the joint polar satellite system (JPSS) program. Some may argue that loss of polar orbiting data will not degrade our current weather/climate observing and forecasting skill . . . but, what if they are wrong! Polar and geostationary weather satellites are an integral and critical core element of providing very accurate weather forecasts and life saving planning and decisionmaking for weather and other natural disasters from tornadoes and hurricanes to fires, drought, dangerous air quality and oil spills.

11. Integration of social science expertise into our core physical science institutions of observing, forecasting and communicating weather forecasts and warnings can help improve the critical decisionmaking element of the end-to-end forecast process mentioned in item 9 above. Each of us feels we can improve communication to better help weather forecast/warning decisionmakers, including the general public, make better decisions especially during rare life threatening extreme weather events such as the recent tornado outbreak. The core weather enterprise Federal agency NOAA's National Weather Service employs one social scientist-an economist. More understanding of how the public interprets and acts on weather warnings and statements about imminent natural disasters is needed. The use of customer satisfaction surveys (CSS) as required of Federal agencies to show approval or "satisfaction" with forecast products is useful. But fundamental research of how forecasts from color coded warnings to simple descriptions to the needed wording for correct decisionmaking before potential weather disasters, such as Katrina, snow storms, blizzards and tornadoes is very much needed. The next significant improvement in the value of weather forecasts will come from better communication and decisionmaking as much as continued advance in the accuracy of the actual forecast.

Mr. Chairman, thank you for the opportunity to present some thoughts I hope are helpful to you and the Committee. All of us in the weather and climate community feel the Federal investments are paying off. But as we know forecasting the weather will never be 100 percent accurate, we can and will work cooperatively to effectively communicate with the public and strive for 100 percent accurate forecasts and also 100 percent best decisionmaking.

The CHAIRMAN. Absolutely.

Dr. Anne Kiremidjian.

STATEMENT OF ANNE S. KIREMIDJIAN, PH.D., PROFESSOR, DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING, STANFORD UNIVERSITY ON BEHALF OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Dr. KIREMIDJIAN. Mr.—thank you—Mr. Chairman, members of the Committee, it is an honor for me to be here today and representing the American Society of Civil Engineers.

I've been a Professor at Stanford for 38 years, specializing in earthquake engineering, and most of my research has been in earthquake hazard and risk analysis and development of wireless structural monitoring systems. Therefore, my comments will be focused primarily on earthquakes, but they easily apply to many of the other hazards.

The question that you had put in front of us is whether our investments in earthquake hazard and other natural disasters have—are worth it—have been paying off. The short answer, just like Mr. Ryan said, is yes. And the public is a lot safer today because of all the activities that the National Earthquake Hazard Reduction Program has been involved in.

We have made great strides in understanding the geosciences, the behavior of our buildings and other infrastructure when subjected to severe earthquakes, how people and economies are affected by earthquakes, and how we should mitigate and upgrade our structures to prevent and minimize future disasters. However, we are not there yet, not even close; the reason being that, with every earthquake, we see and learn how much we don't know. To continue—we continue to be humbled by every single earthquake event. And we find something new and different that we didn't know before.

The last earthquake, in Japan, the earthquake of March 11 of this year, has indeed shown us what a truly devastating event can do to a very large community. Our laboratory tests, our sophisticated numerical models, cannot replicate, cannot produce, and cannot teach us what such a large earthquake can do. What we can do, however, we can prepare to take measurements and study these events, which enable us to greatly improve and enhance our models and technologies in order to apply them in a systematic way and enable us to prevent future losses.

Europe has also played a very important role in mitigation activities. I happened to be involved in a study, in 2005, where we looked at the effect of mitigation and how our—a dollar—each dollar that we spend is paying off. The study was conducted by the National Institute of Building Sciences. There were several conclusions, but the key one, the—probably the most important one, was that, for every dollar spent in mitigation, we are saving $4 of—in future losses.

With recent budget cuts, and with states and communities getting deeper in debt, we have seen major reduction and in—sadly enough, in many places, outright elimination of mitigation programs. The result will be devastating. If future—if we reduce our research in mitigation budgets, we will not be benefiting from the current advances, and we will be putting our communities at even greater risk.

Moreover, we need to invest funds specifically to study the great Tohoku earthquake of March 11. This is the first time that a magnitude-9 earthquake has hit a country that has a building and infrastructure that's very similar to ours, that has design practices that are very similar to ours, that has a general social and economic environments similar to ours, and where we are seeing, for the first time, and have evidences and measurements from the largest tsunami we have observed. Some of the tsunami waves were as high as 37.8 meters, close to—almost 100 feet, if not higher.

The lessons to be learned are enormous. Unprecedented. I should mention that, after the 1995 Kobe, Japan, earthquake, Japan invested more than a billion dollars in all kinds of instrumentation. The data has been gathered, waiting to be analyzed. It is our duty to participate in these activities. We are fortunate to have forged excellent alliances with our Japanese colleagues. And this gives us an opportunity to really study and test and improve our models, our mitigation practices, and understand what we need to do to prevent future disasters.

You might ask, after spending all this money over the years, "Why are our structures and our communities still at high risk?" There are at least two answers. And I will bring the two most important answers why.

The first one is, our infrastructure—all of our structures—a majority of them, probably about 80 percent of them—were built prior to current design practices. Moreover, we have allowed our infrastructure to greatly deteriorate, making the problem even worse.

The second problem is that earthquake engineering and earthquake-related sciences is relatively young. We have been working on this problem for the last 30 years, but with every earthquake, we have learned more and more.

In order for us to start addressing some of the questions, we need to continue in a systematic manner. Let me give you one example. After the 1994 Northridge earthquake, what we observed was that, particularly, businesses required their facilities to continue functioning in a manner where their business will not be interrupted. Our design practices up until then had been to design strictly for life safety. We didn't worry how much damage there was to the structure, as long as the structure didn't collapse and kill people. And indeed, we have done very well in that respect, looking at the number of casualties. What we have—what we understand now is that, in order to have economic viability, we need to have business continuation. And our critical infrastructure needs to function immediately after an earthquake.

ASCE has been at the center in the design and development of all of these mitigation activities.

And I see that I'm out of time. I will just conclude by saying something that we have said over and over again. We cannot prevent earthquakes from happening. However, what we can do—through our research, through our mitigation activities, we can greatly reduce the consequences from such events and prevent them from becoming a disaster.

Thank you very much, Mr. Chairman and Senators.

[The prepared statement of Dr. Kiremidjian follows:]

PREPARED STATEMENT OF ANNE S. KIREMIDJIAN, PH.D., PROFESSOR, DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING, STANFORD UNIVERSITY ON BEHALF OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Mr. Chairman and members of the Committee: I am Anne Kiremidjian and I am testifying on behalf of the American Society of Civil Engineers (ASCE). During my forty years of involvement with ASCE, I have served as Chair of various committees and most recently as Chair of the Executive Committee on Disaster Reduction and Management (CDRM) and Chair of the Executive Committee of the Technical Council on Lifeline Earthquake Engineering (TCLEE). As professor of structural engineering at Stanford, I have been the direct beneficiary of the funding to the National Science Foundation (NSF), U.S. Geological Survey (USGS), National Institute of Standards and Technology (NIST) and the Federal Emergency Management Administration (FEMA). These organizations have supported my research, educational and business endeavors. In addition, I have served on the board of directors, institutional boards and external advisory board to the various research centers and consortia on earthquake engineering research. Over the years I have also actively participated in committees and workshops that have set the standard for research and development related to earthquake engineering and disaster mitigation.

My research focus over the past thirty-eight years has been on the development of earthquake hazard and risk assessment methodologies, and wireless structural monitoring sensors and systems for rapid structural damage assessment from normal loads and extreme loads such as those from large earthquakes. My research has been greatly enhanced by the numerous first-hand observations and investigations of the damage, social and economic consequences following major earthquakes around the world.

Founded in 1852, ASCE is our Nation's oldest civil engineering organization representing more than 140,000 civil engineers in private practice, government, industry and academia. ASCE is a 501(c)(3) nonprofit educational and professional society. Research in civil engineering aims to advance the quality of life of individuals and our society by building innovative structures and infrastructure and by providing essential service with minimal adverse effect on the environment by applying the principles of sustainable development and disaster resilience.

ASCE is pleased to offer this testimony before the U.S. Senate Committee on Commerce, Science, and Transportation on the hearing: "America's Natural Disaster Preparedness: Are Federal Investments Paying Off?"

Have Our Federal Dollars Been Paid Off?

Since the establishment of the National Earthquake Hazard Reduction Program in 1977, we have made tremendous strides toward our understanding of the earthquake phenomenon, its effects on the built environment, and on the social and economic systems that may be affected by the occurrence of a major earthquake. To site a few examples, the ground shaking maps produced by USGS are extensively used in building and other infrastructure design and assessment; the three earthquake engineering centers (the Pacific Earthquake Engineering Research Center (PEER), the Multi-hazard Center on Earthquake Engineering Research (MCEER), and the Mid-America Research Center (MAE) have each focused on development of models and technologies for their respective geographic regions of interest; they have changed the design paradigm from the traditional code-based prescriptive approach to a performance based approach where the design of building and other infrastructure is expected to achieve performance goals geared toward not only life safety but also toward functionality and rapid recovery after an earthquake event; Over the past 10 years, the Network for Earthquake Engineering Simulation (NEES) has performed the systematic testing of scaled structures and structural components enabling validation of theoretical models; hospitals and schools are being upgraded or completely reconstructed to meet higher performance as a result of our increased understanding of the needs following a major earthquake; local governments perform periodic emergency response drills in the attempt to identify gaps in their emergency plans; tsunami evacuation routes have been identified and marked to aid in the event of a tsunami; technologies such as base isolation systems, various damping and energy dissipative devices to reduce damage to structures, wireless structural monitoring sensing systems, nano-level and bio-inspired sensing devices for more robust damage detection, and remote sensing techniques are being developed for rapid information retrieval, damage assessment and control of structures; similarly rapid mapping dissemination following an event are now made available after every earthquake in California, as the shake maps produced by USGS, and can be used by local and state governments in their early stages of planning for the response and recovery operations, the multi-hazard loss estimation software tool HAZ–US developed by FEMA is also being used by state, local and the government to estimate potential losses for scenario events; and so on. By no means is this intended to be a comprehensive list and I am sure to have missed some key developments and innovations in this brief summary.

In a 2005 study supported by FEMA and the U.S. Department of Homeland Security, the Multihazard Mitigation Council (MMC) of the National Institute of Building Sciences (NIBS) conducted a study "*Natural Hazards Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities*" (*http://www.fema.gov*). One of the main conclusions from this study was that, for every dollar spent by FEMA in mitigation activities during the period from 1993 to 2003, society saved $4 on the average. Moreover, the mitigation activities "resulted in significant benefits to society as whole" and "represented significant potential savings to the Federal treasury in terms of future increased tax revenues and reduced hazard-related expenditures." Mitigation is indeed one of the most effective ways of reducing the consequences of large earthquakes and other natural occurrences and potentially preventing them from becoming disasters.

The Tohoku, Japan earthquake of March 11, 2011, combined with the tsunami and damage to the Fukushima Daichi Nuclear Power plant resulted in perhaps one of the worst natural disaster we have seen during our lifetimes. Preliminary estimates of the total losses are approximately $600B (S&P) of which $300B are attributed to the earthquake shaking and the tsunami. The tsunami waves were estimated to range from 9 m to 37.9 m in height causing the majority of building and other infrastructure destruction with 13,591 confirmed deaths, 4,916 injuries and 14,497 missing. Early damage reports, however, are indicating that structures built to meet current design criteria performed overall very well. Damage has been primarily to older buildings and other infrastructure that were built with much less stringent seismic design criteria. Like the United States, and perhaps even more so, Japan has had a long tradition to invest in earthquake research and development. We have also been the beneficiary of the extensive funding by the Japanese government following the 1995 Kobe, Japan earthquake which spent more than $100M in seismic instrumentation both for ground motion and building performance monitoring and more than $500M to build the world's largest shake table enabling full scale testing of structures subjected to earthquake motions. Perhaps it is premature to make a conclusion based on these early observations, but one might say that the advances made toward current design practices are paying off.

Can We Prevent Future Natural Disasters?

No.

Why Not?

An earthquake does not become a disaster if it occurs in an unpopulated area. It becomes a disaster when it affects densely built and populated communities that are not prepared to cope with the forces of strong and great earthquakes. Here are some of the reasons why we find it difficult to prevent future disasters from earthquakes:

- We are still in the process of understanding the true effects of strong earthquakes—ground shaking, ground deformations and tsunamis—because large earthquakes such as the Tohoku, Japan earthquake of March 11, 2011, occur rarely, we have not been able to obtain direct information on their consequences;
- The performance of various ground conditions, structures and infrastructure components is only now beginning to be understood with much remaining to be investigated and evaluated;
- Many technologies that can prove to be useful in disaster response and recovery are only in the form of prototypes, untested in real situations;
- Majority of structures and infrastructure systems were built before current design methods were developed;
- Our structures, lifelines and transportation systems are old and deteriorating;
- Many earthquake prone areas in the U.S. did not adopt seismic design until recently—e.g. Oregon adopted seismic requirements in 1994;
- Great earthquakes affect vast geographic regions—*e.g.,* a repeat of the 1906 San Francisco earthquake would affect all cities and towns spanning a 400+ km segment from San Juan Bautista to Eureka; an earthquake of moment magnitude 9 on the Cascadia subduction zone will affect all communities along the Oregon and Washington coastline;
- Critical facilities are being upgraded (*e.g,* hospitals, police and fire stations) but local and state governments lack the resources to address the problems more aggressively;
- Key industrial facilities are potentially vulnerable but at present it is up to the owners to evaluate their performance—failure of these facilities can have a serious economic impact on a community and the rest of the country;
- Local and state governments lack the resources to evaluate their earthquake risk in order to develop and implement disaster mitigation policies—*e.g.,* the State of Oregon had undertaken a plan to identify vertical evacuation structures for tsunami refuge; these activities have stopped due to budget cuts.

Funds are needed for fundamental and applied research that encompasses the geosciences, geotechnical engineering, structural and infrastructure engineering, social and economic sciences, and policy decisionmaking. Recent strong earthquakes have shown that we are only now beginning to understand the phenomenon and its consequences. As an emerging field it requires extensive research and development that can only be achieved through the dedicated efforts of its professionals with appropriate funding. Community resilience to major earthquakes can only be achieved through the implementation of findings from the research and development and through appropriate mitigation and preparedness actions.

Where Are the Greatest Gaps?

A comprehensive approach for earthquake related research and development that takes further steps toward community resilience is laid out in the 2009–2013 NEHRP Strategic Plan. In addition, the National Research Council of the National Academies (NRC 2011) has released a study that recommends a road map of national needs in research, knowledge transfer, implementation, and outreach that will provide the tools needed to implement the NEHRP Strategic Plan (Poland, 2011). Key areas that need extensive investigation include:

- Worldwide monitoring and data gathering and interpretive tools:
  - Instrumentation for assessing the energy release and variation of intensity of strong shaking of earthquakes;
  - Instrumentation of buildings and other infrastructure components;
  - Methods and tools for data assessment and interpretation leading to useful information.
- Framework for resilience in terms of performance goals that consider communities as systems of structures, lifelines, people, economics and governments, and their interdependencies.
- Social science research to quantify the role of improvisation and adaptation, how decisions are made at all levels and the need for rehabilitation.
- Development of Performance-Based Earthquake Engineering (PBEE) design tools to enable rapid and widespread adaptation of advanced design methods.
- Development of new technologies and adaptation of existing technologies for pre-disaster assessment and for rapid response and post disaster evaluation.

The recent earthquakes of February 22 and 25, 2011, in Christchurch, New Zealand, and the great magnitude 9 earthquake of March 11, 2011, in Tohoku, Japan present an unprecedented opportunity to study their effects to communities, geographic exposure and design practices that are the closest to those in the U.S. The extensive instrumentation placed by Japan prior to the earthquake has provided a wealth of new information that needs to be investigated in collaboration with our Japanese colleagues. The social, economic and policy implications from the earthquake and tsunami are unlike any other event we have seen during our short history of earthquake research. It is imperative that funds be allocated to study these earthquakes and use the lessons to greatly enhance the resilience of our communities to large earthquakes.

Summary

In conclusion, ASCE plays critical role in the research, implementation and policies for earthquake hazard and risk mitigation leading to resilient communities. The activities can be achieved through continued support of the National Earthquake Hazards Reduction Program by focusing on the specific goals mapped in the Program's Strategic Plan. Funding for research on the Tohoku 2011 earthquake presents a unique and long-awaited opportunity to study the effects of a truly great earthquake on a community that most resembles our.

Thank you for the opportunity to present our views. I would be happy to answer questions you might have and to provide the Committee with further information.

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The CHAIRMAN. Thank you.
I call on Senator Hutchison.

STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

Senator HUTCHISON. Yes, I just wanted to introduce the witness that I invited.

Dr. Dawson is a Professor for the Institute for Computational Engineering and Sciences at my alma mater, the University of Texas at Austin. And if I might say, we are also the alma mater of the Vice Admiral who led the assault on Osama bin Laden. He is a University of Texas graduate. So, there are two proud Longhorns in the room.

[Laughter.]

Senator HUTCHISON. I'd just like to point that out.

And I would like to introduce Dr. Dawson. We're glad you're here.

[The prepared statement of Senator Hutchison follows:]

PREPARED STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

Thank you, Chairman Rockefeller, for holding this important hearing on the effectiveness of Federal investments in disaster preparedness. Before we examine this important issue, I would like to express my sincere condolences to the victims of the recent natural disasters that have devastated both the Southeast and my home state of Texas.

Just last week tornadoes wreaked havoc on the Southeast, destroying communities and resulting in over 350 fatalities, the destruction of 10,000 homes, and an estimated $2 to $5 billion in property damage.

In Texas, brave men and women have battled wildfires that that have destroyed over 2 million acres, 900 structures, and resulted in the loss of life of two firefighters. I continue to strongly urge the Administration to grant the State of Texas' request for a Federal disaster declaration for the Texas counties that have suffered damage from these wildfires.

Both of these tragedies underscore the importance of Federal investments in disaster preparedness and response.

The World Bank and the United States Geological Survey have estimated that economic losses worldwide from natural disasters in the 1990s could have been reduced by $280 billion if an additional $40 billion had been spent in preventative measures. Therefore, it is vitally important that we spend our Federal research dollars wisely in order to reduce both loss of life and economic damages resulting from the natural disasters that can have devastating impacts on our Nation.

Many of our past investments have proven that increased research into natural disasters can save lives and reduce property damage. Today, we will hear testimony from Dr. Clint Dawson of the Institute for Computational Engineering and Sciences at the University of Texas at Austin. Dr. Dawson will testify about his experience using "Ranger," the most powerful computer in the National Science Foundation's network of academic high-performance computers, to develop storm surge models to aid in the evacuation during Hurricane Ike.

Dr. Dawson's use of this supercomputer helped save thousands of lives and we need to continue to ensure that our scientists and first responders have access to the best tools possible to help protect both life and property.

I also look to hearing from our other witnesses to examine the most effective way to spend our Federal research dollars to both predict and prepare for future natural disasters.

Thank you again, Mr. Chairman, for holding this important hearing.

STATEMENT OF PROFESSOR CLINT DAWSON, JOE J. KING PROFESSOR OF AEROSPACE ENGINEERING AND ENGINEERING MECHANICS, DEPARTMENT OF AEROSPACE ENGINEERING AND ENGINEERING MECHANICS, INSTITUTE FOR COMPUTATIONAL ENGINEERING AND SCIENCES, THE UNIVERSITY OF TEXAS AT AUSTIN

Dr. DAWSON. Thank you, Senator Hutchison.

Thank you, Mr. Chairman and the members of the Committee, for the opportunity to speak with you today.

My research efforts are focused primarily on modeling and simulation of processes in the coastal ocean. The primary sources of Federal funding for this work are the National Science Foundation, the Department of Defense, and the Department of Homeland Security. And my group collaborates with a number of researchers at other universities, government laboratories, and state agencies. We utilize the computational resources of the National Science Foundation Teragrid and the Texas Advanced Computing Center, or TACC, at UT Austin. We have partnerships with the National Oceanographic and Atmospheric Administration, and we use NOAA products and data extensively in our research.

One of the main applications of interest of this research is the predictive simulation of storm surges due to hurricanes and tropical storms. By predictive simulation, I am referring to the development of computer models which can be used in real-time to forecast storm surge as hurricanes approach land, to study the impacts of historical hurricanes and attempt to reproduce actual measurements which were taken during the storm, and to study future scenarios, for reasons which I will discuss below.

The computer model that we have developed is called ADCIRC, which stands for Advanced Circulation Model. For hurricane storm surge simulations, this model takes input from various sources and computes water levels and currents driven by hurricane-force winds and waves. It's been used to study hurricanes for over a decade. It was used extensively in forensic studies of Katrina, as part of the Interagency Performance Evaluation Task Force, or IPET study.

As I mentioned, predictive simulation of storm surge can fall into three categories: forecasts, forensic studies, and future scenarios. Let me elaborate. In forecast mode, our model uses supercomputers, such as the Ranger computer at UT Austin, to generate a high-resolution forecast, typically within an hour. For a storm approaching Texas or Louisiana, this data is transmitted to the state operations center and the Texas Governor's Division of Emergency Management, which is responsible for emergency response, evacuation, search and rescue, and other operations.

In forensic mode, the ADCIRC model is used to analyze historical hurricanes. Here we attempt to match the output of the model with measured data, as was done for Hurricane Katrina. The hindcast studies help validate the predictive capabilities of the model, help to build understanding of complex physical processes which occur during hurricanes, help to quantify the vulnerability of coastal regions to storm surge, and can be used to understand the successes or failures of various protection systems.

Hurricane Ike is an interesting example of where new physical insight was gained through hindcasting. Ike produced a—what we call a “storm surge forerunner” of about 6 feet along the upper Texas coast 24 hours before landfall. A similar phenomenon was documented during the Galveston hurricanes of 1900 and 1915. Ike was very similar, in track and intensity, to these hurricanes. Our forecast model was able to reproduce this surge. And now that it’s discovered, future forecasts of similar storms will be able to predict this surge and to alert the public to the possible danger.

Finally, ADCIRC is run under various hypothetical scenarios to facilitate the planning and design of future protection systems and to help quantify risk in low-lying areas. Future protection systems include soft options, such as wetland restoration and restrictions on land-use practices, and hard options, such as the construction of seawalls, levees, and storm gates.

Are Federal investments paying off? Government funding of fundamental research in coastal ocean modeling can reap tremendous benefits by enabling economic activity, promoting healthy and sustainable coastal environments, improving the safety and well-being of coastal populations, and protecting critical infrastructure located on the coast. There are several future research directions which are critical to advancing the science, and government funding of the computational infrastructure available, for example, through the NSF Teragrid, and basic research funding in computational science and engineering, has paved a path toward revolutionizing the modeling of storm surge, and we are already reaping benefits in this area. As I mentioned, we are now able to do high-resolution predictions within the time-frame required by emergency managers. This would have been impossible 5 years ago.

Overall, however, in my experience, Federal funding for coastal ocean modeling research has been piecemeal across different agencies and focused more on the short term rather than long term. I would welcome any effort to promote longer-term, focused, sustained funding of research in this area.

With respect to storm-surge forecasting, it’s my opinion that future forecast models should be performed at the highest fidelity possible, given the computational resources available and the uncertainties inherent in any forecast.

There’s still basic research to be done to improve our understanding of winds, waves, and currents, and their interactions with coastal features and coastal structures. The ability of natural and manmade systems to withstand and possibly mitigate surge is not well understood, nor is the long-term impact of hurricanes on coastal ecosystems, geomorphology, and energy, communication, and transportation infrastructure.

All of these challenges are best met through knowledge and experience gained by theoretical research, experiments and computation in collaboration that involve multidisciplinary teams of investigators with connections to government laboratories, state and Federal agencies, and private industry.

Thank you.

[The prepared statement of Dr. Dawson follows:]

PREPARED STATEMENT OF PROFESSOR CLINT DAWSON, JOE J. KING PROFESSOR OF AEROSPACE ENGINEERING AND ENGINEERING MECHANICS, DEPARTMENT OF AEROSPACE ENGINEERING AND ENGINEERING MECHANICS, INSTITUTE FOR COMPUTATIONAL ENGINEERING AND SCIENCES, THE UNIVERSITY OF TEXAS AT AUSTIN

Thank you, Mr. Chairman, and members of the Committee for the opportunity to speak with you today.

My name is Clint Dawson. I am a Professor at the University of Texas at Austin (UT Austin). I am also the head of a research group called the Computational Hydraulics Group which is housed in the Institute for Computational Engineering and Sciences at UT Austin. Our research efforts are focused primarily on modeling and simulation of processes in the coastal ocean. The primary sources of Federal funding for this work are the National Science Foundation, the Department of Defense and the Department of Homeland Security. My group collaborates with a number of researchers at other universities, government laboratories and state agencies. These include the University of Notre Dame, the University of North Carolina-Chapel Hill, the U.S. Army Corps of Engineers Engineer Research and Development Center, and the State of Texas Division of Emergency Management. We utilize the computational resources of the National Science Foundation Teragrid, and the Texas Advanced Computing Center (TACC) at UT Austin. My collaborators have partnerships with the National Oceanographic and Atmospheric Administration (NOAA) and we use NOAA products and data extensively in our research.

One of the main applications of interest of this research is the predictive simulation of storm surges due to hurricanes and tropical storms. By "predictive simulation" I am referring to the development of computer models which can be used in real-time to forecast storm surge as hurricanes approach land, to study the impacts of historical hurricanes and attempt to reproduce actual measurements which were taken during the storm, and to study future scenarios for reasons which I will discuss below. The computer model we have developed is called ADCIRC, which stands for Advanced Circulation model. For hurricane storm surge simulations, ADCIRC takes inputs from various sources and computes water levels and currents driven by hurricane force winds and waves. ADCIRC has been used to study hurricanes for over a decade. ADCIRC was used extensively in forensic studies of Katrina as part of the Interagency Performance Evaluation Task Force (IPET) study. ADCIRC was able to match the data from this storm incredibly well, particularly high-water marks, which are measurements of maximum water level taken at various locations. Since 2005, the amount of data collected during Gulf storm events has increased substantially, and ADCIRC has been used to study several major storms, including Rita, Gustav and Ike.

As I mentioned, predictive simulation of storm surge can fall into three categories: forecasts, forensic studies, and future scenarios. Let me elaborate.

In forecast mode, the ADCIRC model uses supercomputers such as the Ranger computer at TACC to generate a high resolution forecast typically within an hour. These forecast simulations utilize the information coming from the National Hurricane Center, and are automated so that each time the hurricane forecast is updated, new storm surge predictions are generated. For a storm approaching Texas or Louisiana, this data is transmitted to the State Operations Center in the Texas Governor's Division of Emergency Management, which is responsible for emergency response, evacuation, search and rescue, and other operations. We work closely in this regard with Dr. Gordon Wells, who analyzes the results of forecast models to assist decisionmakers in the State Operations Center.

In forensic mode, the ADCIRC model is used to analyze historical hurricanes. Here we attempt to match the output of the model with measured data, as was done for Hurricane Katrina. These hindcast studies help validate the predictive capabilities of the model, help to build understanding of complex physical processes which occur during hurricanes, help to quantify the vulnerability of coastal regions to storm surge, and can be used to understand the success or failure of various protection systems. Hurricane Ike is a very interesting example where new physical insight has been gained through hindcasting. Ike produced a storm surge "forerunner" of about 6 feet along the upper Texas coast 24 hours before landfall. A similar phenomenon was documented during the Galveston hurricanes of 1900 and 1915. Hurricane Ike was very similar in track and intensity to these hurricanes. The forecast models used as Ike approached landfall did not predict this surge, it was only after careful hindcasting using the ADCIRC model that the cause was discovered. Now that this phenomenon is understood, future forecasts of similar storms will be able to predict forerunner surge and alert the public to the possible danger.

Finally, ADCIRC is run under various hypothetical scenarios to facilitate the planning and design of future protection systems and to help quantify risk in low-lying areas of the coast. These studies are used to develop Digital Flood Insurance Rate Maps (DFIRMS), for example, which determine eligibility for Federal flood insurance. Future protection systems include "soft" options, such as wetlands restoration and restrictions on land use practices, and "hard" options, such as the construction of seawalls, levees and storm gates. ADCIRC has been used to model the effectiveness of all of the new levees which are currently under construction in Louisiana. In the aftermath of Hurricane Ike, many different options are being considered for protecting the Houston-Galveston region. One option is the so-called "Ike Dike," which was proposed by Prof. William Merrill at Texas A&M University at Galveston. Other options which have been proposed include building gates which would protect the Houston Ship Channel, designating large parts of the coastal region around Galveston and Bolivar as a National Seashore and Recreational Area, building oyster reefs offshore near critical infrastructure, just to name a few. We are working with the Severe Storm Prediction, Education, and Evacuation from Disasters (SSPEED) Center at Rice University to study these various protection systems, using high fidelity numerical simulations and hypothetical hurricane scenarios.

Are Federal Investments Paying Off? Government funding of fundamental research in coastal ocean modeling can reap tremendous benefits by enhancing economic activity, promoting healthy and sustainable coastal environments, improving the safety and well-being of coastal populations, and protecting critical infrastructure located on the coast. There are several future research directions which are critical to advancing the science. Government funding of the computational infrastructure available through the NSF Teragrid, and basic research funding in computational science and engineering has paved a path toward revolutionizing the modeling of storm surge, and we are already reaping benefits in this area. As I mentioned above, we are now able to do high resolution storm surge predictions within the time-frame required by emergency managers. This would have been impossible 5 years ago. Overall however, in my experience Federal funding for coastal ocean modeling research has been piecemeal across different agencies and focused more on short term projects rather than long term priorities. I would welcome any effort to promote longer-term, focused, sustained funding of research in this area.

With respect to storm surge forecasting, the standard hydrodynamic model which has been used throughout the United States has been the Sea, Lake and Overland Surge from Hurricanes (SLOSH) model which is run at the National Hurricane Center. SLOSH was developed many years ago. Currently, NOAA is re-evaluating SLOSH along with other computer models, including ADCIRC, to determine which model or models to use for future storm surge forecasting. It is my opinion that future forecast models should be performed at the highest fidelity possible given the computational resources available and the uncertainties inherent in any hurricane forecast. We must attempt to quantify these uncertainties where possible. It is also important that we work closely with emergency management personnel to understand the type of information that is needed and to develop ways in which risk can best be conveyed to the public.

There is still basic research to be done to improve our understanding of winds, waves and currents and their interaction with coastal features and coastal structures. The ability of natural and man-made systems to withstand and possibly mitigate surge is not well understood, nor is the long-term impact of hurricanes on coastal ecosystems, geomorphology, and energy, communication and transportation infrastructure. The coastal population and economic activity along the coast continue to grow and expand, and policies for managing coastal development are required sooner rather than later. If recent history is any indication, no coastal protection system will be completely fail-safe over the long term, and in the event of disaster the resilience of coastal communities will determine their future. All of these challenges are best met through knowledge and experience gained by theoretical research, experiments and computation, in collaborations that involve multidisciplinary teams of investigators, with connections to government laboratories, state and Federal agencies and private industry.

The CHAIRMAN. Thank you. We'll start on the questions.

It's such a profound subject. And one of the things that interests me most is how little people know about it and, actually, how little people think about it.

Dr. Hooke, you made an interesting observation, in your testimony, that 85 percent of businesses that are affected by a disaster close their doors and don't reopen it. Now, a lot of things come to mind. Americans tend to think of earthquakes, like—Japan really kicked that off, obviously—but, we tend to think of the absolute calamities. And the research that's being done on that is incredibly important. But, I'm thinking about 85 percent. That would not be an earthquake; that would be some kind of other flooding, or whatever, event.

The—what I'm really trying to get at is, How can you prepare? Or do we have to say, at some point, that you can't prepare? I think I heard on the news yesterday, somewhere, that in Iowa they've just blasted down a whole bunch of levees which they put up for the purposes of defending against flooding.

Senator BOXER. Missouri.

VOICE. Missouri.

The CHAIRMAN. Missouri. And so, the—you know, hundreds of thousands of acres are getting flooded. And that's kind of what I'm talking about, that we cope as best as we can. We see images of people piling sandbags on sandbags.

The question, Doctor, that you mentioned, about the structure of buildings—I mean, that's—the Japanese are really good at that because they have something like 3,000 earthquakes a day; obviously, most of them very small. We aren't good at that. I think, Mr. Ryan, in my own state, we've had so many floods I can't even count them. And houses get washed away up and down various rivers. And people don't leave. They might leave temporarily, but they always come back. And they do rebuild. Hence, back to your small business.

What is the psychology, what is the practicality of how we can defend against these things which we—even if we can predict them—because, even if we can predict them, what use is it unless we can abate their effect, which, it occurs to me that we're not very good at? I've thrown a bunch of things at you.

Dr. HOOKE. You sure have.

[Laughter.]

Dr. HOOKE. OK? And I went into science because baseball wasn't my strength. So—anyway. Thank you for those insights. And I think you're absolutely correct.

So, here's the starting point. The starting point is that we have some very humble objectives. We want to live a little better. We'd like a nice quality of life. You know, we aspire to a good life for our kids, and so on. But, we are trying to do this on a planet that does its business through extreme events. So, when Anne talked about earthquakes, you know, you can go to your science class and learn about continental drift. And you find, in some parts of the world, that hurricanes are providing about a third of the total yearly rainfall. And so, these severe events make up what is really the planet average. And yet, what we do is, we see these events as somehow suspensions of the natural order. So, you know, I have 100 straight days where the sun shining or there's a little bit of rain or something, and then all of a sudden the heavens open. So, we're not very good at rare high-consequence events.

The 85 percent of the small businesses that don't reopen after they close their doors, they have a variety of causes. Their business may be OK. It may be on dry ground. The business may have survived. But, their whole customer base disappeared. So, you have a restaurant that specializes in Asian cuisine, but suddenly everybody is spending their money at Home Depot. So, it's very complicated. Alternatively, all the customers could still be there. They could be whole, but your business was in the flood plain, some— you know, down by the river. And so, it's fairly complex.

Another example, if you think about the homes we build, you can look at mobile homes or manufactured homes, and they're especially vulnerable. But, they're the only way to homeownership for large fractions of people. And for, you know, 100 years of the life of a building, the job of the walls is to keep the roof up. And for maybe a day out of that 100 years, the job of the walls is to hold the roof down. And we don't put in the hurricane straps or whatever we need.

That's a long answer, but you ask a complicated question.

The CHAIRMAN. Well, I also ran out of time.

[Laughter.]

The CHAIRMAN. So, Senator Hutchison.

Senator HUTCHISON. Well, thank you, Mr. Chairman.

I have introduced, in the last two sessions, weather modification legislation; not to do it, but to start doing research to determine if there is a benefit to trying to modify the ferocity of tornados and hurricanes, if it can be done. And if it is done, does it affect other areas? I think that we should have the research to start determining that.

My question is, probably to Dr. Hooke or Dr. Dawson, do you think that this is an area we should pursue? Can it be done computationally with any degree of accuracy? And how would you pursue trying to determine a way to mitigate the enormous damage we're seeing now, which seems to me so different from the past?

I grew up in Galveston County. So, I've seen the hurricanes. But, we never had hurricanes like Katrina or these Alabama tornados. The damage just seems to be so much more, and the ferocity seems to be so much more, in the last 10 years than it was in the previous era.

So, with that, would research help? Could it be done with computers? And where would you go from here, in your judgment?

Dr. HOOKE. If we could. I'd like to begin by suggesting that Bob Ryan be brought into this conversation, because, in his graduate work, he actually worked for one of the leading lights in weather modification, up——

Senator HUTCHISON. Wonderful.

Dr. HOOKE. Let him tell you that story.

Mr. RYAN. Bernie Vonnegut was—had discovered the use of silver iodide. And before him, Vince Schaefer had done the first weather modification experiments at—under Irving Langmuir, at Schenectady.

Senator HUTCHISON. Great. I'd like to hear from anyone who has an opinion.

Mr. RYAN. And one of the things, I think, to address that is that I think all research meteorologists would agree that the more we can understand what is going on, and the more we understand the process that initiates, let's say, hurricanes, and how these go through lifecycles—and tornados, the better understanding we can have of the fundamental science—and I would dare say that, before we can really have an intimate and detailed understanding of the lifecyle of some of these even very small-scale but extreme events, that we're not in a position to then say, "Let's try and do something to mitigate." We have to do everything, I think, first, that we can do to create an environment where people take action. And it's interesting, the convergence of the structure issue for earthquakes and also, as Bill mentioned, for tornados. Forty-four percent of the fatalities in tornados occur with people who live in mobile homes. So, there is that, to that issue of, How can we ensure that the structures that people are living in, and certainly given the economic times, are able—and we have communities where these people can seek a secure shelter for whatever natural disaster comes, whether it be an earthquake or a tornado or a flood.

But—the basic science has made tremendous advances, but there are still many, many unanswered questions. And I think the more that we can understand the evolution and the lifecycle and the details of what's going on, then, at some point in the future, we may be in a position to begin to take—and try to interfere a little bit and at least mitigate the maximum impact on population centers.

Dr. HOOKE. If I could say just a word about your second point, which had to do with the growing severity, apparently, of events of this sort.

So, really, we're ratcheting up, slowly, day by day, our vulnerability to events all over this country, whether it's mudslides off Mt. Ranier or hurricanes on the Gulf Coast or tornados in between. And what's happening is, nobody wakes up in the morning saying, "I think I'm going to increase the vulnerability of my city or my county or my state to these events." But, what—we make decisions in favor of business development, of needs for today. And we may be compromised at the tenth-of-a-percent level. And we go home every one of these days saying, "That was a pretty good day." But, the accumulated burden of all the slight compromises, not intent or people looking the wrong way or anything of that sort, that adds up, over the time scale for the return of these events, to tremendous vulnerability—levees that are not built well in New Orleans or, as Anne was saying, infrastructure that was 30 years old or 70 years old. You know, it's that kind of effect.

Senator HUTCHISON. Doctor?

Dr. DAWSON. I would just add one thing. With respect to hurricanes, people focus a lot on the intensity of the hurricane. But, in the last few hurricanes that have been the most destructive, such as Katrina and Ike, those were not very intense hurricanes when they actually made landfall. So, we need to understand that the storm surge associated with the hurricane may have absolutely nothing to do with the intensity of the hurricane. It has a lot more to do with the size of the storm and how long it has been churning and the—you know, the radius of the storm and so forth.

So, with respect to hurricanes, I just want to caution people to—you know, to step back a second and realize that it's not just the intensity of the storm that matters, but the size of the storm, and other factors, that contribute to the actual flood.

Senator HUTCHISON. Thank you.

The CHAIRMAN. Thank you.

Senator Klobuchar.

STATEMENT OF HON. AMY KLOBUCHAR, U.S. SENATOR FROM MINNESOTA

Senator KLOBUCHAR. Thank you very much, Mr. Chairman. Thank you, all of you.

I just returned from the Grand Forks area, where we share a border with North Dakota, and barely missed visiting the Mayor of Oslo, Minnesota, population 345, in a boat, because of the fact that their entire town is ring-diked, and that's the only way they survived the floods.

Just a few things. I've been amazed at the help of weather forecasts and water-level forecasts and the difference it has made in flood preparation in Fargo and Moorhead. Literally, Saint Paul, Minnesota, decisions were made this time, because we've had so much flooding, how high the sandbags have to be, how big the wall needs to be, completely based on these forecasts that change daily. And they are completely dependent on them. It made a huge difference in reducing damage, reducing the loss of life. So, I'm a big fan of what the weather bureau is doing.

Same with the tornados. We had one town this summer, Wadena, Minnesota, a mile wide of complete decimation, a public high school, where the bleachers were found two blocks away. It's like a bomb had gone off in it. Not one person died in that town. This was all neighborhoods. They got the warnings. The sirens went off, I think, 25 minutes ahead of time. A pool with 40 kids with only high school life guards, the neighbors were able to pick up all the kids, and the five that were left that their parents hadn't come, the high school kids brought them across the street to a basement. All of this was because of emergency warning systems. Clearly, we had better basements and more basements than they did, sadly, in the South. But, it made such a difference.

And then, finally, some unique things we're doing with floods now. Literally 24/7, there are cameras on the flooded areas in towns all over our state so citizens can actually watch the river so they make prudent decisions. They can actually make their own decisions. They see where the river is. They're watching it, at certain points, on the Web, live, at every minute. These are even small towns, they're doing this, as well as the power of the broadcasts, where, in Fargo and Moorhead, they actually break in live every single day leading up to the flood moment, for an hour in the morning, so that the citizens get full report on radio and TV.

So, I guess my first question would be of you, Mr. Ryan, from your perspective of a private partner in disaster preparedness, Where do we excel? Where do we fall short in communicating severe weather to the communities?

Mr. RYAN. Well, thank you very much, Senator. And I—you know, I think it's—for those of us—Bill and myself, who have been in the field of meteorology for a bit, it is satisfying to be able to see the advances in the science and the application and now the real utility in life-saving events, and having it not only be a benefit to the public, but to the economy, too.

I think, as you point out, we're using, now, modern technology, things like live webcams, to help people make the best decision. And I think that's the area that is probably most exciting, going forward. And when we talk about the storm surge or earthquakes or a tornado outbreak like last week, we're really thinking of a—still a small area, even though it impacts hundreds of thousands of people, but that also are still very rare events. And how can we best communicate these perhaps once-in-a-lifetime events that people have never experienced before correctly so that they still make the best decision?

We saw that in Katrina. There was a tragic example of a family that had a storm cellar, in Alabama—invited their neighbors into the storm cellar when the warning was out, and the neighbors said, "No, we'll ride this out." They did not ride it out. The family that went into the storm cellar survived. Once-in-a-lifetime event. And so, we have, I think, as an enterprise, a job to do involving probably bringing in the social sciences and social science expertise in how people make decisions and how we can best communicate some of these rare events graphically, using some of the new communication technologies and, of course, the broadcasts, to help people make the best decision.

Ultimately, as I mentioned, we can have a 100-percent accurate forecast and a bad decision. The forecast has failed.

Senator KLOBUCHAR. Right. And then, Dr. Hooke, you talked about some of the investment in studying some of these past disasters. I can tell you, Austin, Minnesota, had some bad floods. They employed flood mitigation, got a grant, moved hundreds of houses. One guy decided to stay. He wouldn't take the deal. He's the house that got flooded when those Iowa floods came. And so, I'm a big believer. And it is very difficult for the cities to make these decisions, but it saves so much money in the long term. Could you talk a little bit about the mitigation issue?

Dr. HOOKE. OK. And I also think that Anne talked quite a bit about that——

Senator KLOBUCHAR. OK.

Dr. HOOKE.—as well. So——

Senator KLOBUCHAR. She can answer.

Dr. HOOKE.—why don't we go ahead and talk about the earthquake issue, because it's quite related to the weather and flooding issue.

Dr. KIREMIDJIAN. Thank you. Earthquake mitigation has been taking place systematically. But, we have to recognize that it is a very expensive process. Let me give you the example of Stanford University. We've been upgrading and replacing and repairing our buildings for, now, more that 20 years, at the cost of $200 million a year. Mitigation strategy—there are no specific mitigation policies for earthquakes that are in place. There was one policy that was in place in San Francisco and in Los Angeles to identify all unreinforced masonry structures. And there were provisions made for owners to upgrade and retrofit those structures. And I think we have succeeded in that effort. But, to upgrade all the remaining structures and the infrastructure that is out there——

Senator KLOBUCHAR. If I could—I think what I'm talking about is a little different. I'm talking about houses in the Midwest that are just moved or they are——

Dr. KIREMIDJIAN. Yes.

Senator KLOBUCHAR. But, they are——

Dr. KIREMIDJIAN. Yes. I'm sorry, I don't have experience with that. So, maybe I'll divert the question to——

Senator KLOBUCHAR. I know. That's what I mean. It's a lot less expensive. These are houses, maybe——

Dr. HOOKE. When you rebuild——

Senator KLOBUCHAR.—$50–$100,000 homes——

Dr. KIREMIDJIAN. Yes.

Senator KLOBUCHAR.—that are simply moved to a different part of town. They're put on the back of a truck. And it's just a lot cheaper. And they have beautiful parks, then——

Dr. KIREMIDJIAN. Right.

Senator KLOBUCHAR.—on the river. And it's expected to actually flood on those parts instead of losing all these homes——

Dr. KIREMIDJIAN. Right.

Senator KLOBUCHAR.—loss of life, those kinds of things. So, I believe you about the earthquakes, but I——

Dr. KIREMIDJIAN. Right. We can't move the buildings for earthquakes. It won't help.

Dr. HOOKE. Well——

Senator KLOBUCHAR.—the towns on the river need to look at more across the country.

Dr. HOOKE. In both cases, it's a matter of culture and values, though, isn't it? So, if we want a big house, and we want kind of a showcase, and we like some of the jazzy features, we go for that. Or maybe, we're thinking about the safety of the kids and whether we're putting our kids to bed in the flood plain at night, or—you know, call yourself a parent and doing things like that—not so good. But, we can change that culture.

One way to do it—and I was kind of encouraged on this by my staff, and I didn't follow it, to my regret, now, in the notes here—was talk a little bit about STEM education and earth sciences for kids in public school, because they're a great way into each household and developing this culture and this set of values.

Senator KLOBUCHAR. Thank you very much, to all of you.

The CHAIRMAN. Senator Boxer.

Mr. RYAN. So often the children and the students take home important messages for their parents. And we've had a number of examples where the young people have made the proper decision for their family, and ended up saving lives. Education is certainly important.

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

Senator BOXER. Thank you——

The CHAIRMAN. Senator Boxer.

Senator BOXER. Thank you, so much.

Thank you for holding this hearing. And I'm proud that you're—you've joined with me and Senator Cantwell to sponsor the Natural Hazards Risk Reduction Act of 2011, which will reauthorize, for 5 years, some very important programs that deal with national earthquake hazard reductions and windstorm impact reductions.

And I'll put the rest of my statement in the record, if I might. And I'd just summarize here. Is that OK?

[The prepared statement of Senator Boxer follows:]

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

Mr. Chairman, thank you for holding this important hearing today to examine Federal efforts to prepare for natural disasters and the Boxer-Cantwell-Rockefeller Natural Hazards Risk Reduction Act of 2011.

My state is no stranger to natural disasters. Californians understand that it is a matter of when—not if—the next major earthquake will strike.

According to the U.S. Geological Survey, there is a 99 percent chance that California will suffer a magnitude 6.7 earthquake within the next 30 years.

This is comparable in size to the earthquakes that struck San Francisco in 1989 and Los Angeles in 1994. Together these earthquakes killed 120 people and caused tens of billions of dollars in damage.

The horrific March 11 earthquake in Japan is a stark reminder to my state of the potential for destruction and the importance of preparedness.

But, no part of this Nation is immune from the devastation caused by natural disasters. Tornados, hurricanes, earthquakes, and wildfires are a constant threat to human life.

Just last week, at least 342 people were tragically killed when a record number of tornados ravaged several southern states.

To address these threats, we must invest in programs that minimize risks and mitigate damages so our communities can better withstand these types of natural disasters.

That is why I am proud to sponsor the Natural Hazards Risk Reduction Act of 2011.

This legislation will provide a 5-year reauthorization of the National Earthquake Hazards Reduction Program (NEHRP) and the National Windstorm Impact Reduction Program (NWIRP).

These programs are designed to mitigate earthquake and windstorm hazards through research, development, technology transfer, and outreach activities.

The National Earthquake Hazards Reduction Program develops earthquake research, seismic building codes, and increases awareness of the threat of earthquakes.

The National Windstorm Impact Reduction Program works to improve knowledge and awareness of windstorms, and develop wind-resilient designs that can be incorporated in the construction of buildings and infrastructure.

This is a wise investment of Federal funds. Not only does it save lives, but the Congressional Budget Office estimates that for every dollar invested in disaster mitigation, three are saved by reducing future damages.

I want to thank our distinguished panel for joining us today, including Dr. Anne Kiremidjian, a Professor with the Department of Civil and Environmental Engineering at Stanford University who will testify on earthquake hazards and risk mitigation.

Thank you, Mr. Chairman.

Senator BOXER. Mr. Chairman, I came to the House of Representatives in 1983, and since that time, California has experienced 31 significant earthquakes. Significant earthquakes. And, out of those, nine had deaths associate with them. The most deaths, I think people know, were Loma Prieta, in northern California, and Northridge, in southern California. Between the two, 123 deaths. So, when we talk about hazards, we talk clearly about saving lives. And we see we lost 342 people in the South; there are still people missing. No part of this Nation is immune from devastation of one kind or the other.

But, I am going to just focus in on earthquakes with the good doctor from Stanford and ask you this. Earthquake early warning systems, this is something that I—you know, I'm hoping, in my lifetime, to see. I know that we're testing and evaluating them right now. Could you give us a report as to how soon we could expect those to be deployed in a larger scale?

Dr. KIREMIDJIAN. I think the technology is being worked on right now. We have made advances. We have to remember that earthquake warning will help, primarily, lives—save lives. They will not help with preventing damage to infrastructure. In that respect, they are really important. How far along we are? I think we are getting closer every day.

Senator BOXER. Give me an idea of what you're looking at. We're looking at years to have this? Are we looking at months to have this? Are we looking at a decade to have this? What do you see?

Dr. KIREMIDJIAN. My estimate, from whatever I know, I would say 3 to 5; at most, 10 years.

Senator BOXER. OK. That's good news.

Let me ask you this question. And I don't mean to put you on the spot, but I'm going to. We have two nuclear powerplants in our state——

Dr. KIREMIDJIAN. Right.

Senator BOXER.—that are located on or adjacent to fault lines that are very dangerous. And, you know, after looking at the—what happened in Japan, these two plants are up for reauthorization. Just as a scientist, without any agenda—you know, for me, I'm looking at it.

One of my plants, Mr. Chairman, has 7 million people living within 50 miles, which is the area that——

Dr. KIREMIDJIAN. Diablo Canyon.

Senator BOXER.—evacuated in Japan. And the other has a half a million people.

So, do you have concerns about these plants?

Dr. KIREMIDJIAN. I would say that those plants have been evaluated and reevaluated and reevaluated. What would concern me is that they are such complicated systems that there's always some chance of something going wrong. And it can be due to the earthquake, but it can be also due to human error.

How do we prevent that? We have to be vigilant. We have to study the systems continuously. My understanding is that—and actually, one of my very first consulting jobs was on the Diablo Nuclear Power Plant, after finding the existence of the Hosgri Faults——

Senator BOXER. Yes.

Dr. KIREMIDJIAN.—some 7 kilometers away from it. And we did look at the type of ground motions that we might expect. We have learned a lot more. And, based on my understanding—I haven't kept up with it all these years—but, based on my understanding, those plants are being reevaluated every 2 or 3 years. From earthquake safety point of view, I think the structures—the containment structure has been designed very appropriately, and I don't expect to see any damage. What would worry——

Senator BOXER. Well, is——

Dr. KIREMIDJIAN.—me are other things.

Senator BOXER. Wait a second.

Dr. KIREMIDJIAN. Yes.

Senator BOXER. You're right. They were designed to withstand a certain earthquake——

Dr. KIREMIDJIAN. They were——

Senator BOXER.—size.

Dr. KIREMIDJIAN. Yes.

Senator BOXER. But, they were not designed to protect against larger earthquakes, which are now predicted. So, I think—could we follow up? Can I follow up with you on these? Because, I think——

Dr. KIREMIDJIAN. Absolutely.

Senator BOXER.—it's very serious. Because, when you say they've been evaluated, they have not done the 3D evaluation that needs to be done. They are now agreed, finally, to do that, when the state said they would not allow NRC to reissue the license. So, can we follow up on this? Because, I—this is very—I mean, when we talk about this, we're talking about millions of people.

Dr. KIREMIDJIAN. Correct.

Senator BOXER. And that's my concern. I mean, whether the—if the building is still standing there is one thing. It's what happens to the radiation.

Dr. KIREMIDJIAN. Right. That's—I was just about to say that the——

Senator BOXER. And the tsunami——

Dr. KIREMIDJIAN.—building would stand, but what happens to all the systems within the building—the cooling system, the backup generators.

Senator BOXER. Right.

Dr. KIREMIDJIAN. One of the reasons why the Daiichi Nuclear Power Plant suffered the damage was because their backup generators were damaged.

Senator BOXER. Exactly.

Dr. KIREMIDJIAN. And so, we need to look at the entire system and all of its components and how they work together. And that evaluation, I believe, needs to be done——

Senator BOXER. Good.

Dr. KIREMIDJIAN.—again in a much more detail.

Senator BOXER. Well, I'm glad you said that. And also, the tsunami threat, particularly for——

Dr. KIREMIDJIAN. Yes.

Senator BOXER.—San Onofre.

Thank you so much. And I look forward to getting our legislation moving. Because, for every dollar we spend, we save three.

Dr. KIREMIDJIAN. Four.

Senator BOXER. So, good investment. Four?

Dr. KIREMIDJIAN. Right. Well——

Senator BOXER. Wow.

Dr. KIREMIDJIAN.—we save three.

The CHAIRMAN. Well, I have to actually——

Senator BOXER. OK.

Dr. KIREMIDJIAN. After we take the one out.

The CHAIRMAN. I beg forgiveness——

Senator BOXER. Very good.

The CHAIRMAN. We have to be in our seats at 3:30 for a highly symbolic and important vote. If you're willing to wait—yes—we'll come back.

VOICE. Sure. All right.

The CHAIRMAN. OK?

VOICE. It's a deal.

The CHAIRMAN. So, this hearing is temporarily recessed.

[Recess.]

The CHAIRMAN. We will resume our hearing. And it—I'm sorry, the vagaries of the Senate, which are many—some good, many bad—are in operation this afternoon. So, this cannot be very long. And I say that with sorrow, because you are all so good and because the subject is so important and complex.

I don't think most people know that the Commerce Committee has a whole subcommittee and group of experts who deal with exactly what we're talking about, and—you know, the whole question of funding and what will NOAA have, what will the National Weather Service have. All of these are so important.

I want to ask a—what will sound like a controversial question, but I'm just plain curious. The question of global warming has its place. I happen to believe in the science of global warming, and I do believe that part of our problems are created by people. And—but, I don't know to what level that reaches. For example, I can't imagine that it creates an earthquake or, you know, the shifting of plates and things of that sort. But, I'm just curious if carbon emissions, at some point, create havoc with, for example, weather patterns or the shifting of, I don't know, heat sections from here to there, or whatever. Who would like to answer that?

Mr. RYAN. Kevin Trenberth, who is a eminent researcher at NCAR, points out—and I think it's fair to say that—and we tend to think of—for those of us in the meteorological field—that weather and climate are separate. They are not. You know, we love to say that weather is what you get and climate is what you expect. But, the two are integrally linked. And indeed, if, as the overwhelming number of climate scientists, scientists working in this field, believe that we are seeing the very distinct footprints of man's influence on the climate, then there is part of climate change. And I really, when I talk to the general public, prefer to talk about climate change, because it involves many more things than just global warming—changes in land use, changes in ocean acidification.

So, there is part of—Kevin believes—part of the global change, climate change, in weather events. If the amount of water vapor—moisture—in the atmosphere is increasing in a warmer world, then that increases the probability of more severe or high precipitation events which could lead to more—a higher probability of localized flooding.

The CHAIRMAN. In that that has taken place measurably, are there—have there been incidents which you can tie, at least cerebrally, to, you know, carbon emissions?

Mr. RYAN. I think—I don't think anyone would be comfortable saying that there is one weather event that we can pin on man's influence on the climate. However, in the instances where we're dealing with storm surges and with inundation in a world, let's say, 50 to 100 years from now, I think it's fair to say that the probabilities of more coastal communities being at increased risk for having a once-in-a-lifetime inundation and flood is probably increasing. And the probabilities—we all deal with probabilities—and certainty—unfortunately, the certainty may be there when we're out at 50 to 100 years. The climate doesn't respond to us turning off our lights all at once. It takes a long time to adjust to significant changes in long-term patterns, which may be changes in Earth orbits, the makeup of the atmosphere. It will take a long time to respond to anything that we do to change in, let's say, a positive way in mitigation, rather than it adapting to a changing world.

The CHAIRMAN. I thank——

Dr. HOOKE. Mr.——

The CHAIRMAN.—you. I want to ask one more question.

Dr. HOOKE. Mr. Chairman, if I could——

The CHAIRMAN. I'm sorry.

Dr. HOOKE.—just add to that, because I think it's a very important question, and——

The CHAIRMAN. I do, too.

Dr. HOOKE.—Bob gave a good answer. But, it—we talked, a little bit ago, about how climate is an average of cycles of flood and drought. So, the Earth is doing its business through these extremes. And what we call the average is very difficult to actually measure or compute, given that there are cycles of hot and cold, and wet and dry, and so on. So, if you think about sort of a four-star kind of restaurant guide to climate science, and you give four stars to things that everybody agrees on, and fewer stars to things that people have trouble with, everybody would give four stars to the idea that greenhouse gases are going up and four stars to the idea that, on the average, that creates a little warming. But, when it comes—and everybody would say, "We know that this warming will have some effect on storm tracks, storm intensity, storm duration—all those aspects." But, then when it comes to what kind of effect that would be, that's where the real uncertainty is.

The CHAIRMAN. Understood.

I'm pushing a bill very hard—in fact, it's my number-one priority—and I'm curious as to your reaction to it, because I think it would be favorable. It strikes me that—just the four of you, it's sort of like you work together anyway. You phone call each other every day and exchange information. And I'm sure that's not true. But, that's the appearance of it. In other words, there's a kind of a common path that you all are walking.

We—9/11 is coming up, the tenth anniversary, very shortly. And, you know, it was made famous in—at Kuwait, when the Army and the Navy and—you know, nobody could communicate with each other, because they all had different communication wavelengths and sets. And it turns out that 10 years—almost 10 years after 9/11, first responders, from firefighters to police officers to sheriffs to hospital folks—you know, everybody who is involved with trying to protect the public—they're in the same situation. States do it state by state, and some don't do a very good job at it. They take little nuggets of a piece of spectrum and apply it to something, and it's not efficient.

Now, my bill would—our bill would make 10 megahertz, which is referred to as the "D block," of spectrum available, on an interesting basis. Users of spectrum, on a voluntary basis, could return to the government the spectrum that they are not using. This would not be mandatory, but it would be voluntary. It works much better if it's voluntary. And, from that, you get the White House and others—figure between 28 and 31 billion dollars.

Now, what you can do is use that for a variety of purposes. One is, you can—we will definitely have, and it's in our bill, a spectrum auction so that people can buy back or buy those pieces of spectrum that they want. And then the question would be, What would be the priority? The main priority, from my point of view, would be to have a entirely nationwide single interoperable wireless broadband communications network in which, yes, everybody would have to have new hand-held sets—they would be different; they would cost several thousand dollars. But, everybody, absolutely everybody in the national safety network would be on exactly the same wavelength.

I can't think of going into 9/11—the 9/11 Commission charged us to do this—without having done that. And it can be done for, some would say, $10–, $11–, $12 billion. But, you see, if you're going to get 28 to 31, you've got some margin. You need to put some research into that. You need to do some upgrading of technology, as it happens, for that. And then you can also probably use $9– or $10 billion of that for deficit reduction. Originally, that was what everybody wanted to do, just get it all and then use it all for deficit reduction.

But, the 9/11 compulsion and moral obligation is overwhelming. And so, some of us are pushing very, very hard for this purpose. All mayors, all police officers, all public safety officials, all Governors—you know, everybody is for it. It doesn't mean it'll pass, but it's—the President's strongly for it, the FCC is for it—was a little bit skeptical at first, but is now very much for it. So, in other words, all the pieces are in place.

And what I'm obviously rather blatantly doing is asking you whether you think it's a good idea.

Mr. RYAN. Why is everybody looking at the broadcaster?

[Laughter.]

Mr. RYAN. I think communication, which I had talked about, is critically important, going forward—how we make decisions, how we can help the emergency managers better communicate and better prepare for these extreme emergencies, whether they be natural or manmade. And anything that, I think, allows for a wide and effective communication across multi-agencies that will then better serve the public, I think would certainly be supported.

On the other hand, we who are an integral part of communication in weather emergencies or other extreme events feel that we have, certainly, our public obligation, as holders of the—part of the public spectrum, too, to then serve the public. And, as we saw in the example that I cited, of last week, with broadcast meteorologists being on the air sometimes 15 hours straight, and those are the last stop, if you will. Those are the people that still, in this day and age of hand-held devices and mobile devices and multi-frequency and laptops and so forth, still turn on the TV to see the person that is in their community, that they know and trust, to help them make a decision.

So, I think it has to be—certainly, I agree with you 100 percent, but we still communicate best one-to-one and help each other make decisions. And the current system is still an integral part of what would be a great step forward in coordination, if you will, of communication of emergencies and emergency information. But——

The CHAIRMAN. Mr. Ryan, I mentioned, I thought rather forcefully, the use of the word "voluntary"——

[Laughter.]

The CHAIRMAN.—and that really is the key to it.

Mr. RYAN. Yes.

The CHAIRMAN. In other words, you really do have, in states, when the—for example, West Virginia and Ohio can't talk to each other.

Mr. RYAN. Right.

The CHAIRMAN. It's embarrassing. But, the state has a system, and it's a—little bits of spectrum here and there. And it's not fully functional. It's not subject to the larger national approach. So, I'm going to put you down as a yes.

[Laughter.]

Dr. HOOKE. I was going to say, it's——

The CHAIRMAN. The networks have no problem with this.

Dr. HOOKE. It's easier, from my perspective, to be enthusiastic about this. As long as I can remember, everyone in the hazards community—and I think Anne's going to——

Dr. KIREMIDJIAN. Yes.

Dr. HOOKE.—say something similar—is—this has come up in every kind of disaster, that people have looked at the emergency response and it's like a Tower of Babel out there; you've just got people who cannot reach each other, there's no set of protocols, and so on. And it's important, I think, that the Senate take some step to start a national exploration of—you know, the chances of getting something as complicated as that correct the first time are slim, but if you put it into place, you can quickly refine it and improve it, and it would be wonderful to be better off 10 years from now than we are today with regard to this issue.

The CHAIRMAN. Thank you.

Dr. HOOKE. And so, put me down for a yes.

The CHAIRMAN. I will do that.

Dr. KIREMIDJIAN. I think Bill articulated it very well. And I will just add that I'm surprised that we haven't done anything yet, that we're still talking about doing it. I was under the impression that we are already doing that.

The CHAIRMAN. We're not.

Dr. KIREMIDJIAN. I am shocked and disappointed. But, I'm glad to see that you're pushing for it.

The CHAIRMAN. Good.

Dr. Dawson.

Dr. DAWSON. Well, I work with people, indirectly, through the state operations center at—in the Texas Governor's Division of Emergency Management. And I'm sure that they would support this. For example, as you mentioned, West Virginia and Virginia can't talk to each other. Well, neither can Texas and Louisiana. And in a hurricane situation, it's—that has been quite disastrous.

The CHAIRMAN. I have a very unhappy Senator from the State of Florida who is looking at—I am—that I've gone almost 8 minutes over my time. But, I now yield, dutifully, to him.

STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Senator NELSON. Do I look unhappy, Mr. Chairman?

[Laughter.]

The CHAIRMAN. You never do.

Senator NELSON. Well, may I enter a opening statement for the record, please?

The CHAIRMAN. Absolutely. It's—it is entered.

[The prepared statement of Senator Nelson follows:]

PREPARED STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Mr. Chairman, I am glad that we are discussing a concern that is so important to the folks of my State of Florida and throughout the country: the possible devastation that natural disasters such as hurricanes, tornadoes, and earthquakes can leave. And tragically, we have witnessed some of devastation play out over the past weeks with the deadly tornadoes throughout Alabama and the south, the March 2011 earthquake in Japan, and the approaching the 2011 hurricane season, where scientists predict 16 named tropical storms, 9 of which to become hurricanes.

Damage from natural disasters is certainly not new to Floridians. On September 1926, the Great Miami Hurricane was an indication of things to come. Two years later, a category four hurricane caused Lake Okeechobee to flood its banks killing 2,500 out of South Florida's 50,000 residents. In August 1992, Hurricane Andrew struck South Florida causing an estimated $26 billion in damage to the United States. In August of 2005, we all know the destruction Hurricane Katrina caused through Gulf Coast region, causing more than $91 billion in economic losses, forcing more than 770,000 people from their homes, and killing an estimated 1,833 people.

The sheer magnitude of this loss is staggering and underscores the need for increased funding for hurricane research and improved forecasting. But hurricanes and natural disasters do not just affect those living along the coasts. These extreme events have national consequences from increased fuel prices to severe inland flooding.

Improvements in track and intensity forecasts mean better preparedness for coastal and inland communities, saving lives and reducing devastating impacts. Accurate, timely, and detailed information is essential for emergency managers to make decisions and disseminate information to the public. And the issues that we are discussing today clearly call for prudent investments that will protect lives and prevent economic devastation, reducing our vulnerability to hurricanes.

One way to protect lives and prevent economic destruction is through improved coordination and investment in hurricane research. A bill before this committee that I introduced, the National Hurricane Research Initiative Act of 2011, will dramatically expand the scope of fundamental research on hurricanes, enhancing data collection and analysis in critical research areas, and translating of research results into improved forecasts and planning. When fully implemented, the National Hurricane Research Initiative will improve our understanding and prediction of hurricanes and other tropical cyclones, including, storm tracking and prediction, storm surge modeling, and inland flood modeling. This research will expand our understanding of the impacts of hurricanes on and response of society and help us to develop infrastructure that is resilient to the forces associated with hurricanes. We never know when the next natural disaster will strike. This type of research is urgently needed, and that research needs to be well coordinated.

But, even with possible legislation like the National Hurricane Research Initiative and the Natural Hazards Risk Reduction Act of 2011 introduced by Senator Boxer, there remain areas left unaddressed. For example, one significant area is that NOAA needs $800 million for its JPSS, the Joint Polar Satellite System. JPSS is an elaborate satellite system used to track environmental conditions, and collect and data on weather, oceans, land. It allows forecasters and scientists to generate and compile data into complex models to predict and prepare. JPSS provides consistency in collecting data and developing complex predictive models and investment in such systems are integral in our natural disaster preparedness. A lapse in JPSS monitoring could risk missed forecasting signs for severe weather and natural disasters including hurricanes and tornadoes, something I and the rest of the American people do not want to have happen.

I'd like to thank the witnesses for being here today. I look forward to your testimony and valuable commentary regarding these important concerns.

Senator NELSON. And before I get to the subject matter of, "Is Federal investment paying off?" I want to say to Mr. Ryan, your profession—before we had a lot of Federal investment on national disaster preparedness, your profession was key. For example, remember the name Brian Norcross, in a Miami TV station, that stayed on the air when we were so unprepared for the monster hurricane, Hurricane Andrew, that hit south Miami Dade County, a relatively unpopulated part? Had it turned 1 degree to the north and hit downtown Miami or the area in between Miami and Fort Lauderdale, it would have been a $50–$75 billion insurance-loss hurricane. As it turned out—and this is 1992 dollars—it was a—almost a $20 billion insurance-loss hurricane. It would have taken down every insurance company, financially, that it was in the path. And then, of course—and this is just to say to Mr. Ryan, that his profession—no telling how many lives were saved because of Brian Norcross staying on the air and telling people what to do when we were basically unprepared.

You know, hurricanes are a way of life in Florida. And when I grew up as a kid, it was an excuse to get out of school. Later, when I was a bachelor, it was an excuse to have a party. Now, since we've had so many people that have moved to Florida and the coast is so urbanized, now it is—for a monster, it is unmitigated disaster in economic loss and loss of life.

So, turning to the question, "Are we better prepared, federally, to meet these kind of disasters?" I think the answer is clearly yes. But, I think it happens to be on who is running an organization like FEMA or NOAA and so forth. And fortunately, right now we have a couple of good ones that are running those organizations.

But, there are some troubling signs. For example, NOAA needs about $800 million for a satellite called the JPSS—Joint Polar Satellite System, something like that, JPSS—which would complement the existing array of weather satellites that we have up. And yet, how in the world are we going to get $800 million? And yet, they need it now.

Or, what about the troubled life of a satellite called Triana that has now been made over into a satellite called DSCOVR and needs to be launched that will tell us about the solar explosions? There are nuclear explosions on the surface of the sun. And if we don't have a warning from a satellite—and we've got military satellites out there now that'll give us a warning, but they're just about at their end of life—and we can't give a sufficient warning before all of those cosmic rays hit the Earth or hit our satellites in orbit around the Earth so that they can get into the safe position to protect against that radiation, we can suddenly go blind. And yet, to try to get that satellite up is another one that we've been struggling with. And I hope we're on a path now, because the Air Force realizes that it is so important, to get that satellite into orbit.

And it orbits, Mr. Chairman, in a place that is called, the "LaGrange Point." It's at the point that the Earth's gravitational pull, between Earth and sun, stops and the sun's gravitational pull starts, so that it sits right there. And another thing that it'll do, it'll have a camera back—since it sits in a fixed position between the sun and the Earth, it'll have a camera looking right back at Earth. This is a second instrument on the satellite. And we will see our Earth as it completely goes through its 24-hour turn every day. We'll be able to look at our planet from approximately a million miles away, seeing this incredible planet that we have.

So, any of you, would you please comment on the necessity for these kinds of satellites.

Dr. HOOKE. Well, that's a wonderful speech, and I'm strongly supportive. In fact, I was hoping, when the Chair was talking about $30 billion which showed up out of nowhere, that perhaps $800 million of that might be spared for this one particular satellite.

I said something about that in my opening remarks. And I'd like to reemphasize it. The whole process of developing warnings for weather that represents a threat is kind of a multi-day process. And it's not enough, even in the case of a tornado, when you're tracking it on the radar and you've got the 20 minutes of warning that Bob talked about. If people weren't prepared that morning—"This is a dangerous day. I need to pay attention to what the radar is going to be showing later in the day"—they're not going to be prepared. Similarly, they won't be prepared in the morning if they didn't see some hint of it, you know, a day earlier.

And the fact of the matter is that the polar orbiting satellite provided about a 4- or 5-day head start on seeing this system that caused us so much trouble last week. And each day—and this is the important part of taking those satellite data and putting them into the models—if you put them in the models and, 5 days out, it says, "Gee, it looks like Wednesday is going to be a bad day," but then, 4 days out, it says, "Oh, call that whole thing off. Wednesday looks OK," and then, 3 days out, it says, "Whoops, we were wrong. Wednesday's back in the picture," people don't know how to be prepared.

And what's vital about that polar satellite system is that it makes the difference, in terms of these models. And we've seen this not only in the U.S. models, but also in the European models, and being able to provide that consistency, day in and day out, as that hazardous period, that interval that's going to be dangerous, approaches. So, I think you really hit the mark with that comment.

Mr. RYAN. And if—Senator, if I might add, as you—Brian Norcross, of course, did, really, a lifetime of work in the few days that he was on and literally saved lives and was so well recognized. And yet, Andrew was just one hurricane that struck the United States that year. That was the only one. So, we cannot be complacent about, "Oh, the predictions and the outlooks for X number of hurricanes." All it does is take one.

And Bill has been working—has done a lot of work on the improvement and the advance of the science in being able to narrow the landfall. That is certainly a continuing issue. A continuing research is landfall and trying to narrow the probability of landfall—landfalling hurricanes. As you well know, the economic value of being able to decrease the envelope, if you will, of landfall can have—be paid off in millions and millions of dollars in unnecessary evacuations. So, when we look at the cost of some of these systems, and turning on or turning off systems, and where we have made—and the progress we've made in the fundamental understanding of, one, hurricanes, but also the ability to predict ever more accurately the path and the probabilities of landfall, the economic value of that and the advances that we've made far, far outweighs, by many, many times, the risk that we are taking by terminating a program and then trying to restart it in 2 or 3 years when we find out we've lost something.

Senator NELSON. Mr. Chairman, if I could just make the final observation——

The CHAIRMAN. Well, then I'll have to say something first, because it won't be final.

[Laughter.]

Senator NELSON. No, I'm talking about me making my final observation.

The CHAIRMAN. Well, I know, but I've got to go do a bunch of things. I was hoping, if you could—if you had questions, that you could stay and just do this.

Can I just make one observation?

Senator NELSON. Sure, sure.

The CHAIRMAN. And that is that, really, actually, we haven't even been very square with you. The point of this hearing is, in fact, to put, in terms of lives of people and destruction, mass destruction of land, and hopes and futures and all the rest of it, in the context of what we are now going through, which is our budget. And the only budget which exists is—has been passed, vigorously, by the House. And, with the exception of Social Security, it would take every—just out of the discretionary part of the budget—it would cut government by 50 percent—money, people, the whole works. That's why we're doing this, in part: to hear you explain why—as well as Senator Nelson—why you need to have certain things in order to save lives and to give people an orderly hope for their own futures, much less you all having a sense, as a scientific community of practitioners and researchers, a good feeling about your future.

I mean we are at such a critical, drastic point. And the whole question of defaulting on our national debt and all of that is staring us in the face, and we're having to make decisions, and we want to hear from people from people like you about what happens if, for example, this solar satellite doesn't exist. And I think both of you have spoken to that. So, that's just a little bit of context.

And you've been very, very helpful in that.

And if I have your permission, Senator Nelson—Senator Nelson and I are very good friends, and we give each other a very hard time—may I turn this all over to you?

Senator NELSON. Are you sure that you want to?

The CHAIRMAN. Absolutely.

[Laughter.]

The CHAIRMAN. I trust you fervently.

Senator NELSON. [presiding]. Thank you, Mr. Chairman.

Mr. RYAN. Thank you, Mr. Chairman. It has been a pleasure to be here.

Senator NELSON. I just want to make the observation that, whereas we have been able to be so sophisticated in our computer modeling and doing a lot of the things, that you all just described, which save a lot of lives and save a lot of money, nevertheless the insurance industry is still set in its ways in economic computer modeling that determines insurance rates and will let—not let the regulatory governmental organizations see their proprietary information of what goes into those computer models and, therefore, what they are charging in rates. And of course, if you are in a higher-hazard area for storm, hurricane, whatever it is—floods—the rates are going to be much higher.

And I'd like any comment that you all have of prying open the can of these computer models by insurance companies to determine if these are accurate rates that they are charging.

Dr. HOOKE. I'd like to comment on that. And it's a little piece of responsiveness and a little piece of shabby self-interest.

So, the insurance problem, as you know, is an extremely complicated one. And the insurance companies don't come in a single flavor, do they? I mean, we've got reinsurance, and we've got property and casualty, and we've got commercial and different things. And the way they—and then we've got states who are taking on some of the insurance and—you know, proposals floated to have the Federal Government do the same thing. So, it's worth discussion.

It—from the standpoint of a bystander, it has similarities to the healthcare debate, you know, and where the insurance will come from and what all that means and, you know, how we might live healthier lifestyles and reduce health costs and all the rest of that. So, I see some similarities.

So, this is a very important topic. And I think you've said, extremely well, that we have to get it right, we have to keep working on it, because if I'm a homeowner and I'm trying to live where I've lived the last 10 years, and suddenly I can't get insurance because it's no longer available, that's a catastrophe as bad as if the hurricane actually hit, isn't it? So, it's a terrible thing.

The shabby part: So, the American Meteorological Society, which might not be the organization that you think of as doing this, has had a couple of dialogues between the Commerce Department, particularly, and the insurance industry over the last 10 or 15 years. And we would be very interested in hosting a similar kind of dialogue now.

Now, I'm looking around the meeting and I see people with IQs in three digits, and we all know that there are enough meetings already. But, I think that such a meeting, which the AMS would be willing to host and provide kind of a neutral ground for insurers and the government, the way we have in the past, would be useful toward resolving some of the issues that you bring up. And in fact, you might have enough convening power that if people knew you were going to be present at this meeting, even for a small period, it would be electrifying, in terms of the response.

Senator NELSON. Well, thanks to all of you for a most illuminating panel. We are very appreciative.

Does the staff have any further questions? OK.

Thank you. Good afternoon.

The meeting is adjourned.

[Whereupon, at 4:40 p.m., the hearing was adjourned.]

A P P E N D I X

Prepared Statement of Hon. Tom Udall, U.S. Senator from New Mexico

I would like to thank Chairman Rockefeller for holding this important hearing. In recent weeks and months natural disasters have dominated news broadcasts and left many of our loved ones, friends, and citizens with damages and injuries.

In New Mexico widespread and intense drought has left farms, grassland, and forests dry and vulnerable. Already this spring, New Mexico has experienced dozens of wildfires. Almost daily new fires are identified and responses are organized. All of New Mexico's Federal, state, and tribal land managers are on alert fighting to contain wildfires through wick response and safe management.

I commend these local and Federal officials who have coordinated efforts across the state, resulting in what the public has recognized as well organized and productive responses to the fires.

As the skies remain clear and the land continues to dry, we can surely expect more fires and the associated difficulty for New Mexico's landowners and citizens. Already the USDA has recognized the hardship weighing on producers in New Mexico and is responding with the appropriate disaster assistance.

With severe weather and a troubled economy, this is a difficult time for all Americans. I again thank Chairman Rockefeller for keeping the preparedness for natural disasters a focus of this Congress, and I urge my colleagues to remember the value of preparedness and quick response as we enter the FY12 Appropriations debates.

Prepared Statement of Hon. Mark Warner, U.S. Senator from Virginia

Mr. Chairman, thank you for the opportunity to include this statement in the record, at this most difficult time.

Just last week, on April 27 and 28, tornados and other severe weather tore through the southern United States, including Virginia. In addition, Virginia faced several other severe storms earlier in the month and had tremendously affected areas including Goochland, Halifax, Pulaski, Rockingham, Shenandoah, Smyth, Washington and other Virginia counties.

Although the evaluation of damage is still underway, initial reports coming out of Virginia show that the weather was responsible for the tragic loss of at least five lives and damage of more than 400 homes and other buildings. Furthermore, as of Friday, at least 6,000 people were still without power. Trees are still downed and countless acres of farmland are damaged. At this critical moment we must keep in mind the needs of all Americans affected by this severe weather, and do all that we can to help them restore their livelihoods.

Virginia has suffered from natural disasters as have all states. The challenge is that the government has limited resources and natural disasters typically occur with less than ideal warning. We need to find the best ways to combine State, Federal, and private sector resources to become aware of, plan for, and recover from natural disasters. The question is, how best to use our resources? As a former Governor, I believe technology can be a large part of the solution, whether we focus on improving early warning systems or tasks such as building an interoperable public safety network. We should focus on leveraging our best-available technology to protect our citizens and make the most of the planning opportunities.

The leaders at all levels of government must highlight the need for a renewed and increased focus on improving our emergency preparedness measures. In the aftermath of previous national disasters such as Hurricane Katrina and the unexpected recent earthquakes and tsunami in Japan, many Americans still wonder whether local, state, and Federal Governments will be prepared to offer assistance when they need it the most.

Mr. Chairman, as we work to provide support for those affected by recent severe weather, we must be relentless in preparing for the next event. I look forward to working with you and other colleagues to ensure that we do all that we can to plan for natural and other disasters and respond appropriately one strikes.

Thank you.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN D. ROCKEFELLER IV TO WILLIAM H. HOOKE, PH.D.

Question 1. Throughout your career, including during your tenure as Deputy and Acting Chief Scientist of NOAA, you have focused on determining the most effective policies to reduce the negative societal impacts from natural disasters. Can you tell me some of the key recommendations that you have provided to Congress in the past for reducing the harm to the citizens and the economy of the United States caused by natural disasters?

Answer. There were several:

1. With Max Mayfield, former director of the National Hurricane Center, I supported the establishment of a new Federal agency, which would be an analog to the National Transportation Safety Board, but for natural disasters. The concept is described more fully in a paper Gina Eosco and I published in the Bulletin of the American Meteorological Society: it is on the web at *http://journals.ametsoc.org/toc/bams/87/6*.

2. I have supported the call of the Association of State Floodplain Managers for a *No Adverse Impact* policy with respect to floodplain land use and building codes, as described in much greater detail on the ASFPM website. See, for example the material at: *http://www.floods.org/index.asp?menuID=349&firstlevelmenuID=187&siteID=1*.

3. I have supported the recommendation of the National Academy of Sciences National Research Council *The Impacts of Natural Disasters: A Framework for Loss Estimation*, published in 1999 and online at: *http://www.nap.edu/openbook.php?record_id=6425* to the effect that the U.S. Department of Commerce should keep track of U.S. losses to natural hazards.

4. I have recommended that the U.S. Department of Commerce offer resources to the private sector to maintain business continuity in the face of hazards, and that it develop formal coordination mechanisms (analogous, say, to fisheries management councils) with the private sector for this purpose.

Question 2. Which of these recommendations have been implemented to date?

Answer. None.

Question 3. In your opinion, what are the main obstacles to the implementation of these recommendations?

Answer. The first two would require Federal funding (although they would reduce hazard losses and therefore increase incomes and tax revenues by amounts many times larger than their cost). Some conservatives might choose to argue that these measures constrain individual freedoms, though again this objection is more rhetorical than substantive.

Question 4. The National Windstorm Impact Reduction Program was created in 2004, but to date has received little funding—just $7.5 million out of the total $71.5 million authorized. What is the greatest challenge we face in minimizing damage from windstorms?

Answer. Building codes and zoning that would require safer construction techniques (such as roof straps and other measures—these are inexpensive but not cost free), including construction of safe rooms and/or tornado shelters (these are more expensive, and will not save property but will save lives). However, for those most part, these measures are the province of the states, not the Federal Government. The Federal Government could require that state and local governments take such measures in order to receive Federal disaster assistance.

The greatest challenge, however, the fundamental challenge, is that we although we know how to reduce wind damage, it always comes at greater cost, and this means a tradeoff between safety and affordability, especially for lower-income families.

Question 5. With limited resources, what windstorm risk reduction activities should the government prioritize?

Answer. The primary activities should be those that provide information that states, counties, and cities can use to estimate their risks and consider wind hazard reduction options.

Question 6. You have mentioned the tension between funding for research on short-term projects rather than for long term priorities. Your fellow witness, Dr.

Kiremidjian, has described the results of the 33-year focus on earthquakes provided by NEHRP. If long-term funding were available, what projects would you undertake that you currently cannot?

Answer. Phased-array radar development and implementation; an expanded U.S. Weather Research Program; and social-science research into the economic value of warnings, the communication of risk and warnings, the behavior of society in the face of risk, and other social factors contributing to natural disaster reduction.

Question 7. While we know that mitigation saves lives and money, you bring up the excellent point that we have no standardized way to know how much disasters cost, let alone how much we might save. What should we be measuring and who should be measuring it?

Answer. We should be measuring loss of life, injuries, property damage, and business disruption. The Department of Commerce should maintain the records, but work with FEMA and state and local agencies to gather the data. See the NAS/NRC report cited above: *http://www.nap.edu/openbook.php?record_id=6425*.

Question 8. You suggest in your testimony that warning systems are crucial for helping those in danger save themselves. The Administration recently announced an overhaul of the color-code terrorism alerting system. Do you think it is appropriate to develop and use a universal alerting system for incidents of all kinds, or does it make more sense to keep alerting systems separate?

Answer. Universal warnings lead to public confusion, especially where the desired behavior (*e.g.,* shelter in place vs. evacuate; seek higher ground (flooding), versus go to the basement (tornadoes) differs depending on the hazard. However, complicated separate warning systems require frequent public drills and programs to educate and build awareness in order to be effective.

Question 9. Have you had a chance to review the new terrorism system to determine any applicability to natural disasters?

Answer. No, I have not.

Question 10. What specific steps should the Federal Government pursue to communicate messages in a more timely and efficient manner?

Answer. Hazard watches and warnings are relatively well executed. However, getting the information that last mile to people who are out and about, or home asleep, or otherwise oblivious or unaware of the threat they face, is the problem. What's needed are not only good warnings, but pre-positioning of shelters and programs to build public situational awareness, especially of the actions they should be taking. Children need to know what to do. Adults who are separated from their children need to know those children are being protected. And as society changes, new social research is needed to track the implications for warning systems.

Question 11. How can social media sites be leveraged to provide more timely information?

Answer. I'm afraid I don't have expertise in this area.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO WILLIAM H. HOOKE, PH.D.

Question 1. In your statement you mentioned that $800 million is needed to launch the Joint Polar Satellite System. Dr. Lubchenco stated in a recent NOAA budget hearing that there will be at least an 18-month gap in polar satellite coverage. How will this 18 month gap impact weather forecasting and modeling?

Answer. There will be a real deterioration in the accuracy of forecasts and warnings. I've been told that this will degrade such forecasts to the lower quality that existed twenty years ago. In today's society, it's not enough to have a few hours' notice of a tornado or other hazard. Emergency managers and others need several days' notice of increasing threat in order to begin mobilizing. It's essential that the forecasts over such an interval of several days be giving a consistent message of decreasing or increasing threat. Oscillations back and forth between "threat" or "no threat" in the run-up a few days prior to the threat compromise preparation, the entire warning process, and public safety, and increase false alarms.

Question 2. Washington State will be disproportionately affected by the gap in satellite coverage. Do you propose any alternate weather prediction methods during that time to protect human life, property and economies?

Answer. I know of no available measures that will compensate for this gap.

Question 3. Are there privately owned, or international satellites that can help fill this gap in coverage?

Answer. None that I know of.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. ROGER F. WICKER TO WILLIAM H. HOOKE, PH.D.

Question 1. Last week five southern states, including Mississippi, experienced devastating tornadoes that resulted in hundreds of lives lost and extensive property damage. Early warning systems alerted those in danger to the threat an average of 24 minutes prior to tornadoes touching the ground. However, many residents in southern states do not have safe escape options to fit that timeframe. What research is being conducted to improve advanced warning systems for tornadoes?

Answer. The Senator raises an excellent question, which goes at the heart of the issue. The simple fact is that 24 minutes of warning does not provide adequate lead time for those in harm's way. The entire approach of the National Weather Service, and emergency managers at both state and local levels, is aimed at a comprehensive strategy for managing tornado risk. That strategy begins years in advance in tornado-prone areas, through efforts to build awareness and support building codes that strengthen homes against tornado damage, provide for safe rooms within those homes, or underground tornado shelters offering quick access, provide education in the public schools, and all the rest. It continues at the beginning of each tornado season with special efforts designed to build public awareness. From this point on, the effort focuses on outlooks and warnings. The goal is to begin to let the affected public know as much as several days in advance that a state (like Mississippi) or an extended region will be at higher-than-normal tornado risk for the next few days. Then, as time passes, the subsequent outlooks, watches, and warnings then seek to refine the area and the time interval at risk, right down to the actual tornado warning itself. The basic principle is that the public can't be expected to maintain a high state of alert all the time, but rather only for brief periods.

Research is currently underway at NOAA, and at universities sponsored by NSF and NASA, to improve every link of this chain, from characterization of the areas at climatological risk, to the 3–5-day forecast, to forecasts the morning of, to the radar detection of the tornadoes. Emphasis is primarily on the physical development of and/or presence of the tornado. Big-ticket research items include the numerical modeling of warm-season weather, the adaptation of JPSS data for this purpose, and the development of phased array radars. More support is needed for social science, especially the communication of tornado risk. We ought to be as disciplined in our approach to how we warn as we are to the quality of those forecasts themselves

Question 2. How is science being used to better protect citizens and property from catastrophic events such as those that occurred last week?

Answer. As indicated above, the science is directed at extending the time horizon; improving the accuracy of tornado outlooks, watches, and warning; and the communication of those warnings to the public.

Question 3. There are several Federal agencies that support national weather prediction and natural hazard preparedness. There is also a great deal of research on natural hazards that is carried out by academic institutions and the private sector. How are efforts by the Federal Government utilizing resources available through academic institutions and the private sector? In what ways could this be improved?

Answer. NOAA and the National Weather Service provide some academic research funding themselves, and also work with NASA and NSF to coordinate that academic funding and ensure that research progress is translated into societal benefit. Much of this is accomplished through means such as the U.S. Weather Research Program. However, this program is funded at levels much below what had originally been envisioned. More resources for this program could accelerate the societal benefit substantially, at modest cost.

Question 4. Can the government leverage resources through academic and private entities to advance natural hazard preparedness while saving costs to the American taxpayer?

Answer. The reality is that virtually all of this academic work is accomplished only through the use of Federal funding from NOAA, NASA, and NSF. There's very little opportunity for additional leveraging here.

Question 5. Hurricane Katrina devastated thousands of homes in Mississippi and Louisiana. Following the storm there were disputes regarding wind versus water damage to coastal properties and how residents should be compensated for their losses by insurers of wind versus the National Flood Insurance Program for flood damage. These disputes have been litigated for years in the courts, further delaying recovery of the Gulf Coast. Does the proper science and technology exist today that could tell us, with reasonable certainty, wind speeds and storm surge levels during a hurricane that could allow for a better understanding of how these perils impacted coastal properties? In other words, can reliable scientific data be collected to better assess wind and water property damage following a hurricane?

Answer. Another excellent question, and one highlighting an opportunity before the Senate to improve national policy. The answer to the question itself is regardless of the level of science and technology, it will always be possible, in a certain class of cases, to distinguish between wind versus water damage to coastal properties. But regardless of the level of that science and technology, there will always be an additional class of cases where the prior cause will be in dispute. It will be possible, by improving the science and technology, to shift slightly, the class of homes at issue, but not by very much.

There is an analogy here to a similar problem many of us face every day. At my work, phone service is provided by an Internet provider. That provider uses cabling and other infrastructure that belongs to the building where we rent our office space. Then the phone lines are linked to a carrier (Verizon in our case, I believe), once they reach the street. Sometimes our phone service goes down. Often it's clear whether the problem rests with our VOIP, the building, or the outside phone service. But not always. Then we're in dispute with all three as to where the problem lies.

So, fundamentally, we have created a problem with regard to insurance coverage by our policy decision to separate flood insurance from wind insurance. My understanding of the history of this is that flood insurance was thought to be inherently difficult for private-sector insurers to handle because flood events are rare but when they do happen they impact every home in a large area. Home insurance got its start 100 years ago when the primary cause of home loss was fire, which would occur relatively frequently, but only affect a home here or there. This allowed for actuarial approaches to work well. However, with the rise of private-sector reinsurance, the industry is much better equipped today to handle flood loss.

Recognizing this, some property and casualty insurers have begun to offer to their customers, at a premium, insurance against flood and wind under a single policy. For the homeowner or business owner, this represents an alternative to the National Flood Insurance Program. [Something similar is happening in health care, where those who are able and willing can attain a higher level of patient service.]

I thank the Senator for these thoughtful questions and the chance to discuss the issues they raise. *Working together, scientists, forecasters, emergency managers, homebuilders, insurers, and the general public can reduce the risks tornadoes pose.* These issues matter to me and to the American Meteorological Society, and we would be happy to discuss them further if that would be helpful.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN D. ROCKEFELLER IV TO ROBERT RYAN

Question 1. In my own state of West Virginia, flash floods are a too common event, and they cause tremendous harm including loss of life, homes, and jobs. But I also understand that NOAA has been able to improve the lead time available for flash flood warnings from an average of 10 minutes to about 75 minutes. Can you explain to me how this came about? Specifically, what technological changes were made to allow the greater lead time?

Answer. There have been two significant advances that have lead to the increase in flash flood warning lead time. The nationwide use of the government/taxpayer funded NWS Doppler radars has allowed meteorologists to "integrate" the water in storms and especially thunderstorms and to accurately measure rainfall rates. The second significant advance has been in utilizing the highly accurate geophysical measurements now unavailable of stream and river basins and drainage areas to then give us a way of estimating the flooding potential for certain rainfall rates. The NWS Advanced Hydrologic Prediction Service (*http://water.weather.gov/ahps/*) is now providing operational river and stream flood guidance to local NWS offices. This combined with the integration of input from various NOAA/NWS forecast centers (Storm Prediction Center, HPC-Hydrometeorological Prediction Center and local NWS WFO (Weather Forecast Office)) have provided the significant increase in flood accuracy and advanced warning. The public response to these warnings, especially for flash flooding events that are extreme, life threatening and may only occur once in 20 or 50 years is still as much a social science issue as a meteorological issue.

Question 2. While certainly the improvements that have made to date are extremely important, we should never be complacent. In your view, what more should be done in the coming years at the Federal level to ensure that we have a system in place to provide the public with as much notice as possible, and the best opportunity to keep families and homes and businesses safe?

Answer. We have to make sure that the basic structure we have in place of fundamental, critical funding for the NOAA/NWS operations from satellites, to weather radars, ground based observations, super computers and support for applied and fundamental research is never compromised or degraded. If we agree that one of the fundamental purposes of any government is the protection of the lives and property of its citizens, few government organizations do that day in and day out to the extent and value that we taxpayers receive from our Nation's weather services and NOAA/NWS. Funding for one of the most critical and economically beneficial segments of our government should never be unnecessarily reduced or endangered for political purposes.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO ROBERT RYAN

Question 1. As a prominent meteorologist who recognizes the need to incorporate social science research into natural hazards risk reduction measures, is there value in cellphone and other novel early warning system communications technology?

Answer. Given the still unpredictable nature of earthquakes any mobile warning is not feasible but there is great value in mobile warning systems for tsunami. As we saw in the tragic tsunami in Japan, in some areas a tsunami may follow an undersea earthquake in a matter of minutes. The time for warning and action is a similar time scale to warning and action with tornadoes. Communication of the warning and importantly, what action to take, though the use of smart phones and other mobile devices I believe can have life saving value. NOAA/NWS is working with FEMA on a program called IPAS (Integrated Public Alert and Warning System) recently outlined to over 200 attendees at the just concluded AMS conference on broadcast meteorology and Weather Warnings and Communication. Here is an outline of the program presented to the broadcast meteorologists: *http://ams.confex.com/ams/39BROADCAST/webprogram/Paper188896.html*.

Question 2. Do you see this type of warning system as a way to save lives in the event of a natural disaster in the United States?

Answer. Most definitely. My answer above with the example of the joint NOAA/NWS/FEMA program does address this.

Question 3. As you stated that the communication of severe weather warnings, by both traditional and new media, is critical to saving lives and reducing economic damage. You also indicated that how a message is sent is just as critical as the information it contains about severe weather. What are the specific gaps in the current communications used to inform the public that are preventing critical information from reaching individuals?

Answer. The false alarm rate for tornado warnings is still about 70 percent. That is 70 percent of the time a "tornado warning" is not followed by an actual tornado. The warnings are based primarily on detection of rotation in the thunderstorms sometimes 1000s of feet above the ground that may not produce a tornado or an observation of a funnel cloud which also often may not led to the funnel reaching the ground as a tornado. The critical information is still the risk/severity of the event whether it is the tornado warning, a hurricane warning, flood warning etc. which better communicates the magnitude/risk of the event. The tornado warning siren network in many states is an effective way of sounding an alarm or risk but many feel it is overused by emergency managers and could be made more selective with the current NWS warning capabilities to only sound sirens for those communities in the path of possible tornadoes rather than entire counties which cover thousands of square miles. Over warning may lead to public complacency in the face of a great risk from say an EF3 or EF4 or EF5 tornado, as opposed to a slight risk from a small EF0 tornado. The entire weather enterprise community (NWS, broadcasters, emergency managers, social scientists) need to work together to more effectively communicate the level of risk through all media using common language to help the public make the best weather and life threatening weather related decision. There are now a multitude of ways of communicating critical weather information and weather warnings to the public. There is a gap in communicating the actual risk and what action individuals should take. About 40 percent of the public still does not know the difference between a weather "watch" and a "warning". We as a community should seriously look at the words and terminology we use to communicate risk to facilitate best decisionmaking.

Question 4. Has there been success in improving disaster warnings so that more individuals choose to follow instructions on how to stay safe during the emergency?

Answer. I think the public outreach/education efforts of both NWS and private partners (local broadcasters, emergency managers, media such as The Weather Channel) have been very helpful in having the public understand any danger and take action. Efforts to reach out to our young people though school programs are very beneficial. Students often will learn what to do in weather emergency at school and go home to "educate" their parents. The issue of what we say to have everyone make the correct choice, weather related decision when the weather threat may be a once in a lifetime experience (a Joplin tornado, a "Katrina", a "Blizzard of 96" etc.) is a challenge. Again meteorologists, trained as physical scientists, may not always be the best at effective communication. A social science based program at NCAR called WAS*IS *http://www.sip.ucar.edu/wasis/* has been very successful, bringing NWS forecasters to summer workshops to better understand social and communication science issues and should be further supported and expanded.

Question 5. How are agencies collaborating with the media to ensure that we continue to develop and employ the best possible methods to reach United States citizens during a natural disaster? If agencies and media are not collaborating in this way, why not? Do you see value in this type of collaboration?

Answer. I have just returned from the recent joint AMS (American Meteorological Society) Conference on Broadcast Meteorology and Weather Warnings and Communication. It was 3 days of excellent collaboration and communication between and among weather communicators and Federal employees primarily NOAA/NWS. It was one of the best and most productive conferences I have attended since my first broadcast conference in 1972. I believe many of the papers and recorded presentations will be available soon. The complete program is still available here: *http://ams.confex.com/ams/39BROADCAST/webprogram/1STORMWARN.html*.

Joint conferences such as this and the Annual Meetings of professional and scientific societies and organizations such as the AMS, AGU, NWA (National Weather Association) and regular local and regional workshops and meeting foster very productive communication and understanding across all sectors (academic, public and private) of the weather enterprise. This spirit of communication, partnership and shared goals is greater now than at any time in years past and in my professional experience.

Question 6. Would you please explain how weather forecasts available to American citizens will change without polar-orbiting satellite capabilities? For example, how will the weather on the nightly news differ, when we are missing a polar orbiting satellite?

Answer. The loss of data from polar orbiting satellites is a loss of critical data. The loss of any data, given the current capabilities of the weather forecasting science and process will harm, and decrease the accuracy of the forecast. The advances we are seeing in increased lead times for life threatening weather may be ended and lead times reduced rather than extended. The risk is too great, the cost of maintaining polar orbiting weather satellites too low to stop a program which is an integral part of the weather forecast/warning process.

Question 7. How will warning times for severe weather differ when we are missing a joint polar satellite?

Answer. Warning times can only decrease. There is no way warning times can be extended, perhaps by life saving minutes, if data from satellites is lost or the program terminated or interrupted.

Question 8. Does the type of storm or region affect the forecasting and modeling impact?

Answer. The more data we have and usually the bigger the storm, the better the forecast. Thus a small storm or shower moving in from the Pacific Ocean into the northwest U.S. can be harder to forecast (few surface observations in the ocean other than weather satellite soundings) than a large storm moving across the center of the country. The current weather forecast system, as I may have mentioned, may be thought of as a three legged stool. One leg is fundamental science-understanding of the physics of the atmosphere/ocean/Earth system; one leg is data and the third leg computer power to solve the mathematics and equations that describe the system we are forecasting. The loss of data or computer power, even as we understand more of the fundamental science will decrease the accuracy of the forecast. The "models" are only as good as the data and computer power necessary to give us some answers to the question, "What will tomorrow's weather be?"

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. ROGER F. WICKER TO ROBERT RYAN

Question 1. Last week five southern states, including Mississippi, experienced devastating tornadoes that resulted in hundreds of lives lost and extensive property damage. Early warning systems alerted those in danger to the threat an average of 24 minutes prior to tornadoes touching the ground. However, many residents in southern states do not have safe escape options to fit that timeframe. What research is being conducted to improve advanced warning systems for tornadoes?

Answer. I have given thought to Senator Wicker's questions and waited to respond after the recent terrible Joplin tornado and other severe weather. This has been an exceptional year of tragic and deadly weather events with a huge human and economic toll. My responses follow.

The primary tool for issuing current warning is the national network of NWS Doppler radars. Research is underway at the National Severe Storm Laboratory (NSSL) on the next big step in weather radar technology the Phased Array Radar: *http://www.nssl.noaa.gov/research/radar/par.php* which many researchers believe may increase warning times by 10–15 minutes. Any national coverage of PAR is probably 10–15 years away.

Private sector companies are also now developing new detection systems looking at intracloud lightning flash rates as an indicator of developing severe storms with possible tornadoes. *http://weather.weatherbug.com/weatherbug-professional/products/total-lightning-network*.

Question 2. How is science being used to better protect citizens and property from catastrophic events such as those that occurred last week?

Answer. "Protection" has to be a combination of best forecasts and warnings, best communication and best decisionmaking by the public. This means we as a community really need to bring in social science expertise into the weather forecasting/warning and communication process. Programs such as WAS*IS at NCAR *http://www.sip.ucar.edu/wasis/* and the University of Oklahoma program "Social Science Woven into Meteorology" *http://cimms.ou.edu/sswim/index.htm* are examples of increasing use of social science expertise within the physical science of meteorology and forecasting. These programs should continue to be actively and increasingly supported and used to learn how to better communicate life threatening warnings to the public and importantly learn more about how and why people make weather related decisions. Interestingly some recent research indicates that more than 50 percent of our citizens do not know the difference between weather "watch" and a "warning" and tornado warnings are too often ignored perhaps in part due to the "crying wolf" syndrome of a "false alarm" rate for tornado warnings of still over 60 percent *http://news.msu.edu/story/8505/&topic__id=13*.

The "Weather Enterprise" is working cooperatively, following a number of the recommendations of recent NRC reports to ensure that all sectors (public, private, academic) work together to best serve the public and advance the service of meteorology to the public and the economy. A coming example: *http://www.ametsoc.org/MEET/fainst/2011summercommunity.html*.

Question 3. There are several Federal agencies that support national weather prediction and natural hazard preparedness. There is also a great deal of research on natural hazards that is carried out by academic institutions and the private sector. How are efforts by the Federal Government utilizing resources available through academic institutions and the private sector? In what ways could this be improved?

Answer. A number of examples are given in my answer to question 2. The NWS should involve the academic and private sector from the beginning in consideration of new products, warning and communication tools. In the past, it has appeared that the NWS was adopting tools/systems that have been more rapidly developed and utilized by the private sector. Examples are from use of icons on the Internet to the many new methods of mobile communication. The move from pure digital/deterministic forecasts to methods of communicating probability and uncertainty (as example there is no easily available public forecast product for type of winter precipitation (rain, snow, sleet, freezing rain) during the past winters severe winter weather along the East Coast) should be lead by NWS as called for in the recent NRC report. *http://www.nap.edu/openbook.php?record__id=11699&page=R1*

Question 4. Can the government leverage resources through academic and private entities to advance natural hazard preparedness while saving costs to the American taxpayer?

Answer. I think through the response of the NWS/NOAA to the above NRC report and efforts by the American Meteorological Society in establishing the entities such as the Board on Enterprise Communication *http://www.ametsoc.org/boardpges/*

cwce/docs/BEC/index.html, efficient use of government funds and resources is being accomplished. The efforts of the AMS in establishing a number of workshops bringing together leaders from the academic, private and public sectors has helped foster true partnerships to benefit the common goals of service to the public and economy. NWS/NOAA should continue to be open participants in these efforts by the AMS, NCAR, NWA and other independent scientific organizations.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN D. ROCKEFELLER IV TO ANNE S. KIREMIDJIAN, PH.D.

Question 1. You cite as a positive example of Federal research and development the creation of a wireless structural monitoring system to provide more robust damage detection to buildings and other infrastructure. How are these sensors currently inserted into infrastructure? And would it be possible to retrofit buildings with this technology?

Answer. The main advantage of wireless structural monitoring sensors is that no cables need to be installed up and down a structure. As a result, these sensors can be placed at key locations on buildings by simply attaching them to vulnerable components or at places where we expect to see the highest damage. Thus, mounting the sensors is relatively easy and cost effective (cost savings can be as much as 30 percent with a wireless system in comparison to a wired system). Given these characteristics, they are particularly well suited for placing them on existing buildings.

Question 2. How is this information generally collected and who uses the data?

Answer. For large facilities, it would be the facility manager or his/her designate who will have access and collect the information onto a local computer. Our challenge is currently interpreting the data in a reliable and robust way that the owner can use to make decisions. Presently, we can issue first alerts immediately after a major event such as an earthquake that the structure may be in imminent danger of collapsing, thus requiring occupants to evacuate. These systems can provide the equivalent of red, yellow and green alerts that reflect the degree of danger of buildings or other structures. The technology currently exists to transmit this information to cell phones, PDAs, laptops or dedicated computers. The alert can also be connected to a warning system that sounds an alarm. We envision that these systems will be first deployed on critical facilities and gradually over time to other structures.

Question 3. Japan, which is widely considered the most prepared nation in the world when it comes to seismic hazards, has suffered greatly from the March earthquake and tsunami event. A similar threat faces the Pacific Northwest from the Cascadia fault. The U.S. Geological Survey reports that in the next 50 years there is a 14 percent chance of a massive magnitude 9 earthquake and tsunami in the Pacific Northwest, similar to the tragic events of this March. What would happen to the Pacific Northwest if an earthquake and tsunami event similar to that of Japan occurred along the Cascadia fault?

Answer. As you have stated, our Pacific Northwest is particularly vulnerable to large earthquakes and tsunamis. The most recent study of the Cascadia subduction zone has shown that it is capable of a magnitude 9 earthquake with a high potential for generating a tsunami. The last major earthquake has been estimated to have occurred approximately 300 years ago on January 26, 1700 and ruptured 1000km segment of the subduction zone similar to the earthquake of March 11, 2011 in Japan.[1] Moreover, the January 26, 1700 event caused a very large tsunami that swept across the Pacific.[2] The recurrence of these events is highly uncertain and can range between 200 and 700–1,300 years. The fact that there has not been such an even since then makes it more likely to occur within our lifetime—a characteristic that the Japanese scientists appear to have ignored.

An earthquake of magnitude 9 can be truly devastating to all coastal cities and towns starting from Mendocino, California all the way to our border with Canada. We can expect damage to unreinforced masonry structures, lightly reinforced concrete structures built prior to 1979, single family dwellings that are built on cripple walls (*i.e.,* the foundations are simple 1′ to 2′ high 4″x4″ columns sitting on top of concrete base supporting the base-beams, with poor connections between the columns and the beams), and pre-cast concrete and tilt-up structures. In addition, a large number of the bridges especially in Oregon and to a lesser extent in Wash-

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[1] John J. Clague (1997). Evidence for large earthquakes at the Cascadia Subduction Zone, *Rev. Geophys*. 35(4), 439–460. Doi:10.1029/97RG00222.

[2] Natural Resources, Canada. *http://earthquakescanada.nrcan.gc.ca/histor/15–19th-eme/1700/1700-eng.php*.

ington and California will be damaged; underground water, sewer and gas pipelines are likely to rupture in numerous locations leaving residents without water and contaminating ground water; there will be damage to power transmission lines and communications lines, limiting rescue operations and stopping functionality of all facilities. With water lines broken, there is also the potential for fire spread typically ignited because of leaking oil or gas. We have seen these scenarios with every past earthquake. What has varied is the degree to which these occur.

What will be even more devastating is the tsunami that can occur with very high likelihood if a magnitude 9 earthquake occurs. Damage to coastal towns and villages will be extensive as there are no tsunami walls built in any of the three states that are exposed. Depending on the time of warning (which in this case could be in of the order of 20 minutes to 1 hour depending on location) the number of casualties will be very large because people just cannot evacuate in such a short time. While most of these regions have tsunami evacuation plans, whether the evacuations will be effective will greatly depend on the height of the tsunami and the speed with which it reaches the coastal areas and travels inland. Recent efforts in Oregon and Washington to provide vertical evacuations (these are in buildings that can sustain the tsunami forces and are tall enough not to be completely engulfed) have sadly been abandoned due to state budget shortfalls and cuts leaving tens of millions of people highly exposed to the tsunami treat. The losses will be in the hundreds of billions of dollars. A study of potential losses should be initiated and corresponding mitigation action should be undertaken.

Question 4. I read that you have recently been working on earthquake risks to transportation systems. How would our Nation's infrastructure fare during a significant earthquake?

Answer. How our transportation systems will fare is very region dependent. In California, the Department of Transportation (Caltrans) has been systematically upgrading and retrofitting bridges in the state to meet higher earthquake design levels. However, there will be some damage to bridges. Bridges at present are designed for life safety and not for functionality. This design criterion allows for bridge to have minor damage under moderate earthquake, moderate damage under a severe earthquake, and can have extensive amount of damage but should not collapse under a great earthquake (such as the one in Japan). Thus the expected damage and loss.

In addition to California, Oregon's and Washington's transportation departments have engaged in seismic retrofitting activities. These, however, were commenced only recently and most likely have not been completed. Similar variations in transportation resiliency also exist in states that are exposed to hurricanes and tornados. To the best of my knowledge, Florida is at the forefront in their transportation system upgrade for hurricanes. I am not sure about Texas and other Gulf states. The problem throughout the United States, however, is that we have a large number of infrastructure components that have gravely deteriorated and are vulnerable under every-day loads posing a serious threat without an extreme event. With an extreme event, the problem is even greater.

Damage to bridges is only part of the concern. When a bridge or a section of a road is damaged to the extent that it is either closed or traffic on it is reduced, key transportation links may be severed hampering rescue operations and interfering with the recovery process. Functionality of the system is defined as the ability to travel from an origin to a destination in a reasonable amount of time. Based on our recent study, we estimated that closure of bridges and roads due to damage will cause significant increase in travel time that will result in losses that are of the same order as the losses from direct damage to bridges (see also response to Senator Cantwell below4). Requirements for functionality following an earthquake or a hurricane will bring transportation system in line with building performance based earthquake engineering design approaches (PBEE). Current design takes only damage to components into consideration. PBEE strives to increase the resiliency of the entire system and not just the components.

Question 5. While any one disaster may directly affect just a small corner of the globe, the response is frequently worldwide. You have described the benefits of the Japanese investment in earthquake research. How has the world community benefited from American research?

Answer. U.S. research supported by NSF, NIST, USGS and FEMA has resulted in numerous developments that are being used by other countries. For example, seismic design codes particularly for reinforced concrete, (*ACI 318–08, Building Code Requirements for Structural Concrete, American Concrete Institute*) have been adopted by earthquake prone countries throughout the world. It is the main reason why the damage from the Chile earthquake in 2010 was relatively small. Probabilistic seismic hazard mapping was first developed in the U.S. (in fact at Stanford) and is now being used virtually be all earthquake prone regions of the world. The Applied Technology Council (an organization that is part of the Structural Engineers Association of California) developed some of the first methods for regional earthquake damage and loss estimation. In addition to translating these methods to other hazards, such as hurricanes and tornadoes, these methods have resulted in important technologies that enable insurance and reinsurance companies from around the world to assess their risks from extreme events. Furthermore, Japan, China, Taiwan, Chile, Mexico and Italy are a few of the countries that have adopted these methods for their internal risks assessment. These methods are also being used by the Global Earthquake Model (GEM)—an international consortium funded by the insurance and reinsurance industry to develop an open source earthquake risk model. Seismic retrofit strategies and methods for multi-story steel moment frames that were developed shortly after the 1994 Northridge, California earthquake with funding from FEMA have been adopted by Japan and other countries in the world. The performance based seismic design paradigm that has emerged as a result of our research in the past 10 years through the three NSF funded earthquake research centers is currently being considered by other countries in Europe, Asia and South America.

There are also many technological advances invented in the U.S. that are being adopted in other countries but are yet to be implemented in the US. Wireless structural monitoring systems are being used for variety of purposes in Germany, Italy, France, China, Singapore and Korea. These systems were first developed in the U.S. and sadly enough are still to be implemented in our country. Fiber reinforced concrete was also invented in the U.S. (my colleague Professor Mike Lepech is one of the pioneers in the field) and is now used extensively in Japan for seismic retrofitting of high-rise concrete structures. China and several European countries are also quickly adopting these materials and technologies. Again, we are yet to use them and include them in our practice. You may raise the question of why we are so slow in adopting our own innovations. There many factors why, but the most important ones are: first lack of investment from industry—it is cheaper to build with existing methods and materials even if it has been demonstrated that in the long run it may be more cost effective to use the new materials; and the second one is fear of potential litigation.

Question 6. What can we learn from Japanese preparedness that we can apply to our own country? Are there things that the Japanese do that we aren't?

Answer. Following the 1995 Kobe earthquake, Japan invested several billion dollars in instrumentation, research and preparedness. The extensive instrumentation has enabled them to study the earthquake phenomenon in far greater detail than before that earthquake. In addition to instrumentation for seismic ground motion, they also placed instruments in variety of structures to enable them to study the behavior of structures when subjected to severe ground shaking. Moreover, they built the largest shaking table in the world to test full scale buildings (up to four stories). These tests have enabled them to understand not only the motions that buildings experience, but also how non-structural components perform and how people react to such motions. I am not advocating that we build such a facility as it is prohibitively expensive. However, we have directly benefited from their investment through our joint collaborative projects (typically supported by the NSF program on Network for Earthquake Engineering Simulation (NEES)). While I am not advocating to build large testing facilities here in the US, we can greatly benefit from the extensive amount of data that they have collected from the March 11 event. Such events are extremely rare and these types of data have never been collected until now.

Japan has also engaged in systematic retrofitting of structures that are considered to be particularly vulnerable. For example, there are thousands of weakly reinforced concrete structures (those built prior to 1979—prior to a major design code change) both in Japan and throughout the United States. Their vulnerability is well understood and structural engineers have brought it to the attention to local and state officials, but there has been little action in the U.S. to systematically retrofit them. Only few owners have taken the initiative to upgrade their vulnerable structures. An ordinance combined with incentives should be seriously considered.

Another area where Japan has been taking a systematic action is to renovate and upgrade the lifeline systems—water, sewer, power, gas, communications and transportation systems. Even if damage to buildings is minimal, if the lifelines are not functioning, a community cannot survive. We have seen our lifelines fail under normal operating conditions due to deterioration. Damage due to a large earthquake can be truly devastating.

Japan had built tsunami walls that showed to be ineffective with the March 11 event. They had initiated vertical[3] evacuation strategies before the earthquake and the tsunami; however, they had not gone far enough in their implementation. Oregon had initiated vertical evacuation studies jointly with Japan, but these have been suspended due to state and local government budget cuts. It is imperative that we review our tsunami evacuation plans and provide for vertical evacuation. Much of the technology is available for designing such structures and they can be made cost effective if combined with other uses.

Although there are still many people living in shelters after the Japan earthquake, Japan has been able to care for their citizens reasonably well. We can learn and greatly improve on what they did. A team of social scientists sponsored by the Earthquake Engineering Research Institute (EERI) looking into these issues has just returned from Japan and we are likely to learn a great deal from their findings.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO ANNE S. KIREMIDJIAN, PH.D.

Question 1. Japan has created an early earthquake warning system, which gave its citizens over a minute warning prior to the earthquake in March, a critical amount of time for people to find safety. Does the United States have a similar warning system as far as warning time, accuracy and communications technology?

Answer. The United States does not have a widely installed earthquake warning system. Researchers at in the West Coast have been working on the development of such systems for the past decade. Much of the technology is available but we are well behind in implementation.

Question 2. Is such a system feasible in the United States?

Answer. Yes it is and a prototype earthquake warning system is presently being considered in Coachella Valley, CA. In addition, several fire stations in the San Francisco Bay Area also have earthquake warning systems. Japan has demonstrated that it is feasible and has gone ahead and implemented it. The United States is seriously lagging behind in this respect.

Question 3. The Japanese earthquake warning system was able to send text messages to Japanese citizens before the earthquake, enabling citizens to seek shelter. Could the United States have this capability? What efforts are underway to create or test the feasibility of a similar system in the United States?

Answer. The United States has the necessary technologies to implement such a system. In general, a comprehensive early earthquake warning system should consist of two types of warnings. The first is that an important earthquake will occur within the next 5 to 30 seconds. The warning should include the potential size and location of the event. This will give an opportunity for individuals to take cover, have back-up generators be started in critical facilities such as hospitals (particularly in their operating rooms), stop high speed trains, slow down traffic on bridges or outright close bridges, prepare emergency personnel to ready for their response and so on. The second part of the alarm system should be tied to the response of structures—buildings, bridges, pipelines, chemical plants, etc. These systems will issue a warning immediately after the event. The warning can alert occupants that they need to evacuate a building that is in imminent danger of collapsing, for example. It can also alert emergency personnel which buildings have been severely damaged or have collapsed so that they can focus their response to those structures. The technology for both warning stages is presently available. It is a matter of funding and implementation.

Question 4. Is there adequate funding for tsunami and earthquake warning system research proposed in the FY12 budget?

Answer. Not even close. The total research budget of the National Earthquake Hazard Reduction Program is in the order of $130M that includes geosciences, engineering, social and economic issues, and response and preparedness. Only a small fraction is likely to be spent on tsunami research. This amount, however, does not include funding that may be given to NOAA for this purpose.

Question 5. In addition to earthquake warnings, tsunamis can be detected using tsunami buoys offshore. At the time of the Japanese earthquake and tsunami, there

[3] Vertical evacuation facilities refers to structures that can withstand a tsunami and can provide shelter to people who live in the vicinity of the structure. Typically, when people try to reach higher ground, roads may be blocked and reaching high ground on foot may not be feasible. However, if tall structures are present in close proximity, they can climb the four or five stories in less than 15 minutes.

were at least three United States tsunami buoys classified as inoperable. How does the earthquake/tsunami warning system work with tsunami buoys to predict natural hazards and warn citizens?

Answer. According to Eble and Stalin (2007)[4] "the Deep-ocean Assessment and Reporting of Tsunamis (DART) real time tsunami buoy system is comprised of two parts—the Bottom Pressure Recorder (BPR) and the accompanying surface buoy with its related electronics. The BPR resides on the ocean bottom and monitors water pressure. Data are transmitted from the BPR to the surface buoy" and then transmitted to ground systems via IRIDUM satellites4. The data is then used with a computer model to predict the water height which is compared to normal levels. If two readings of the water height exceed what is considered normal height, then the monitoring continues for a minimum period of 3 hours. The system will revert to infrequent readings of data if for 3 hours there are no anomalies observed. As long as readings indicate that normal water levels are exceeded, data will be collected (typically 4 minutes of 15 second observations followed by one-minute average values). The data and a numerical model are then used to forecast the propagation of the tsunami wave height. Moreover, site-specific tsunami inundation models are used to estimate the area that will be affected by the forecasted tsunami. These estimates are continuously updated as new data becomes available. Tsunami guidance is then issued.

Question 6. With some buoys inoperable, how were predictive capabilities impacted? Please answer in terms of accuracy and warning time.

Answer. I am not qualified to give you specifics in terms of accuracy and warning time. This question should be addressed to the National Oceanic and Atmospheric Administration's Pacific Tsunami Warning System who operates the tsunami system. Based on my limited understanding, there are approximately 26 instruments in the Pacific Ocean and the model utilizes those to update the tsunami height continuously. How the results are affected will depend on which instruments were inoperable and where they were located. This is one reason why in general we would like to have dense instrumentation. Instruments do malfunction when exposed to extreme weather conditions and with dense networks we can greatly reduce the error of tsunami height and time of arrival forecasts.

Question 7. You identified a need to develop a "performance-based earthquake engineering (PBEE) design tools to enable rapid and widespread adaptation of advanced design methods." Is the United States on track to develop these tools?

Answer. Provided the NEHRP program is funded, we will continue to make progress in that direction. We have the knowledge, intellectual capacity and expertise to achieve this goal.

Question 8. Has your research group collaborated with economists to model the average annual cost of earthquake damage with and without PBEE tools? If so, what is the cost of preparedness compared to the potential cost of damage without PBEE?

Answer. While I have collaborated with economist throughout my career to answer similar questions, we have not addressed this specific issue. However, PBEE will address an issue that is totally ignored in current seismic codes that require life safety design only. With PBEE we will be designing structures to different requirements for functionality. For example, a hospital will need to be designed so that it is fully operational immediately after an earthquake without interruption. This means that it should not have any structural, contents or non-structural damage (these are partition walls, elevators, mechanical equipment, etc.). Another example is a large manufacturing facility will need to be functional within 5 to 10 days depending on what the owner specifies. The consequence of this design is that there will be minimal loss from business interruption.

You may ask why we are interested in minimizing losses from non-functionality of facilities. We conducted a study to estimate the losses from damage to transportation systems in the San Francisco Bay Area. Two types of losses were estimated. The first is the loss from direct damage to bridges and the second is increase in travel time due to the closure or reduction in lanes of damaged bridges. The second type of loss is what we call functionality loss. The results show that functionality losses can exceed direct losses from damage to structures. The figure below shows annual probability of loss exceedence for direct, functionality and total losses. For

[4] Marie C. Eble and Scott E. Stalin (2007). *Description of Real-Time DART System Messages*, Report by the U.S. National Oceanic and Atmospheric Administration, Pacific Marine Environmental Laboratory, Engineering Development Division, 7600 Sand Point Way, Seattle, WA 98115.

example, at the .004 annual probability, the direct structural loss is $1 Billion and the operational (or functionality) loss is $1.2 Billion.

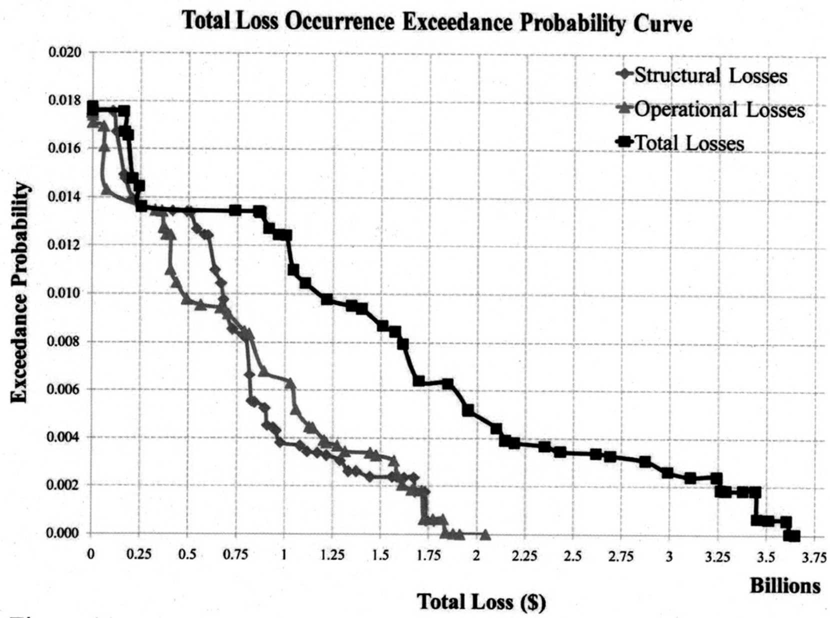

Figure 11 Annual risk curves of the transportation network in five counties in the San Francisco Bay area.[5]

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. ROGER F. WICKER TO ANNE S. KIREMIDJIAN, PH.D.

Question 1. Last week five southern states, including Mississippi, experienced devastating tornadoes that resulted in hundreds of lives lost and extensive property damage. Early warning systems alerted those in danger to the threat an average of 24 minutes prior to tornadoes touching the ground. However, many residents in southern states do not have safe escape options to fit that timeframe. What research is being conducted to improve advanced warning systems for tornadoes?

The response to this question is developed by Professor Anne Kiremidjian, Stanford University and Professor Kishor Mehta, Texas Tech University. Both are members of ASCE.

Answer. Tornado warning systems have been in existence for some time and they are deployed in most if not all tornado prone areas. Tornadoes can be identified as being formed 20 to 30 minutes prior to reaching a populated area and typically a tornado warning will be issued about 15 to 20 minutes before it reaches a populated region. According to local accounts, tornado warnings were issued during the recent tornadoes in the Midwest (Jeremy A. Kaplan, April 28, 2011, *FoxNews.com*). These are operated by the National Weather Service of the National Oceanographic and Atmospheric Administration (NOAA). In order to provide more accurate potential of tornado occurrence, the National Weather Service uses surface observation, radar data, satellite, airplanes, and balloons that are launched twice daily. Data from these observations are used to measure the atmospheric changes and are used in a computer model to predict the storms. Radar imagery is used to note the formation of a vortex that is the beginning of a tornado leading to a warning. The greatest difficulty is to predict the path and the intensity with accuracy. Typically a wide area is reported with the warning to provide a more inclusive warning.

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[5] Stergiou, E. and Kiremidjian, A. (2009), Risk Assessment of Transportation Systems with Network Functionality Losses, *Structure and Infrastructure Engineering*, Vol. 6, No. 1, pp. 111–125.

There are several reasons why warnings may not have been effective in the recent tornado events. The most common is complacency and inaction by individuals when hearing a tornado warning. This problem is often due to coarseness in tornado path identification. As stated previously, when a tornado warning is issued, it covers a broad area and as a result, some of the locations that received warning are unaffected leading people to ignore subsequent warnings. Currently researchers are pursuing projects in improving technology to more narrowly predict the path of a tornado. An example of a project is VORTEX2 in which almost 100 scientists spent 6 weeks in the field in 2010 and 2011 chasing tornado producing thunderstorms to measure a wide variety of meteorological data. Analysis of data gathered in this project will result in to improved understanding and potential improvement in prediction including intensity of tornadoes. National Weather Service will need to educate and train NWS office personnel to improve in issuing warnings, thus limiting the number of false alarms and increasing public confidence in the credibility of the warnings.

Question 2. How is science being used to better protect citizens and property from catastrophic events such as those that occurred last week?

The response to this question is developed by Professor Anne Kiremidjian, Stanford University and Professor Kishor Mehta, Texas Tech University. Both are members of ASCE.

Answer. Providing shelters for people who do not have basements or are in mobile homes is a long recognized problem. Providing shelters for the general public can be achieved at several levels.

a. On the individual household level, basements have shown to provide adequate safety against tornadoes. The problem is that with construction costs increasing as well as by tradition many areas in the country build houses directly on the ground without any basements. In addition, about 30 percent of the population lives in mobile homes that is most vulnerable to all natural hazards, not just tornadoes. However, solutions other than basements do exist. There are safe rooms that can be built inside residence that are relatively inexpensive. Federal Emergency Management Agency has published a booklet, *Taking Shelter from the Storm: Building a Safe Room Inside Your House, FEMA 320*, which is available on FEMA website. This booklet contains construction details for eight different safe room modules for a combination of various construction materials. Several manufacturers have developed modules that are commercially available and vendoers or builders can install them. Builders can also build safe room on-site in a new home or retrofit in an existing home. Affordability, of course is always a question, and government subsidy may be justified if no other solution can be provided.

b. In schools, nursing homes and other public buildings where people have difficulty moving rapidly it is possible to build a large safe room using criteria given in *Design and Construction Guidance for Community Safe Rooms, FEMA P–361, second edition, August 2008.* These guidelines can also be used for construction of safe room in manufactured home park or for a community. They need to be strategically located within 10 minute distance of populated areas. To make these cost effective, they should serve a dual purpose. For example, a local library can be built to be sturdy enough to resist a large tornado and can house several hundred local residents when a warning is issued. Existing buildings may not be strong enough to resist a severe tornado and may need to be strengthened needing subsidies from local, state or the Federal Government since that can be an expensive process. The expenditure, however, is well justified given that these structures will result in saving of lives.

c. Reduction of property damage in tornadoes is a challenge. Vast majority of tornadoes are not severe. Only 10 percent of tornadoes out of approximately annual 1,200 tornadoes are rated as severe (EF–3, EF–4. EF–5). Of these, 2 to 3 percent are catastrophic causing majority of fatalities. However, we continue to see property damage even in EF–1 and EF–2 tornadoes. There are several reasons for this level of damage. Residential structures are generally not designed by engineers. Building codes and standards have improved over the years though the requirements are not enforced by localities. Also, we do not have cost effective way of retrofitting residential structures. In commercial buildings wind borne debris in windstorms break window glass which leads to extensive damage to the interior and furnishings not to mention business interruption. In most parts of the country there is no requirement of debris resisting glazing. Institute of Building and Home Safety (IBHS, an insurance industry organization) has recently constructed a large wind tunnel facility where a typical two-story house can be tested. There is very little ongoing research in academic institutions for retrofitting and damage mitigation. Providing funds for Windstorm Hazard Mitigation program will build government and private partnership with the ultimate goal of reducing property damage and also injuries and fatalities.

d. The insurance and construction industries, research and development institutions, and the government can work together to promote windstorm damage mitigation measures. It is envisioned that every dollar invested in a meaningful mitigation measure has potential of saving the country four dollars. Innovative approaches are needed to develop construction criteria for new construction and retrofitting existing buildings that are cost effective. This would be a long term solution to mitigate damage in windstorm and other natural hazards and save money for the country.

There are several Federal agencies that support national weather prediction and natural hazard preparedness. There is also a great deal of research on natural hazards that is carried out by academic institutions and the private sector.

Question 3. How are efforts by the Federal Government utilizing resources available through academic institutions and the private sector? In what ways could this be improved?

The response to this question is developed by Professor Anne Kiremidjian, Stanford University.

Answer. Weather prediction is not my specialty and thus my comments will be addressed to natural hazards preparedness in general. To the best of my knowledge, various Federal agencies have utilized academic resources in the following ways:

a. Engaging academics and private sector individuals who are at the forefront of various disaster related research and development to serve as consultants on key issues. For example, FEMA's engaged jointly academics and private industry in the development of natural disaster assessment software called HAZUS–MH (*http://www.fema.gov/plan/prevent/hazus/hz_overview.shtm*) was developed by a team comprised by academics and private industry personnel. HAZUS currently has earthquake, hurricane winds and flood loss estimation capabilities and is used by variety of local and state governments in addition to FEMA to project potential losses. Another example is the study initiated by FEMA following the January 17, 1994, Northridge California earthquake to evaluate the problem of the joints in steel moment frames and to develop technologies for retrofitting all existing steel moment frames that are in earthquake prone areas. The results of these investigations have been adopted in the latest International Building Codes and are part of the current seismic design requirements of structures.

b. Workshops are organized on annual basis (sometimes several times per year) to identify technologies that can be implemented or further developed. These workshops are usually intended as technology transfer mechanisms.

c. Support for technology transfer to industry is provided by the National Science Foundation through the Small Business Innovation Research (SBIR) program. Similar programs are available through other Federal agencies, but those are typically not for disaster related research. Small business loans are usually ineffective in this industry because they require personal guarantees for all loan amounts and the business model does not justify the expenditures. While the National Institute for Standards and Technology has had a successful Technology Innovation Program (TIP) I am not aware that any of the projects supported through that program are specifically disaster related. Some of the technologies may eventually be used for disaster purposes.

Are these sufficient? In general, adaptation of disaster-related advanced technologies is extremely slow in the U.S. I have seen other countries, notably Japan and most recently China take developments from the U.S. and adopt them on large scales, while we are still sitting and waiting for funding or acceptance by industry. For example, a new material developed by one of my colleagues, Professor Michael Lepech from Stanford, is being adopted both in Japan and in China for earthquake resistant retrofitting of vulnerable reinforced concrete structures. Why are these countries willing to rapidly commercialize such research and development efforts and we are not? They are willing to put the financial resources in the implementation of these technologies and have minimal concerns about possible litigation. Adaptation in the U.S. is hampered by lack of resources for developing proof of concept projects. An added problem is the unwillingness of both professionals and owners to accept new technologies even if they are more cost effective over existing proven methods. Part of the problem is the high cost of litigation that can result from potential failures.

How can we improve? Perhaps the best way to accelerate the acceptance of new technologies is to enable demonstration project. Other nations invest far more (relative to their GDP) in disaster research and development than we do in the US. For example, Japan spend several billion dollars after the January 17, 1995 Kobe, Japan earthquake in installing instruments, tsunami early warning system, development of evacuation plans, retrofitting vulnerable structures, etc. The fact is that there are many technologies that if implemented can result in great reduction of losses. Some of those are simple things that people can do, while others require significant financing. What we are lacking is a plan for resiliency against natural disasters and then implementation of this plan. In the study that I cited in my testimony related to disaster mitigation strategies, we demonstrated how communities that were provided funding by FEMA through "Project Impact" greatly increased their disaster resiliency. Reinstatement of this program will be highly beneficial to our country.

Question 4. Can the government leverage resources through academic and private entities to advance natural hazard preparedness while saving costs to the American taxpayer?

Answer. The simple answer is yes. We have some of the best researchers and private industry professional. These include geoscientists, atmospheric scientist, engineers (structural, geotechnical, earthquake, wind, and flood engineers), computer scientists, and practitioners from the respective industries. A plan should be developed on how to implement existing technologies to greatly reduce future losses from natural disasters and increase community resilience. There should also be a plan for developing technologies that are currently lacking. The National Research Council study has identified some key elements of the research needs. The plan that is needed, however, is to identify all currently existing viable technologies that can be implemented today and to have a specific step by step approach on how to apply these technologies. Such a plan should assess the costs and identify an approach for cost sharing between individuals, private entities, professionals and governments. Example of such an activity would be a community identifying a structure that can serve as a shelter but needs further strengthening. A community wide effort that involves local contractors and engineers with some funding from local, state and Federal agencies can do the retrofitting.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN D. ROCKEFELLER IV TO PROFESSOR CLINT DAWSON

Question 1. You have mentioned the tension between funding for research on short-term projects rather than for long term priorities. Your fellow witness, Dr. Kiremidjian, has described the results of the 33-year focus on earthquakes provided by NEHRP. If long-term funding were available, what projects would you undertake that you currently cannot?

Answer. In my area, the critical needs are to study the fully coupled atmospheric, oceanic, coastal and geo-morphological system, to determine how storm surge is generated and propagated from the ocean onto the shore, and how storm surge interacts with and impacts the natural and man-made coastal environment. The goal of this research agenda would be to identify, categorize and mitigate risk, and hopefully convey information to govt. officials and the public in a way that informs future coastal development, public policy and the sustainability of coastal environments. This is a difficult problem for several reasons. One, there is tremendous uncertainty in almost all aspects of the problem, the uncertainty needs to be quantified and if possible new measurement techniques designed to reduce the uncertainty. Second, the problem is inherently multi-scale, it involves processes on the global, regional and local climate scales (on the order of kilometers), the basin, continental shelf and inland oceanic scales (from kilometers to hundreds of meters), down to the submeter scale in areas such as wetlands and channels. Third, we do not currently have the ability to model these problems on present-day computers. New computer algorithms and software will need to be developed which can handle complex multiphysics and take advantage of new computer architectures.

A few years ago, there was some discussion with Sen. Kay Bailey Hutchison's staff about a proposed national hurricane initiative, which would have created a long-term, multi-agency, interdisciplinary research agenda for hurricane-related research. I supported this idea, as I feel it is the kind of long-term, sustained effort which could create new collaborative research projects and lead to significant and far-reaching breakthroughs. At present, there is no one agency that funds basic research in all aspects of hurricanes. The National Science Foundation has been a welcome source of funding for my research, but only as it pertains to the scientific computing aspects. One would expect that NOAA would be the right agency to fund such research, but my experience with NOAA has been that its mission is more on operations and not basic research. Some sort of cross-cutting, multi-agency sustained research initiative would in my opinion be the best approach.

Question 2. How have computer simulations guided policymakers in preparing for or reacting to natural disasters?

Answer. In my home state of Texas, the results from new high resolution forecast storm surge models being run at the University of Texas at Austin are shared with the Texas Division of Emergency Management, which coordinates emergency response in the event of a hurricane approaching Texas. The results from these simulations are used to deploy first responders and provide guidance to local officials regarding emergency evacuations. We also collaborate with researchers at Louisiana State University to provide information to the State of Louisiana in the event of a hurricane approaching their coast. Our ability to perform these high resolution studies in "real-time" is due to improved computer models and computer technology which has come on-line in the past 3 years.

Similar high resolution computer modeling studies have been used, for example, by researchers at the University of Notre Dame and the U.S. Army Corps of Engineers to study all of the new levee systems which are being built in southern Louisiana in the aftermath of Hurricane Katrina. Similarly my group at UT Austin is working with Rice University and public officials in the Houston, TX region to study potential storm surge mitigation strategies for the Houston-Galveston metropolitan area in the aftermath of Hurricane Ike. These computer models are also being used to develop new Digital Flood Insurance Rate Maps (DFIRMS) for FEMA, which determines which areas of the coast qualify for Federal flood protection.

Question 3. What advances in storm system and disaster modeling are forthcoming that will aid future decision-makers?

Answer. These are advances which are either in the works or proposed:

1. The ADCIRC Surge Guidance System (ASGS) is being deployed at The University of North Carolina-Chapel Hill, Louisiana State University, the U.S. Army Corps of Engineers, and the University of Texas at Austin. The ASGS is a state-of-the-art hurricane surge forecast system which produces predictions of storm-surge in real-time. Results from the ASGS are posted and shared with emergency managers across several states, and with the U.S. Army Corps of Engineers. Future capabilities of the ASGS will include ensemble surge modeling where a suite of potential storm tracks can be executed simultaneously to provide emergency managers with statistical information on the probability of a significant storm surge event in a given region of the coast.

2. There have been significant advances in data collection, measurements, and instrumentation over the past 5 years, primarily through NOAA, the USGS, and state and local agencies. The coupling of data with computer models has led to vast improvements in the physical descriptions of the coastal ocean and coastal environment, and improved our ability to mathematically model hurricanes, and has in turn provided feedback which has led to improved data collection.

3. As we move into the future, we hope to have a better understanding of the longer-term impacts of storm surge on coastal ecology, wetlands, barrier islands, shorelines, as well as on the built infrastructure, including protection systems such as levees, buildings, bridges, ports and harbors, and industrial complexes. This understanding we hope will guide policymakers, government officials, and local communities to make informed decisions about coastal development and help make coastal communities more resilient to disasters.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. ROGER F. WICKER TO PROFESSOR CLINT DAWSON

Question 1. Last week five southern states, including Mississippi, experienced devastating tornadoes that resulted in hundreds of lives lost and extensive property damage. Early warning systems alerted those in danger to the threat an average of 24 minutes prior to tornadoes touching the ground. However, many residents in southern states do not have safe escape options to fit that timeframe. What research is being conducted to improve advanced warning systems for tornadoes?

Answer. This is not my area of expertise.

Question 2. How is science being used to better protect citizens and property from catastrophic events such as those that occurred last week?

Answer. There are several Federal agencies that support national weather prediction and natural hazard preparedness. There is also a great deal of research on natural hazards that is carried out by academic institutions and the private sector.

Question 3. How are efforts by the Federal Government utilizing resources available through academic institutions and the private sector? In what ways could this be improved?

Answer. In my field, the Federal Government agencies that I interact with are the U.S. Army Corps of Engineers, FEMA and to a lesser degree NOAA. The USACE uses our computer models (developed in a partnership with 3 academic institutions) to study levee designs for hurricane protection systems along the Gulf coast. FEMA uses our model to design flood insurance rate maps for coastal states. NOAA is evaluating our model for forecasting storm surge. Essentially these agencies are utilizing resources which were initially paid for by several agencies, including the National Science Foundation. I think this is a great example of basic research eventually becoming useful to the larger scientific community and the Federal Government. One difficulty has been sustaining funding so that we can see the research through to its fruition. That is, once a computer model is developed, getting it to the point where it can be used by a non-expert is difficult. This is one area where interaction with private industry can be helpful, specifically consulting companies which have expertise in software engineering and commercialization. Finding the right mix of financial support is often difficult however.

Question 4. Can the government leverage resources through academic and private entities to advance natural hazard preparedness while saving costs to the American taxpayer?

Answer. Yes and they do. For example, we work at the request of the Texas Division of Emergency Management during hurricane events to provide them with storm surge forecasts for storms approaching Texas or Louisiana. This is in addition to what is provided by the National Weather Service. We utilize computer resources available on our campus funded by the NSF and the State of Texas. We use computer models developed under federally-funded research, but the state doesn't pay us directly to do these forecasts. We do this as a public service and consider it part of our outreach.

Question 5. Hurricane Katrina devastated thousands of homes in Mississippi and Louisiana. Following the storm there were disputes regarding wind versus water damage to coastal properties and how residents should be compensated for their losses by insurers of wind versus the National Flood Insurance Program for flood damage. These disputes have been litigated for years in the courts, further delaying recovery of the Gulf Coast. Does the proper science and technology exist today that could tell us, with reasonable certainty, wind speeds and storm surge levels during a hurricane that could allow for a better understanding of how these perils impacted coastal properties? In other words, can reliable scientific data be collected to better assess wind and water property damage following a hurricane?

Answer. For the most part yes, and this has been done for all of the U.S. hurricanes since 2005. Our computer models have simulated Katrina, Rita, Gustav and Ike. We can match measured water levels over 80–90 percent of the affected areas of the coast to within .5 meter, and often within .1 meter. This work has been peer-reviewed and published (except for Ike which is still underway). We are in a much better position than we were 6–7 years ago with respect to predicting flooding. Also, there have been significant efforts at instrumentation in these regions for obtaining better measurements of water levels, wave heights and wind velocities. There are still a few areas where we see errors between measurements and model results, particularly near certain types of coastal structures, and in wetlands and marshes. These areas need further investigation. There is also still work to be done on predicting the impacts of wave overtopping on coastal structures during a hurricane. But wave overtopping is generally restricted to the area right at the shoreline.

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