THE STATE OF HURRICANE RESEARCH AND H.R. 2407, THE NATIONAL HURRICANE RESEARCH INITIATIVE ACT OF 2007

JOINT HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

AND THE

SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

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CONTENTS

June 26, 2008

Appendix: Answers to Post-Hearing Questions

THE STATE OF HURRICANE RESEARCH AND H.R. 2407, THE NATIONAL HURRICANE RESEARCH INITIATIVE ACT OF 2007

THURSDAY, JUNE 26, 2008

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT,
JOINT WITH THE
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittees met, pursuant to call, at 10:08 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Nick Lampson [Chairman of the Subcommittee on Energy and Environment] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

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Hearing on

The State of Hurricane Research and H.R. 2407, the National Hurricane Research Initiative Act of 2007

Thursday, June 26, 2008
10:00 a.m. to 12:00 p.m.
2318 Rayburn House Office Building

Panel I:

Hon. Alcee L. Hastings
A Representative in Congress from the State of Florida

Hon. Ileana Ros-Lehtinen
A Representative in Congress from the State of Florida

Panel II:

Dr. John L. "Jack" Hayes
Assistant Administrator for Weather Services
Director of the National Weather Service

Dr. Kelvin K. Droegemeier
former Co-Chair
National Science Board's Task Force on Hurricane Science and Engineering

Dr. Shuyi Chen
Associate Professor of Meteorology and Physical Oceanography
University of Miami, Rosenstiel School of Marine & Atmospheric Sciences

Dr. David O. Prevatt
Professor at the Department of Civil and Coastal Engineering
University of Florida

Dr. Stephen P. Leatherman
Director of the International Hurricane Research Center
Florida International University

HEARING CHARTER

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
JOINTLY WITH THE
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

The State of Hurricane Research and H.R. 2407, the National Hurricane Research Initiative Act of 2007

THURSDAY, JUNE 26, 2008
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

I. Purpose

On Thursday, June 26, 2008 the Subcommittee on Energy and Environment and the Subcommittee on Research and Science Education of the Committee on Science and Technology will hold a joint hearing to examine the Nation's hurricane research and development priorities, and to receive testimony on H.R. 2407, the *National Hurricane Research Initiative Act of 2007*.

H.R. 2407, introduced by Representative Hastings (D–FL), establishes a National Hurricane Research Initiative to improve hurricane preparedness. The hearing will examine the proposed legislation that sets research objectives based on the National Science Board's 2007 Report, *"Hurricane Warning: The Critical Need for a National Hurricane Research Initiative."* The hearing will also examine the status of hurricane research, ways in which current research efforts could be improved, and how the proposed legislation would affect the overall state of our nation's hurricane preparedness, including our ability to save lives and mitigate property loss.

II. Witnesses

- **Dr. John L. "Jack" Hayes** is the Assistant Administrator for Weather Services and the Director of the National Weather Service, National Oceanic and Atmospheric Administration (NOAA). Dr. Hayes will discuss the current state of federally funded hurricane research at NOAA, NOAA's perceived role in a National Hurricane Initiative, and the agency's position on the proposed legislation.
- **Dr. Kelvin K. Droegemeier** is the former Co-Chair of the National Science Board's Task Force on Hurricane Science and Engineering. Dr. Droegemeier will discuss the findings and recommendations of the Board's report, "Hurricane Warning: The Critical Need for a National Hurricane Research Initiative."
- **Dr. Shuyi Chen** is an Associate Professor of Meteorology and Physical Oceanography at the University of Miami, Rosenstiel School of Marine & Atmospheric Sciences. Dr. Chen will provide her perspective, as a hurricane researcher, as to the current gaps in hurricane related research, and the role of a national research initiative.
- **Dr. David O. Prevatt** is an Assistant Professor at the Department of Civil and Coastal Engineering, University of Florida. As an expert in hurricane wind damage, Dr. Prevatt will provide input on the proposed legislation from the perspective of the wind engineering community.
- **Dr. Stephen P. Leatherman** is the Director of the International Hurricane Research Center at Florida International University. Dr. Leatherman will discuss the work being done at the Hurricane Research Center and comment on the proposed research initiative in the legislation.

III. Background

An increase in hurricane activity in recent years has brought to the Nation's attention our growing vulnerability to natural disasters. The devastation and far-reaching impact of recent hurricanes have demonstrated the urgent need for an improved understanding of hurricanes and the ways in which we can better prepare so as to minimize loss of life and destruction of property. The economic losses from hurricanes are staggering. It is estimated that hurricane-related losses averaged more that ten billion dollars annually from 1990 to 1995, and upwards of $35 billion a year from 2000 to 2006.[1] These numbers would most likely escalate in coming years as our economy grows and more investments are expected to be made in coastal infrastructure. While billions of tax dollars are spent on rescue and relief efforts after a hurricane strikes, the Federal Government invests relatively little in the science and engineering research that could prevent much of the destruction and greatly minimize losses. The National Science Board (NSB) estimates that federal fiscal year budget investments for science and engineering research related to hurricanes totaled around $200 million dollars in fiscal year 2006.[2] When attempting to assess federal dollars going to hurricane research at the time, the NSB found the exact numbers difficult to pinpoint, indicating a potential lack of focus and coordination among agencies. Even so, the most optimistic of estimates suggest that our current funding levels are inadequate to address our increasing vulnerability to hurricanes.

In December of 2005, the National Science Board[3] established the Task Force on Hurricane Science and Engineering in an effort to assess and improve our nation's ability to predict, mitigate, and better respond to hurricanes. The task force set out to evaluate and make recommendations for ways to improve the Nation's hurricane-related research activities. In January, 2007, the Task Force released the results of its year long assessment, a report entitled, *"Hurricane Warning: The Critical Need for a National Hurricane Research Initiative."* The report concluded that "the U.S. must engage in a nationally coordinated, multi-agency and multi-disciplinary research initiative to greatly expand our understanding of hurricanes and identify more effective strategies for dealing with them."[4] The report outlined the structure and budget necessary to implement such an initiative.

The report concluded that the United States is becoming increasingly vulnerable to hurricanes, while our coastal areas are becoming more and more heavily populated. A National Academies Study found that half of the U.S. populations live with in 50 miles of coastline.[5] Furthermore, taking into consideration the interconnectedness of our economy, hurricane devastation affects more than just the community hit. The effects are felt throughout the Nation through increased fuel prices, displaced citizens, and much more.

National Hurricane Research Initiative, H.R. 2407

The National Hurricane Research Initiative (NHRI) takes the recommendations from the National Science Board report to create a multi-agency effort focused on improving our ability to predict hurricanes and their intensity, and on mitigating the devastating affects on coastal populations. This NHRI would engage all relevant federal agencies, industry, academia, and local government to strengthen hurricane research through an integrated and highly focused framework, promoting multi-disciplinary, multi-agency involvement. The National Oceanic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF) are designated as the two leading agencies responsible for implementation and oversight of the Initiative.

The NSB report outlines four investment categories that are reflected in the bill language of H.R. 2407:

1. Understanding and Prediction: Research will be directed to more quickly and accurately predict hurricane intensification, size, and location of landfall. Also, research is needed to understand and model storm surge, rainfall and flooding from hurricanes. Research will be focused on improving hurricane

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[1] *http://www.nsf.gov/nsb/committees/hurricane/financial.pdf*

[2] Hurricane Warning: The Critical Need for a National Hurricane Research Initiative, 2007. *http://www.nsf.gov/nsb/committees/hurricane/initiative.pdf,* Appendix A.

[3] The National Science Board, comprised of twenty-four members appointed by the President, is the governing body of the National Science Foundation, and serves as an independent body of advisors to the President and Congress on national science and engineering research and education policy issues.

[4] Hurricane Warning: The Critical Need for a National Hurricane Research Initiative, 2007. *http://www.nsf.gov/nsb/committees/hurricane/initiative.pdf*

[5] National Academy of Sciences, *Meeting Research and Education Needs in Coastal Engineering,* p. 11, National Academy Press (1999).

storm observation technology through GPS technology, unmanned aerial vehicles, mobile radars, etc.

2. Impacts: Research will focus on the interaction of hurricanes with engineered structures, so coastal infrastructure can be better assessed for vulnerability to hurricanes. Research will be directed at better understanding the economic and social impacts of hurricanes, so we can identify impediments to implementing research outcomes. Also, fundamental research is needed to understand the relationship between hurricanes and climate and natural ecosystems.
3. Preparedness and response measures: Research will be directed towards implementing a national engineering assessment of coastal infrastructure to identify the levees, bridges, and other infrastructure that may be particularly vulnerable to hurricanes. Studies are needed to develop the most cost-effective improvements that can be made to already built infrastructure. Research will focus on improved technologies for disaster response and recovery as well as the complex challenge of evacuation and risk planning.
4. Cross-cutting activities: Research is needed to learn how to better utilize the next generation of petascale computers in hurricane research and modeling. Research will also be directed towards incorporating hurricane impacts and related engineering principles in to training and education programs.

H.R. 2407 also calls for the establishment of a National Infrastructure Data Base (NIDB) and The National Hurricane Research Test Bed (NHRTB). The NIDB will be a comprehensive database serving as a baseline to develop measurement standards that will aid the research community's ability to measure hurricane impacts and make effective recommendations for improved urban planning and building codes. In addition, the bill calls for the establishment of the NHRTB, which will be an interdisciplinary laboratory focused primarily on the transfer of research knowledge to operational applications. It will link models from a variety of related fields and conduct experimental integrative research. The NHRI is a model for a coordinated system to encourage interaction and collaboration for the purposes of a comprehensive hurricane research effort.

Current Federal Hurricane Research

While private companies are also making important advances in hurricane research, NOAA and NSF are the leaders in the federal hurricane research efforts.

The National Science Foundation invested an estimated $13.5 million dollars in fiscal year 2006 in a variety of hurricane-related research.[6] NSF awards research grants to carry out research in a variety of areas that seek to improve our fundamental understanding of hurricanes. NSF currently invests in research in each of the ten research areas designated in the bill language: Predicting hurricane intensity change; understanding ocean-atmosphere interactions; predicting storm surge, rainfall, inland flooding, and strong winds produced by hurricanes and tropical storms during and after landfall; improved observations of hurricanes and tropical storms; assessing vulnerable infrastructure; interaction of hurricanes with engineered structures; relationship between hurricanes, climate, and natural ecosystems; technologies for disaster response and recovery; evacuation planning; and computational capability.

In response to the recommendations made by the NSB report as well as others, NOAA established the Hurricane Forecasting Improvement Project (HFIP) in order to accelerate improvements in forecasting the tracking of hurricanes, modeling capabilities, and intensity to increase confidence to enhance mitigation and preparedness decisions. Within the HFIP, NOAA seeks to embrace strong collaboration with non-NOAA partners with the objective to transition research into operations.

The April 2008 draft plan, *Proposed Framework for Addressing the National Hurricane Research and Forecast Improvement Initiatives: NOAA's Hurricane Forecast Improvement Project,*[7] provides the basis for NOAA and other agencies to work toward a national effort to coordinate national hurricane research and align not only other agencies, but the scientific communities' efforts in addressing the challenges posed to improve hurricane forecasts. The main goals of the HFIP are to:

- Improve the accuracy and reliability of hurricane forecasts;
- Extend lead time for hurricane forecasts with increased certainty; and

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[6] Hurricane Warning: The Critical Need for a National Hurricane Research Initiative, 2007. *http://www.nsf.gov/nsb/committees/hurricane/initiative.pdf*

[7] National Oceanic and Atmospheric Administration Hurricane Forecast Improvement Plan, 2008. *http://www.nrc.noaa.gov/plans_docs/HFIP_Draft_Plan-1.pdf*

- Increase confidence in hurricane forecasts.

These efforts will require major investments in enhanced observational strategies, improved data assimilation, numerical modeling systems, and expanded forecast applications based on the high resolution and ensemble based numerical prediction systems.

The plan mapped the needs into five research focus areas:

- Conduct basic research on the processes that contribute to rapid intensification and on the theoretical limits of predictability.
- Optimize exploitation of current and planned observing systems for both research and operations and identify observational gaps and develop initiatives to address those with significant potential.
- Improve data assimilation to fully exploit all in situ and remotely sensed data for both research and operational forecast.
- Improve numerical and other models for operational use to reduce error in track and intensity guidance, quantify uncertainty in these forecasts, and extend the timeframe for useful predictions related to hurricane development, evolution, and decay; build in the capacity to represent the physical processes responsible for rapid intensity change.
- Expand and enhance forecast tools and applications to add value to the model guidance and direct use of observations by the forecasters and diverse user community.

H.R. 2407: The National Hurricane Research Initiative Act of 2007

SECTION-BY-SECTION

Section 1. Short Title and Table of Contents

Provides the short title of the legislation: The National Hurricane Research Initiative Act of 2007.

Section 2. Definitions

Defines the terms Director as the National Science Foundation and Under Secretary for Oceans and Atmosphere of the Department of Commerce.

Section 3. National Hurricane Research Initiative

Requires the Under Secretary and the Director to establish a National Hurricane Research Initiative and to cooperate with other specified federal agencies to focus on the improvement of hurricane research, forecasting capabilities, and mitigation impacts.

Also, requires such initiative to set ten research objectives (based on a National Science Board report) and make grants available for carrying out hurricane research in those ten specific areas.

Authorizes appropriations of $285,000,000 for each fiscal year 2008 through 2018.

Section 4. National Infrastructure Database

Requires the establishment of a National Infrastructure Database as a virtual, cyber environment to catalogue traits necessary for providing a baseline; provides information to Federal, State, and local governments for use in policy-making; and provides data to researchers. Authorizes appropriations of $20,000,000 for each fiscal year 2008 through 2018.

Section 5. National Hurricane Research Test Bed

Requires the development of a National Hurricane Research Test Bed to conduct integrative research and to facilitate the transfer of research knowledge to operational applications.

Authorizes appropriations of $130,000,000 for each fiscal year 2008 through 2018.

110th
CONGRESS
1st Session

H. R. 2407

To establish the National Hurricane Research Initiative to improve hurricane preparedness, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

May 21, 2007

Mr. Hastings of Florida (for himself, Ms. Ros-Lehtinen, Ms. Wasserman Schultz, Mr. Thompson of Mississippi, Mr. Melancon, Mr. Taylor, Mr. Jindal, Mr. Meek of Florida, Mr. Klein of Florida, Mr. Wexler, Ms. Corrine Brown of Florida, Mr. Mahoney of Florida, Mr. Mario Diaz-Balart of Florida, Mr. Lincoln Diaz-Balart of Florida, Mr. McIntyre, Mr. Ortiz, Mr. Jefferson, Mr. Keller of Florida, Mr. Mack, and Mr. Buchanan) introduced the following bill; which was referred to the Committee on Science and Technology

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A BILL

To establish the National Hurricane Research Initiative to improve hurricane preparedness, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. Short title.

This Act may be cited as the "National Hurricane Research Initiative Act of 2007".

SEC. 2. Definitions.

In this Act:

(1) Director.—The term "Director" means the Director of the National Science Foundation.

(2) Under Secretary.—The term "Under Secretary" means the Under Secretary for Oceans and Atmosphere of the Department of Commerce.

SEC. 3. National Hurricane Research Initiative.

(a) Requirement To establish.—The Under Secretary and the Director shall establish an initiative known as the National Hurricane Research Initiative for the purposes described in subsection (b).

(b) Purposes.—The purposes of the National Hurricane Research Initiative shall be to set research objectives based upon the findings of the January 12, 2007, National Science Board report entitled "Hurricane Warning: The Critical Need for National Hurricane Research Initiative"—

(1) to make recommendations to the National Science Board and the National Oceanic and Atmospheric Administration Science Advisory Board on such research;

(2) to assemble the science and engineering expertise of State or local government agencies or departments and nongovernmental entities (including universities and colleges and other research and academic institutions), through a multi-entity effort focused on—

(A) improving hurricane and other severe tropical storm forecasting capabilities, including formation, track, and intensity change;

(B) durable and resilient infrastructure; and

(C) mitigating impacts on coastal populations, the coastal built environment, and the natural coastal environment, including but not limited to, coral reefs, wetlands, and other natural systems that mitigate hurricane wind and storm surge impacts; and

(3) to make grants to eligible entities to carry out research in the following areas:

(A) Predicting hurricane intensity change.—Research to improve understanding of—

(i) rapid change in storm size, motion, structure, and intensity;

(ii) storm internal dynamics; and

(iii) the interactions of the storm and its environmental conditions, including the atmosphere, ocean, and land surface.

(B) Understanding ocean-atmosphere interactions.—Observations, theory and modeling, to improve understanding of air-sea interaction in high wind speeds.

(C) Predicting storm surge, rainfall, inland flooding, and strong winds produced by hurricanes and tropical storms during and after landfall.—Research to understand, model, and predict rainfall, flooding, high winds, the potential occurrence of tornadoes, and storm surge, including probabilistic modeling and mapping of risk.

(D) Improved observations of hurricanes and tropical storms.

—Research to improve measurements of hurricanes and tropical storms through mobile radar platforms, Global Positioning Systems technology, unmanned vehicles, ground-based and wireless sensors, oceanic remote sensing technologies, and air-deployed ocean profilers and floats to improve our understanding of the complex nature of storms and their interaction with the ocean and land.

(E) Assessing vulnerable infrastructure.—Research to develop a national engineering assessment of coastal infrastructure, including infrastructure related to levees, seawalls, drainage systems, bridges, water and sewage systems, power, and communications, to determine the level of vulnerability of such infrastructure to damage from hurricanes and to determine strategies to reduce such vulnerabilities.

(F) Interaction of hurricanes with engineered structures.—Research to improve understanding of the impacts of hurricanes and tropical storms on buildings, structures, and housing combined with modeling essential for guiding the creation of improved building designs and construction codes in locations particularly vulnerable to hurricanes.

(G) Relationship between hurricanes, climate, and natural ecosystems.—Research to improve the understanding of complex relationships between hurricanes and climate, including research to determine the most effective methods to use observational information and numerical model simulations to examine the impacts on ecosystems over long and short periods of time, including but not limited to impacts on coral reefs, wetlands, and other natural systems that mitigate hurricane wind and storm surge impacts.

(H) Technologies for disaster response and recovery.—

Research to improve emergency communication networks for government agencies and non-government entities and to improve communications between such networks during disaster response and recovery, including cyber-security during disaster situations and the ability to improve damage assessments during storms.

(I) Evacuation planning.—Research to improve the manner in which hurricane-related information is provided to, and utilized by, the public and government officials, including research to assist officials of State or local government in determining the circumstances in which evacuations are required and in carrying out such evacuations.

(J) Computational capability.—Research to improve understanding of the efficient utility of multiple models requiring sharing and inter-operability of databases, computing environments, networks, visualization tools, and analytic systems beyond what is currently available for transitioning hurricane research assets into operational practice and to provide access to robust computational facilities beyond the facilities normally accessible by the civilian research community for the hurricane research enterprise, including data acquisition and modeling capability during hurricane events.

(c) Cooperation with other agencies.—The Under Secretary and the Director shall cooperate with the head of each appropriate Federal agency or department, research institute, university, and disaster-response or nongovernmental organization to utilize the expertise and capabilities of such entity to carry out the purposes of the National Hurricane Research Initiative, including cooperation with the heads of the following entities:

(1) The National Aeronautics and Space Administration.

(2) The National Institute of Standards and Technology.

(3) The Department of Homeland Security, including the Federal Emergency Management Agency.

(4) The Department of Energy.

(5) The Defense Advanced Research Project Agency.

(6) The Environmental Protection Agency.

(7) The United States Geological Survey.

(8) The Army Corps of Engineers.

(d) Coordination.—The White House Office of Science and Technology Policy, through the National Science and Technology Council, shall coordinate the activities carried out by the United States related to the National Hurricane Research Initiative as a formal program with a well defined organizational structure and execution plan.

(e) Grants.—

(1) Authority.—The Undersecretary and the Director may award grants to appropriate State and local governmental agencies or departments, research universities or nongovernmental entities to carry out the purposes described in subsection (b).

(2) Best practices.—The Under Secretary and the Director shall develop and make available to the public a description of best practices to be used to carry out a project with a grant awarded under this subsection.

(f) Research seminars and forums.—The Under Secretary and the Director shall carry out a series of national seminars and forums that

assemble a broad collection of scientific disciplines to direct researchers to work collaboratively to carry out the purposes described in subsection (b).

(g) Initial research To develop Improved hurricane intensity Forecasts and impact projections.—The Undersecretary and the Director shall within 120 days after the enactment of this Act issue a request for proposals to undertake the basic and applied research with an annual budget in the amounts as deemed appropriate by the Under Secretary and the Director to accomplish the desired research results during a 10-year term.

(h) Authorization of Appropriations.—There is authorized to be appropriated $285,000,000 for each of the fiscal years 2008 through 2018 to carry out this section.

SEC. 4. National Infrastructure Database.

(a) Requirement To establish.—The Under Secretary and the Director shall establish a National Infrastructure Database for the purposes of—

(1) cataloging and characterizing the physical, social, and natural infrastructure in order to provide a baseline for developing standards, measuring modification, and determining loss;

(2) providing information to Federal, State, and local government officials to improve information public policy related to hurricanes and tropical storms; and

(3) providing data to researchers to improve their ability to measure hurricane impacts, separate such impacts from other effects, both natural and anthropogenic, make effective recommendations for improved building codes and urban planning practices, and develop effective procedures for responding to infrastructure disruption.

(b) Database requirements.—The National Infrastructure Database shall be a virtual, cyber environment that uses existing capabilities and facilities, and establishes new capabilities and facilities, as appropriate, to provide an interoperable environment and the necessary metadata and other resources needed by users of that Database.

(c) Authorization of Appropriations.—There is authorized to be appropriated $20,000,000 for each of the fiscal years 2008 through 2018 to carry out this section.

SEC. 5. National Hurricane Research Model.

(a) Requirement To establish.—The Under Secretary and the Director shall develop a National Hurricane Research Model to conduct integrative research and to facilitate the transfer of research knowledge to operational applications, including linking relevant theoretical, physical, and computational models from atmospheric, oceanic, economic, sociological, engineered infrastructure, and ecologic fields, conducting experimental research to understand the extensive complexities of hurricanes, training of the next-generation hurricane researchers and forecasters, and obtaining measurable results in a comprehensive framework suitable for testing end-to-end integrative systems.

(b) System requirements.—The National Hurricane Research Model shall be a physically distributed and highly coordinated working environment in which research from the National Hurricane Research Initiative can be experimentally substantiated using suitable quantitative metrics, and where a culture of interaction and collaboration can further be promoted, including in the areas of—

(1) facilities and cyber infrastructure;

(2) software integration; and

(3) fixed mobile data collection platforms and data provisioning systems.

(c) Authorization of appropriations.—There is authorized to be appropriated $130,000,000 for each of the fiscal years 2008 through 2018 to carry out this section.

Chairman LAMPSON. Hearing will come to order, and I wish everyone a good morning and welcome you to today's joint Subcommittee Hearing on *The State of Hurricane Research and H.R. 2407, the National Hurricane Research Initiative Act.*

We all know the devastation that a hurricane can cause and the billions of taxpayers' dollars needed to recover after one of these natural disasters occurs. The effects of Hurricane Katrina are still very visible in many of our districts, including mine. In my mind I can think back to my first most severe storm back in 1963, where I saw the largest number of houses in the middle of the streets, and it was pretty—those are things that I don't think ever go out of your mind if you witness them or live them.

It goes without saying that there is a need for research to do better, to better understand hurricanes so that we can continue to improve our forecasting and warning capabilities to save lives and to make our communities more resistant to hurricanes to reduce property damage.

And as we will hear from our witnesses today, both NOAA's in-house research and university research programs are making important advances in our knowledge of hurricanes and there is a need for a national effort to address the challenges posed by hurricane forecasting.

H.R. 2407 was introduced by our colleague from Florida, Mr. Hastings, who is here with us today, along with one of the original co-sponsors, Ms. Ros-Lehtinen. We thank you both for your leadership on this important issue.

We also have a distinguished panel of experts here with us today, and I look forward to your testimony and your recommendations of what the Federal Government can do to improve hurricane preparedness and to improve forecasting of hurricane direction and intensity.

[The prepared statement of Chairman Lampson follows:]

PREPARED STATEMENT OF CHAIRMAN NICK LAMPSON

Good morning and welcome to today's joint subcommittee hearing on the State of the Nation's Hurricane Research and H.R. 2407, the *National Hurricane Research Initiative Act.*

We all know the devastation that a hurricane can cause, and the billions of tax payer's dollars needed to recover after one of these natural disasters. The effects of Hurricane Katrina are still very visible in many of our districts, including mine.

It goes without saying that there is a need for research to better understand hurricanes so that we can continue to improve our forecasting and warning capabilities to save lives and to make our communities more resistant to hurricanes to reduce property damage.

As we will hear from our witnesses today, both NOAA's in-house research and university research programs are making important advances in our knowledge of hurricanes, and that there is a need for a national effort to address the challenges posed by hurricane forecasting.

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We also have a distinguished panel of experts here with us today. I look forward your testimony and your recommendations of what the Federal Government can do to improve hurricane preparedness and to improve forecasting of hurricane direction and intensity.

Chairman LAMPSON. At this time I want to yield to my distinguished colleague from South Carolina, our Ranking Member of the Energy and Environment Subcommittee, Mr. Inglis, for an opening

statement, and afterwards we will have the opening statements of Chairman Baird and Ranking Member Ehlers of the Research and Science Education Subcommittee.

Mr. Inglis.

Mr. INGLIS. Thank you, Mr. Chairman. Thank you for holding this hearing.

South Carolina, as you know, is no stranger to hurricanes. I remember September, 1989, when Hurricane Hugo hit the southeastern coastline, causing a total of $10 billion, billion with a B, dollars in damage, taking 82 lives and leaving 56,000 people homeless. It was the most damaging hurricane ever recorded, and since then it has only been surpassed by Hurricanes Andrew and Katrina.

In the aftermath of Hugo, Andrew, and Katrina, news stories and government officials emphasized that better preparations could have helped save lives and minimize damage. A year and a half later, a year and a half after the devastation of Hurricane Katrina, the National Science Board issued their 2007 report, *Hurricane Warning: The Critical Need for a National Hurricane Research Initiative,* highlighting that while billions were being spent in rescue and relief efforts, there was a serious lack of federal dollars being invested in hurricane preparedness research.

Today we'll discuss a bill that is based on that NSB report. H.R. 2407, the *National Hurricane Research Initiative,* directs the government to make much more significant investments in hurricane-related research across several agencies, including NOAA and NSF. This initiative outlines key investment categories including understanding and prediction, impacts, preparedness, and response.

H.R. 2407 authorizes a large sum of money for this research program, 4.17 billion over 10 years. We have an obligation to consider how we can best prepare for hurricanes, but given our limited resources, we also need to carefully consider how best to allocate those scarce resources. I will be looking forward to hearing from our witnesses about what they foresee to be the monetary and non-monetary return on this proposed federal investment.

And, Mr. Chairman, if I may, I would also like to recognize my senior legislative assistant, Phillip Van Steenburgh, who will be leaving me Monday, after two and one-half years to go to an internship at Capitol Hill Baptist Church and perhaps then to seminary. So we wish him well, although we are going to miss him here at the Science Committee and on my staff.

So I thank you, Mr. Chairman, for holding the hearing, and thank you for the opportunity to hear from our witnesses.

[The prepared statement of Mr. Inglis follows:]

PREPARED STATEMENT OF REPRESENTATIVE BOB INGLIS

Thank you for holding this hearing, Mr. Chairman.

South Carolina is no stranger to hurricanes. I still remember September 1989, when Hurricane Hugo hit the southeastern coastline, causing a total of $10 billion dollars in damage, taking 82 lives, and leaving 56,000 people homeless. It was the most damaging hurricane ever recorded, and since then, it has only been surpassed by Hurricanes Andrew and Katrina.

In the aftermath of Hugo, Andrew, and Katrina, news stories and government officials emphasized that better preparations could have helped save lives and minimize damages. A year and a half after the devastation of Hurricane Katrina, the National Science Board issued their 2007 report, *"Hurricane Warning: The Critical*

Need for a National Hurricane Research Initiative," highlighting that while billions were being spend in rescue and relief efforts, there was a serious lack of federal dollars being invested in hurricane-preparedness research.

Today we will discuss a bill that is based on that NSB report. H.R. 2407, the *National Hurricane Research Initiative,* directs the government to make much more significant investments in hurricane-related research across several agencies, including NOAA and NSF. This initiative outlines key investment categories including understanding and prediction, impacts, preparedness, and response.

H.R. 2407 authorizes a large sum of money for this research program ($4.17 B over ten years). We have an obligation to consider how we can best prepare for hurricanes, but, given our limited resources, we also to need to carefully consider how to best allocate those scarce resources. I'll be looking forward to hearing from our witnesses about what they foresee will be the monetary (and non-monetary) return on this proposed federal investment.

Thank you again Mr. Chairman, and I look forward to hearing from our witnesses on their perspectives of this legislation and any suggestions they may have to improve it.

Chairman LAMPSON. Thank you, Mr. Inglis. We wish Mr. Van Steenburgh well, as well.

Chairman Baird, you are now recognized for five minutes.

Mr. BAIRD. Thank you, Mr. Chairman. I want to join you in welcoming our colleagues, Mr. Hastings and Ms. Ros-Lehtinen, and also our distinguished panel of witnesses.

Living in the pacific northwest we only get to look in horror at what happens to our dear friends to the south, and we want to be, this committee, very active in trying to support your initiatives to prepare your area, region, and people for better understanding, predicting, and dealing with the impacts of hurricanes.

Of particular interest to me in today's testimony and in some of the written comments from the NSB is the role of social scientists and social behavioral changes. I was speaking with a hurricane prediction expert awhile back, and he said, you know, Congressman, even if we could predict to the minute and the meter, the location of a hurricane impact, if 60 percent of the people don't prepare, all our predictive capacity, all our super computing, all our satellite observations won't save a life. And that is the social and behavioral problem. How do we get people to implement the engineering guidelines? How do we get them to understand what it means that there is a difference between a category four or a category five storm? How do we get planners to prepare actual evacuation? That is what I will be, I think, most interested in as we listen to our outstanding panel of witnesses.

Thank you for hosting this. Thank you for our distinguished colleagues for introducing this important legislation. We welcome you all here today.

[The prepared statement of Chairman Baird follows:]

PREPARED STATEMENT OF CHAIRMAN BRIAN BAIRD

I look forward to hearing from our panel of witnesses about the steps needed to improve our ability to prepare for and respond to hurricanes. Hurricanes of recent years have brought to our attention the significant and far-reaching effects of natural disasters, such as hurricanes, on local communities and the Nation. The devastating loss of life, dislocation of families, and damage to the economy resulting from Hurricane Katrina and others sent a loud and clear message. It is imperative that we improve our understanding of hurricanes and enhance our ability to predict, prepare for, and respond to them.

Following a year long assessment of the state of hurricane research in our country, the National Science Board came forward with a set of recommendations to better align hurricane science and engineering research with our national needs. The

Board's keystone recommendation was that the U.S. engage in a nationally coordinated, multi-agency and multi-disciplinary hurricane research initiative. Today we will explore the Board's recommendations as well as the proposed legislation, H.R. 2407.

H.R. 2407, the National Hurricane Research Initiative (NHRI), takes the general recommendations of the NSB report and seeks to assemble a multi-agency effort focused on developing a better understanding of hurricane prediction; intensity; and mitigation on coastal populations, infrastructure, and the natural environment.

I hope to hear from our witnesses whether this bill is a workable way to address the gaps in our hurricane research efforts. I look forward to the assessment of current federal hurricane research activities and their thoughts on the proposed legislation. I also welcome their suggestions for ways we might improve the bill.

Finally, I am particularly interested in hearing how the social and behavioral sciences can contribute to our understanding of the ways individuals and entire communities prepare for, respond to, and recover from disasters. I would like to hear what role social science research could play in addressing the need to transfer research outcomes into operational practice.

I thank my colleagues Mr. Hastings and Ms. Ros-Lehtinen for joining us today, and for their effort in addressing this timely issue. Thanks to all of our witnesses for being here, and I look forward to your testimony. I now recognize the Ranking Member for any comments he may wish to make.

Chairman LAMPSON. Thank you, Dr. Baird, and Dr. Ehlers, you are now recognized for five minutes.

Mr. EHLERS. Thank you, Mr. Chairman.

Recent history has proven that the United States needs to be better prepared for hurricanes. There is no question about that. The impacts of these storms may never be eliminated, but the most deleterious impacts can be mitigated by improved prediction, standards, infrastructure, and communication.

I understand that our federal research efforts in these areas are insufficient and commend my colleague, Mr. Hastings of Florida, for putting the recommendations of a recent National Science Board report into the legislation before us today. I think it is also important to emphasize the research needed on construction and infrastructure standards. The Chair mentioned earlier the—I am sorry, Mr. Inglis mentioned earlier the number of houses ruined and damaged, and much of that can be mitigated by better construction methods and standards. And we have to do the research needed to find out what is the best approach.

I look forward to hearing from our witnesses about the proposed legislation and appreciate the work of the National Science Board in crafting what the initiative should look like.

And I yield back.

[The prepared statement of Mr. Ehlers follows:]

PREPARED STATEMENT OF REPRESENTATIVE VERNON J. EHLERS

Recent history has proven that the United States needs to be better prepared for hurricanes. The impacts of these storms may never be eliminated, but the most deleterious impacts could be mitigated by improved prediction, standards, infrastructure and communication.

I understand that our federal research efforts in these areas are insufficient and commend my colleague, Mr. Hastings of Florida, for putting the recommendations of a recent National Science Board report into the legislation before us today. Particularly in the areas of construction and infrastructure standards, we need to strengthen and implement the results of ongoing research.

I look forward to hearing from our witnesses about the proposed legislation and appreciate the work of the National Science Board in crafting what the Initiative should look like.

Chairman LAMPSON. Thank you, Dr. Ehlers.

All additional opening statements submitted by the Committee Members will be included in the record at this point.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Good morning. I want to thank the Chairmen of the Energy and Environment and the Research and Science Education Subcommittees for holding this joint hearing on federal priorities regarding hurricane research for our nation.

Members will also hear testimony regarding Congressman Hastings' legislation, H.R. 2407, the *National Hurricane Research Initiative Act of 2007.*

Hurricane research and preparedness are national security issues.

The frequency and intensity of such storms have caused great economic and personal damage to American citizens.

It is estimated that hurricane-related losses averaged more than ten billion dollars annually from 1990 to 1995, and upwards of $35 billion a year from 2000 to 2006.

Survivors of Hurricanes Katrina and Rita were left with toxic housing conditions and a federal response rate that was unacceptably slow.

Many of these survivors migrated to Texas, causing a sudden increase in the utilization of public services, including hospitals and schools.

There are many trickle-down economic effects that coincide with disasters of this nature.

I will be interested to hear how Mr. Hastings' legislation seeks to coordinate our federal hurricane research efforts.

Witnesses will report on the status of hurricane research, ways in which current research efforts could be improved, and how the proposed legislation would affect the overall state of our nation's hurricane preparedness, including our ability to save lives and mitigate property loss.

Again, I want to thank the leadership of the two Subcommittees for recognizing this issue as one of importance. Our constituents at home need to see that their Federal Government is studying these matters in a bipartisan effort to be proactive, when it comes to storm preparedness.

I thank the Chairmen and yield back the balance of my time.

[The prepared statement of Mr. Carnahan follows:]

PREPARED STATEMENT OF REPRESENTATIVE RUSS CARNAHAN

Thank you, Mr. Chairman for holding this hearing and to the witnesses for taking time to be here today.

In the aftermath of hurricane Katrina and Wilma, we can see how devastating hurricanes can be to coastal regions. It is important to note that hurricanes represent 65 percent of insured losses by natural hazards in the U.S. And, with half of the U.S. population living within 50 miles of coastline, it should be a high priority to invest in hurricane research.

H.R. 2407, establishes the National Hurricane Research Initiative to set research objectives to improve hurricane prediction and to better understand the anticipated impacts hurricanes have on structures. The NHRI would also target research on improved technologies for disaster response and the coordination of evacuations.

I look forward to hearing the testimony from our distinguished witnesses about H.R. 2407. Thank you for appearing before us today.

Panel I:

Chairman LAMPSON. At this time I would like to introduce our first panel. We have with us today Mr. Hastings from Florida who introduced H.R. 2407, and one of the original co-sponsors, Ms. Ros-Lehtinen, also from Florida.

Congressman Hastings, you are recognized for five minutes to make your statement.

STATEMENT OF HON. ALCEE L. HASTINGS, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF FLORIDA, 23RD DISTRICT

Mr. HASTINGS. Thank you very much, Mr. Chairman. It is a distinct honor and privilege for me to be here before you, Mr. Chairman and Chairman Baird and my colleagues, Dr. Ehlers. I came to Congress in 1992, and I cut my eye-teeth in the Science Committee. Points how long I am here, other than Dr. Ehlers, none of you were here. And, yeah, Roscoe was here, too, but it lets you know we have been around awhile.

First I would like to thank the distinguished guests testifying today, particularly those who hail from Florida universities, Dr. Chen, Dr. Prevatt, and Dr. Leatherman.

And Mr. Chairman, I would also like to thank your staff, the Science Committee staff, and my staff and Ms. Ros-Lehtinen's staff. These young people do incredible work on our behalf and are rarely other than among ourselves recognized. And I am really pleased at how cooperative they have been with us.

Also, I am pleased that we are here to discuss the National Hurricane Research Initiative. I introduced this bill with my dear friend and colleague, and we share the distinction of having collaborated on a lot of legislation throughout our careers, most of it in the foreign affairs arena, but of course, we do a consider amount of work on behalf of Florida and this nation as well.

I would also like to take cognizance of our Florida colleagues, Senator Martinez and Senator Nelson, who introduced the companion legislation in the Senate.

The legislation that the Subcommittees are considering today is based on the recommendations presented in a 2007 National Science Foundation report on hurricane research. The report delivered a stern warning, Mr. Chairman and Members, and I want to reiterate and quote that warning. "Relative to the tremendous damage future hurricanes will inflict, the current federal investment in hurricane science and engineering is entirely insufficient."

Mr. Chairman, our government's current investment in hurricane preparation is relegated to providing water bottles and setting up storm shelters for at-risk populations. In my view such shortsighted preparation is wholly inadequate and unacceptable. We need a long-term strategy on how to fill gaps in our hurricane knowledge and reduce losses to the best of our ability.

And let me make it very clear that the residual from this kind of approach will have an impact on disasters elsewhere. As we speak, our friends and colleagues in the mid west are suffering, and some of that could have been ameliorated had we had the appropriate attention advanced before the occurrence of the disaster.

The entire Nation would deeply benefit from enhanced, coordinated hurricane research as required in our bill. As co-Chair of Florida's Congressional Delegation, I have seen and experienced firsthand the destruction that hurricanes have wreaked on our communities. I have the misfortune that some of you have as well, of traveling on Air Force One with President Clinton and President Bush, and I say misfortune because in those instances they were coming out to visit hurricane ravaged areas. Ms. Ros-Lehtinen and I were on both those particular sad situations.

But sadly people are still living in trailers in my Congressional district. They lost their homes in the '04 storms only to have the trailer they were given blow over less than one year later during a 2005 hurricane.

Now, I recognize that the cost for our bill is high, but investing in research now is crucial. Moreover, it is much more efficient than the losses that will ensue when the next hurricane inevitably strikes.

Combined, we spent $77 billion for recovery efforts in the fiscal years 2005 and 2006. Emergency supplement bills. Frankly, our inaction will cost our nation much more if we fail to invest in research now. Let me briefly mention a few of the advancements of our great universities represented by the distinguished panel before us, and we also have other visitors from the fire department. Ms. Ros-Lehtinen will talk about them later I am sure.

Florida International University's Wall of Wind, it is called WOW, has helped us better predict storm survivability, physical structures, and infrastructure. The University of Miami's Center for Southeastern Tropical Advanced Remote Sensing, CTARS's research, has helped to improve our understanding of hurricane structure, intensity, and movement. The University of Florida's research is helping to create hurricane-proof homes and hurricane-resistant building construction. And my university, Florida A&M University, Mr. Baird, has worked in that social science area in assisting in preparation and warning.

Each of these schools is uniquely positioned to conduct the vital hurricane research we are discussing here today. There are many others, including schools in Hawaii, Washington, Colorado, California, Maryland, let us not forget any of you, who will also help lead us into the future of hurricane research.

Mr. Chairman, it is an imperative that we increase our federal investment and coordinated hurricane research. Overarching all of this legislation is the fact that disasters in this nation are going to occur. That is regrettable, but it is a fact, and we need to be prepared.

I urge the Committee to hold the markup of the *National Hurricane Research Initiative Act of 2007,* and as fast as possible, hopefully following the July recess. I stand ready and able to assist in any way possible. In my view there is no time for further delay.

Thank you very much.

[The prepared statement of Mr. Hastings follows:]

PREPARED STATEMENT OF REPRESENTATIVE ALCEE L. HASTINGS

Thank you, Chairman Baird and Chairman Lampson, for holding this extremely important hearing today. I am honored to be here.

First, I would like to thank the distinguished guests testifying today, particularly those who hail from Florida universities: Dr. Shuyi Chen, Dr. David O. Prevatt and Dr. Stephen P. Leatherman.

I am very pleased that we are here to discuss the *National Hurricane Research Initiative Act.* I introduced this bill with my good friend and colleague Representative Ileana Ros-Lehtinen (R–FL). Our Florida colleagues, Senators Mel Martinez and Bill Nelson, introduced the companion legislation in the Senate.

The legislation that the Subcommittees are considering today is largely based on the recommendations presented in a 2007 National Science Foundation (NSF) report, *Hurricane Warning: The Critical Need for a National Hurricane Research Initiative.*

The report delivered a stern warning that I want to reiterate now:

"Relative to the tremendous damage future hurricanes will inflict, the current federal investment in hurricane science and engineering is entirely insufficient."

Mr. Chairmen, our government's current investment in hurricane preparation is relegated to providing water bottles and setting up storm shelters for at-risk populations. In my view, such short-sighted preparation is wholly inadequate and unacceptable. We need a long-term strategy on how to fill gaps in our hurricane knowledge and reduce losses to the best of our ability.

The significant advancements that have been made since the last Category 5 hurricane, Hurricane Andrew, struck my home State of Florida in 1992 are commendable. Unfortunately, our nation's vulnerability only continues to increase and we still lack many of the answers. The state of science today is not advanced enough to inform us reliably about when or where hurricanes are going to strike or what their precise impact on our communities will be.

The 2007 NSF report and the *National Hurricane Research Initiative Act* call for a multi-disciplinary collaboration of relevant Federal Government agencies, academia, industry, and other levels of government to harness their expertise to provide improved hurricane forecasts and response measures.

The entire Nation would deeply benefit from enhanced, coordinated hurricane research. Better intensity forecasting, long-range projections of hurricane activity, emergency management, and hurricane mitigation would be advantageous to everyone—from improving the ability of local communities to respond to hurricanes to reducing the Federal Government's share in recovery efforts by billions of dollars.

We are all too aware of the destruction and devastation that individual hurricanes can cause. As Co-Chair of Florida's Congressional Delegation, I have seen and experienced firsthand the destruction that hurricanes have wreaked on my communities, particularly those that reside in coastal areas or surrounding the Herbert Hoover Dike along Lake Okeechobee.

Since 2001, hurricane damage has cost our nation almost $36 billion in economic losses per year. In 2005, Hurricanes Katrina, Rita and Wilma accounted for over $160 billion in total damages and the loss of almost 1,500 innocent lives. Further, the impact from inland flooding and tornadoes, which can result from the onset of hurricanes and tropical storms, can be felt throughout the entire United States.

Hurricane Andrew caused almost $35 billion in damages as measured by today's economic standards. Experts predict today that if a Category 5 hurricane hit Miami, it could potentially create an over $100 billion disaster, comparable to the economic damage New York suffered as a result of 9/11.

Sadly, from Miramar to Fort Pierce, people are still living in trailers in my district. They lost their homes in the 2004 storms only to have the trailer they were given blow over less than one year later during a 2005 hurricane.

I recognize that the cost for our bill is high. But as I, Representative Ros-Lehtinen, and the other distinguished panelists will relay today, investing in research *now* is crucial. Moreover, it is much more cost efficient than the losses that will ensue when the next hurricane inevitably strikes.

The 2004 and 2005 hurricanes are a prime example of the cost to our Federal Government. Combined, we spent $77 billion for recovery efforts in the Fiscal Year 2005 and Fiscal Year 2006 Emergency Supplemental bills. Frankly, our inaction will cost our nation much more if we fail to invest in research now.

Consider, 50 percent of the U.S. population lives within 50 miles of the coastline. As populations and economies continue to expand in these high risk coastline areas, the economic and societal costs will only increase when future hurricanes strike our nation.

Universities throughout the State of Florida, represented by the distinguished panel before us, have spearheaded innovative and important advancements in hurricane research. It is clear that by increasing our investment in their fields, we can build on their academic successes and provide nationwide benefits.

Let me briefly mention a few of the advancements our great universities have made in recent years.

Florida International University (FIU) leads the Florida System-wide Hurricane Mitigation Alliance, comprised of nine of the eleven Florida public universities. FIU's International Hurricane Research Center conducts research focused on the mitigation impacts of hurricane damage. The Center has produced a storm model to predict highly accurate storm surge heights and flooding potential. FIU's Wall of Wind (WoW) simulates the devastating effects of hurricanes to better predict storm survivability on physical structures, building materials, utilities, and infrastructure.

The Rosenstiel School of Marine and Atmospheric Science at the University of Miami is working tirelessly to conduct research and develop technologies to improve our hurricane forecast abilities. At the University's Center for Southeastern Tropical

Advanced Remote Sensing (CSTARS), scientists have been conducting research using remotely-sensed data from Earth-orbiting satellite systems to help improve our understanding of the dynamics of hurricane structure, intensity, and movement.

The University of Florida's research has improved our understanding of mitigation impacts on physical structures and our nation's infrastructure. At the Broward County Windstorm Damage Mitigation Training and Demonstration Center, the University of Florida is helping to create hurricane-proof homes and hurricane-resistant building construction. The University's hurricane simulator delivers winds up to 130 miles per hour intended to mimic the effects of hurricanes to strengthen building components and improve installation procedures to reduce hurricane damage.

Each of these schools is uniquely positioned to conduct the vital hurricane research we are discussing here today. There are many others, including schools in Hawaii, Colorado and California, who will also help lead us into the future of hurricane research.

As growing research indicates, hurricane trends are linked to climate change. In the National Oceanic and Atmospheric Administration's (NOAA) U.S. Climate Change Science Program (CCSP) recent report, *Weather and Climate Extremes in a Changing Climate,* scientific evidence details that future climate changes will be accompanied by extreme events, including hurricanes. The report specifically states, "For North Atlantic and North Pacific hurricanes, it is likely that rainfall and wind speeds will increase in response to human-caused warming. Analyses of model simulations suggest that for each 1°C (1.8°F) increase in tropical sea surface temperatures, core rainfall rates will increase by six percent to 18 percent and the surface wind speeds of the strongest hurricanes will increase by about one percent to eight percent."

NOAA's Climate Prediction Center's 2008 hurricane season outlook indicates that there could be a more than 60 percent chance of up to 16 named storms, including up to 14 hurricanes, five of which would be categorized as "major." This prediction serves as a stark reminder of the pressing need to conduct such research.

Mr. Chairmen, our government can ill afford to ignore the advice of its premier scientists and put our populations and infrastructure at risk. It is imperative that we take significant actions to increase federal investment in new research to better prepare for, respond to, and mitigate the devastating impacts of hurricanes. Let us resolve to act promptly to address ways to prevent and respond to future hurricanes *before* the next hurricane strikes.

I urge the Committee to hold a markup of the *National Hurricane Research Initiative Act of 2007* immediately following the July recess. I stand ready and able to assist in any way possible. There is no time for further delay.

Thank you very much.

Chairman LAMPSON. Thank you, Mr. Hastings, very, very much. And add Texas to that list.

Congresswoman Ros-Lehtinen, you are recognized for five minutes. You may begin.

STATEMENT OF HON. ILEANA ROS-LEHTINEN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF FLORIDA, 18TH DISTRICT

Ms. ROS-LEHTINEN. Well, thank you so much, Chairman Lampson, Chairman Baird, Ranking Member Inglis, Ranking Member Ehlers. Thank you for the opportunity. I am glad to see our Florida colleague, Mario Diaz-Balart, no stranger to hurricanes, here with us as well.

And I am so glad to have the opportunity to work again with my wonderful friend and my dear colleague, Congressman Alcee Hastings, on this important bill, and I would like to acknowledge the panelists and the guests who are here from our home area of South Florida. Dr. Stephen Leatherman, the Chair Professor and Director of the International Hurricane Research Center and Laboratory for Coastal Research at my alma mater, Florida International University, Dr. Shuyi Chen, Professor at the University of Miami, Rosenstiel School of Marine and Atmospheric Sciences, and

let me say thank you to David Downy, the Division Chief with Miami Dade's Fire Rescue in Urban Search and Rescue, who is here with us today, representing Miami Dade County and the Florida Keys, two regions which often bear the full brunt of hurricanes.

I have gained a great deal of personal experience about preparing for and recovering from hurricanes. Throughout my life in South Florida I have experienced storms including Hurricane Isabel, Hurricane Andrew, Hurricane Charlie, Hurricane Wilma, Hurricane Katrina, just to name a few, and the sheer devastation left in the aftermath of those natural disasters often can be financially and personally crippling to individuals, families, and businesses. With the help of early warning information and more in-depth research from scientists, we can help our constituents properly prepare for and evacuate before these hurricane and natural disasters hit.

The *National Hurricane Research Initiative Act,* which Alcee and I are working on, will fund and support organizations dedicated to improving the forecasting of storms and researching the weather patterns. It is vital for the advancement of early warning systems and tracking mechanisms. It is our obligation to take advantage of these opportunities. Right now the tracking of hurricanes remains—means that large areas fall under evacuation warnings. What happens? Well, as with any repetitive activity, the frequency of these hurricane-prone areas receiving these evacuation orders means that it lessens their impact. More people in my home district will not evacuate until the last possible moment and oftentimes then that is too late.

Congressman Baird, who knows the Keys and understands, there is one road in and one road out. Hurricane trackers deserve a great deal of respect for the gains they have made in recent years on path prediction, but their margin of error is still too great. The cone is still too large. Giving these scientists the tools necessary will make enormous positive differences for all of our constituents. Hurricanes threaten more than just Florida, as the Chairman pointed out. Louisiana, Texas, Mississippi, Alabama, California, Georgia, the Carolinas, most coastal states. In fact, over 50 percent of the United States' population live within 50 miles off of our coast.

A number of major category four and five hurricanes worldwide, the number have nearly doubled over the past 35 years, and the devastation left in the aftermath of Hurricane Katrina, we all know, and that was only a category four. It remains a tragic reminder of how ill-equipped our nation is to deal with widespread disaster.

So it is, indeed, our obligation to ensure that each and every citizen who may reside in harm's way has the information needed to prepare and to evacuate if needed from these storms. As Bill Reed, the Director of the NOAA Weather, National Weather Service, stated this month at a hurricane-preparedness summit that I had in the Keys, storms can intensify at the last minute and cause substantial losses of life and property that could be avoided with better methods of prediction.

In this summit we also learned from experts on the dangers imposed on residents not evacuating during hurricanes. All vital serv-

ices such as water, power, and even hospitals, remain closed for as long as a few weeks after a significant storm. Persons who do not evacuate pose a serious burden to already strained rescuers. Saving lives, of course, remains our focus. This bill will also save U.S. money.

In '92, Hurricane Andrew caused approximately $21 billion in losses to South Florida alone. In 2007, the economic impact of one storm evacuation was $6.5 million in the Keys alone. So with better information provided by scientists, these losses could have been much less. FEMA spent $35.8 billion per year during the last five years on natural disasters, and that was $168 billion in losses of home and property in the years 2004, and 2005, alone.

So the benefits, the financial benefits of preparedness are readily apparent, and we can significantly cut the expenses of our government by knowing beforehand where these storms will make landfall. Our constituents demand that we refine our forecasting, and the bill before you will do just that.

Thank you so much to the Chairmen, thank you to the Ranking Members for the opportunity. I hope you move swiftly.

[The prepared statement Ms. Ros-Lehtinen follows:]

PREPARED STATEMENT OF REPRESENTATIVE ILEANA ROS-LEHTINEN

Thank you, Chairmen Baird and Lampson. Thank you, Ranking Members Ehlers and Inglis. I am glad that you are holding this important joint-hearing and for the opportunity to speak in support of H.R. 2407, a bill which I co-introduced with my dear friend and Florida Delegation colleague Alcee Hastings. I would like to also acknowledge those panelists from my home district in South Florida: Dr. Stephen Leatherman, Chair Professor and Director of the International Hurricane Research Center & Laboratory for Coastal Research at my alma mater Florida International University. Dr. Shuyi Chen, Professor at the University of Miami Rosenstiel School of Marine & Atmospheric Sciences. Also let me say thank you to David Downey, Division Chief with Miami-Dade Fire Rescue's Urban Search and Rescue, who is here with us today. Representing Miami-Dade and the Florida Keys, two regions which often bear the full impact of hurricanes, I have gained a great deal of personal experience about preparing for and recovering from storms.

Throughout my life in Miami, I have experienced storms including Hurricane Isabell, Hurricane Andrew, Hurricane Charley, Hurricane Wilma, and Hurricane Katrina just to name a few. The sheer devastation left in the aftermath of these natural disasters often can be financially and personally crippling to individuals, families, and businesses. With the help of early warning information and more in depth research from scientists, we can help our constituents properly prepare for and evacuate from these natural disasters. The *National Hurricane Research Initiative Act* will fund and support organizations dedicated to the forecasting of storms and the researching of weather patterns. This is vital to the advancement of warning and tracking mechanisms. It is our obligation to take advantage of these opportunities.

Right now, the tracking of hurricanes means large areas fall under evacuation warnings. As with any repetitive activity, the frequency of which hurricane prone areas such as mine are subjected to these warnings lessens their impact. Many people in my home district will not evacuate until the last possible moment, and often times by then it is too late. Hurricane trackers deserve a great deal of respect for the gains they have made in recent years on path prediction, however, the margin of error is still too great.

Giving these scientists the tools necessary will make an enormous positive difference in the lives all our constituents. Hurricanes threaten more than just Florida; they affect Louisiana, Texas, Mississippi, Alabama, California, Georgia, and the Carolina's and most coastal states. To make the importance of this matter more apparent, over 50 percent of the United States population lives within 50 miles of the coast. The number of major Category 4 and 5 hurricanes worldwide has nearly doubled over the past 35 years.

The devastation left in the aftermath of Hurricane Katrina, only a Category 4, remains a tragic reminder of how ill-equipped our nation is to deal with widespread

disaster. It is our obligation to ensure that each and every citizen that may reside in harms way has the information needed to prepare and evacuate from these storms.

As Bill Read, the Director of the NOAA National Weather Service, stated this month at my Hurricane Preparedness Summit in the Florida Keys: Storms can intensify at the last minute and cause substantial losses of life and property that could be avoided with better methods of prediction. During my hurricane summit we also learned from experts on the dangers imposed on residents not evacuating during hurricanes. All vital services such as water, power, and even hospitals remain closed for as long as a few weeks after a significant storm. Persons who do not evacuate also pose a serious burden to already strained rescuers. Saving lives must remain our focus. This bill will also save the U.S. money.

In 1992, Hurricane Andrew caused approximately $21 billion in losses to South Florida. In 2007, the economic impact of storm evacuation was $6.5 million in the Florida Keys. With better information provided by scientists, these losses could have been much less. FEMA spent $35.8 billion per year during the last five years on natural disasters. There was $168 billion in losses of home and property in 2004 and 2005 alone.

The financial benefits of preparedness are readily apparent. We can significantly cut the government's expenses by knowing beforehand where these storms will make landfall. Our constituents demand that we refine our forecasting. Having to evacuate disrupts lives and with the price of gas still climbing, is extraordinarily financially burdensome. However, no monetary figure can be placed a human life and protecting our constituents must remain the focus of this legislation. The progress that will result from this bill will offer invaluable assistance to all of our communities.

The current hurricane season began on June 1, 2008. Three weeks of this season have already passed and it is imperative that this bill receive quick attention. I hope that this committee will move swiftly on this legislation and I appreciate the opportunity to voice my comments to you this morning.

Chairman LAMPSON. Thank both of you for your testimony. You pointed out the tragedy, and you pointed out the real savings that are available in life, property, and resources. When we plan, we can make a huge difference for the American people, and that is exactly what you are trying to do. We appreciate you coming here and you bringing the information and the stories that you have, and we look forward to working with the legislation.

If there are no questions for this first panel, then we will take a very short break, very short break, before hearing from our next panel of witnesses.

Thank you both very, very much. And if the rest of you would come up and take their places.

[Recess.]

Panel II:

Chairman LAMPSON. Before we begin, I would ask unanimous consent that we welcome Congressman Hastings to join us here on this.

Seeing no objection, it is so ordered. Welcome.

Mr. HASTINGS. Thank you.

Chairman LAMPSON. And I want to welcome our second panel of witnesses and thank each and every one of you for being here this morning.

Dr. John L. "Jack" Hayes is the Assistant Administrator for Weather Services and the Director of the National Weather Service, National Oceanic and Atmospheric Administration, NOAA.

Dr. Kelvin K. Droegemeier is the former Co-Chair of the National Science Board's Task Force on Hurricane Science and Engineering.

Dr. Shuyi Chen is an Associate Professor of Meteorology and Physical Oceanography at the University of Miami, Rosenstiel School of Marine and Atmospheric Sciences. That is a lot of big words there.

And Dr. David O. Prevatt is an Assistant Professor at the Department of Civil and Coastal Engineering at the University of Florida.

And I would now like to recognize our colleague, Mr. Diaz-Balart from Florida, to recognize our final witness.

Mr. DIAZ-BALART. Thank you very much, Mr. Chairman. It is truly a privilege actually to see all of these fine men and women, but it is my privilege today to welcome Dr. Stephen Leatherman to this committee.

Since 1997, Dr. Leatherman has served as the Chairman and Director of the International Hurricane Research Center at Florida International University, which is located in South Florida in Miami. FIU serves thousands of students, Mr. Chairman, in the South Florida area and the South Florida community. It is an exceptional university with exceptional faculty, exceptional talent, and exceptional leadership.

The Center's main objectives are to mitigate and prevent damage from hurricanes and to assist communities in dealing with the aftermath of those very destructive storms. Unfortunately, in Florida and South Florida we have way too much experience with those storms. And, again, the Center was established by the private sector in the aftermath of Hurricane Andrew, which caused some debts and also billions of dollars in economic loss in 1992.

The Board of Trustees of the Center include some of the most well-respected and notable members of our community. Now, on a lighter note, Mr. Chairman, my dear friend, Dr. Leatherman, is also, well, he has obviously a lot of expertise in hurricanes, but he also has expertise on storm impacts on coastal areas, but he is also known as Dr. Beach around the world. I am sure all of you have heard about Dr. Beach. As Dr. Beach he has selected the annual top ten beaches, correct? Around since 1991. I am pleased that Florida is home to three of the top ten beaches, including the number one beach, and I am sure all of us here on this committee would agree that even though it is a very tough job, we are glad that somebody is willing to do that, to go around and figure out which are the best beaches in town.

But, anyways, thank you, Mr. Chairman, and thank you, sir, for appearing. It is a privilege to introduce a dear friend, somebody who I have not only known and respected but have admired for so many years. Thank you, sir, and we look forward to your testimony, my friend.

Mr. EHLERS. Will the gentleman yield?

Mr. DIAZ-BALART. Yes, sir.

Mr. EHLERS. Thank you for yielding. I just wanted to make sure so I will know the credibility of the witnesses, I assume you have also ranked the Lake Michigan Beaches.

Mr. DIAZ-BALART. I think we are out of time, Mr. Chairman. I think my time is out now.

Chairman LAMPSON. I will stay out of that fray.

Well, you will each have five minutes for your spoken testimony. Your written testimony will be included in the record for the hearing. When you are all complete with your testimony, then we will begin with questions, and each Member will have five minutes to question the panel.

With that, I would ask Dr. Hayes to begin.

STATEMENT OF DR. JOHN L. "JACK" HAYES, ASSISTANT ADMINISTRATOR FOR WEATHER SERVICES; DIRECTOR, NATIONAL WEATHER SERVICE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE

Dr. HAYES. Thank you, Mr. Chairman and Members of the Committee for this opportunity to testify on the importance of increased hurricane research and preparedness. I am Jack Hayes, the Assistant Administrator for Weather Services and the Director of the National Weather Service.

The National Weather Service is a line office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

The proposed legislation, H.R. 2407, the *National Hurricane Research Initiative Act of 2007,* recognizes the challenge we face as a nation with regard to hurricanes and tropical cyclones, and we applaud the Committee for addressing this complex issue.

We agree with the overall goal of the bill to improve hurricane forecasting and preparedness. We also agree with the most effective path forward is for NOAA and the National Science Foundation to co-chair a committee to oversee and coordinate federally-funded research efforts and ensure successful research efforts that can be incorporated into the operational forecast and warning environment to improve hurricane forecasts and services.

The key to success to improve hurricane prediction is leveraging the capabilities of all partners; federal, State, local, academic, and private sector. While the bill focuses on non-federal assets, we believe federal programs need to be fiscally supported as well as academic research and State and local government programs. We agree with the need for broad areas of research to address the comprehensive impacts of hurricanes.

There are many components to the overall hurricane and tropical cyclone issue as outlined in the bill. Over the past year NOAA developed the Hurricane Forecasting Improvement Project or HFIP for short, described in my written testimony. HFIP focuses our efforts to improve forecasts of track, intensity, wind fields, and storm surge, and identifies improvements in observations and computing capabilities needed to support these forecast improvements.

We are trying to make progress on other activities described in the bill as well, such as improved forecasts for inland flooding, and those efforts will further benefit from improved hurricane track and intensity predictions.

Many federal agencies, State and local governments, and the academic and research communities are focused on improving hurricane prediction. NOAA has expertise in many areas outlined in the purposes section of the bill, including research to understand the impact between hurricanes, climate, and natural ecosystems.

NOAA conducts its research on these topics through its laboratories and centers, including the Atlantic Oceanographic and Meteorological Laboratory, the Earth System Research Laboratory, the Geophysical Fluid Dynamics Laboratory, and the National Centers for Environmental Prediction. This expertise and experience will help NOAA and the National Science Foundation under the auspices of this bill coordinate federally-funded efforts on hurricane research.

Other federal agencies identified in the bill are better suited to lead the work and provide expertise for engineered structures, the national infrastructure, disaster response and recovery technology, and evacuation planning. For example, Department of Commerce's National Institute of Standards and Technology does extensive work with the impact of wind on structures, and the Federal Emergency Management Agency in the Department of Homeland Security has expertise for evacuation planning and an extensive program addressing technologies for disaster response and recovery.

Section four of the bill proposes a national infrastructure database. We do not believe NOAA is properly positioned to lead the effort for such information. We suggest other federal agencies may offer a more suitable lead for this activity. We believe efforts focused on improved track and intensity forecasts will have the greatest impact to the Nation, but efforts in other areas are needed as well.

We see the federal role as critical to ensure federally-funded hurricane research focuses on the needs of society. That includes research on societal dimensions of the hurricane challenge, including response, recovery, mitigation, and planning. We also believe it is a function of the Federal Government to ensure the path is in place for research to be integrated into operations. This step is often under-funded, delaying and complicating the transition of successful research into operations. Our Hurricane Forecast Improvement Plan has a focus on enabling the efficient and rapid transfer of effective research into operations.

In conclusion, let me restate, we applaud the Committee's broad perspective of hurricane impacts and the need for research in areas including storm structure, rapid intensity change, ocean atmospheric interactions, storm surge, rainfall, and inland flooding forecasts. The key to success in improving hurricane prediction is leveraging all available national assets and capabilities to address this national need. NOAA's Hurricane Forecast Improvement Plan addresses a path forward for many of the items outlined in the *National Hurricane Research Initiative Act of 2007.*

We agree the most effective role for NOAA and NSF is to co-chair a committee to oversee and coordinate federally-funded hurricane research efforts to ensure successful work can be incorporated into operational forecasts and warning environment, with the overall goal of improved hurricane forecasts and services.

I thank the Committee for the opportunity to speak about this challenge, and we look forward to working with the Committee as the legislation moves forward.

[The prepared statement of Dr. Hayes follows:]

PREPARED STATEMENT OF JOHN L. HAYES

Thank you, Mr. Chairman and Members of the Committee for this opportunity to testify on the importance of increased hurricane research and preparedness. I am Jack Hayes, Assistant Administrator for Weather Services and the Director of the National Weather Service (NWS). The National Weather Service is a line office of the National Oceanic and Atmospheric Administration (NOAA), within the Department of Commerce (DOC).

The proposed legislation, H.R. 2407, the *National Hurricane Research Initiative Act of 2007,* recognizes the challenge we face as a nation, with regard to hurricane and tropical cyclones, and we applaud the Committee for addressing this complex issue.

Introduction

We agree with the overall goal of the bill to improve hurricane forecasting and preparedness. We also agree the most effective path forward is for NOAA and the National Science Foundation (NSF) to co-chair a committee, such as the National Hurricane Research Alliance, to oversee and coordinate federally funded research efforts, and to ensure successful research efforts can be incorporated into the operational forecast and warning environment to improve hurricane forecasts and services. However, the proposed authorization levels in the bill are significantly higher than current funding levels, and are therefore inconsistent with the Administration's priorities.

NOAA is already addressing many components to the overall hurricane and tropical cyclone issue outlined in H.R. 2407. Over the past year NOAA developed the Hurricane Forecast Improvement Project (HFIP—described in detail below), which focuses our efforts on improved forecasts of track, intensity, wind fields, and storm surge, which require improved observations, modeling, and computing capability. We are making progress on other activities described in the bill as well, such as improved forecasts for inland flooding, and these efforts will further benefit from improved hurricane track and intensity predictions.

Many federal agencies, State and local governments, and the academic and research community are focused on improving hurricane prediction. NOAA's expertise can be leveraged for most of the items outlined in the Purposes section of the bill, including research to understand the impact between hurricanes, climate, and natural ecosystems. NOAA conducts much of this relevant research through its laboratories and centers including the Atlantic Oceanographic and Meteorological Laboratory, the Earth System Research Laboratory, the Geophysical Fluid Dynamics Laboratory, and the National Centers for Environmental Prediction. Other federal agencies identified in the bill are better suited to lead the work and provide expertise for engineered structures, the national infrastructure, disaster response/recovery technology and evacuation planning. For example, DOC's National Institute of Standards and Technology does extensive work with the impact of wind on structures and the Federal Emergency Management Agency in the Department of Homeland Security has expertise for evacuation planning and has an extensive program addressing technologies for disaster response and recovery.

Section 4 of the bill proposes a National Infrastructure Database. We do not believe NOAA is properly positioned to lead the effort for such information. We suggest other federal agencies may offer a more suitable lead for this activity. We believe efforts focused on improved track and intensity forecasts will have the greatest impact to the Nation, but efforts in all other areas are needed as well.

Since 1990, hurricane forecast track accuracy has increased by about 50 percent through the use of enhanced observations, improved model guidance, and increased forecaster expertise. This has led to increased lead time and somewhat smaller warning areas allowing more time for emergency managers to coordinate their evacuation and preparedness activities. However, little progress has been made during this period to increase the accuracy of intensity[1] forecasts and to identify rapid intensity changes in hurricanes. Rapid intensity change presents a challenge to hurricane forecasters during the life of a storm and a serious problem for emergency managers when it occurs just prior to landfall. Rapid intensity events constitute an approximate two-category change within one day, and have a significant impact on preparedness and evacuation actions for emergency managers. Recent cases of rapid intensity changes at or near the U.S. coastline have occurred with little or no warning.

[1] Defined by NOAA's National Weather Service as the peak 1-minute sustained 10-m wind anywhere in the storm (*http://www.weather.gov/directives/sym/pd01006004curr.pdf*)

With recent catastrophic events in 2005 of Katrina and Wilma, back-to-back Category 5 storms in the Caribbean Sea in 2007 (Dean and Felix), and storms that rapidly intensified just prior to landfall like Charley in 2004 and Humberto in 2007, the time is now for the Federal Government and our partners in State and local governments, and the research and academic communities, to undertake an aggressive effort to improve our national hurricane forecasting capability.

This message and sense of urgency for improved hurricane forecasts is consistent with the overarching recommendations in three recent reports: the 2006 NOAA Science Advisory Board Hurricane Intensity Research Working Group report, the 2007 report of the National Science Foundation (NSF) National Science Board (NSB): *Hurricane Warning: The Critical Need for a National Hurricane Research Initiative,* and the 2007 report issued by the Office of the Federal Coordinator of Meteorological Services (OFCM): *Interagency Strategic Research Plan for Tropical Cyclones—The Way Ahead.* All three reports recommend a significant increase in funding for hurricane and tropical cyclone research and development, and transition of research to operations. In addition, many studies and reports have shown that investments in forecasts and other warning information needed for community planners have a significant return for the Nation, including the 2007 report issued by the National Hazards Review,[2] *Hurricane Forecasting: The State of the Art,* and a report from the Multi-hazard Mitigation Council (MMC) of the National Institute of Building Sciences.[3]

Need for Improved Hurricane Forecasts

> *"Billions of tax dollars have been provided for rescue, recovery, and rebuilding after hurricanes strike . . . recent hurricanes have focused public attention on the imperative to enhance our understanding of tropical weather systems and their multi-faceted impacts, ranging from geophysical and engineering elements to human economic dimensions . . . improving our nation's ability to become more resilient to hurricane impacts."*[4]

More than 50 percent of the U.S. population is living within 50 miles of the coast,[5] and roughly 180 million people visit the coast annually. The coastal population explosion (Figure 1) over the last half-century translates to increased risks for these coastal communities. As the U.S. coastline continues to develop, more people will be at risk and impacts are expected to further increase. Annual U.S. hurricane losses average about $10 billion and a recent historical analysis of hurricane damages from 1900 to 2005 suggests a doubling of economic losses from land falling hurricanes every ten years.[6] The need for substantial improvements in hurricane track and intensity forecast capabilities has never been greater. This is a sentiment echoed by our partners in the emergency management communities at the national, regional and local levels, who are issuing strong demands to extend hurricane forecast lead times. These extended lead times are necessary to evacuate some coastal locations that now require evacuation "orders" be issued 48 to 72 hours in advance.

Highly accurate hurricane forecasts are needed to ensure the timely issuance of reliable hurricane watches and warnings. These forecasts are an essential factor in avoiding loss of life and injury and reduced property loss and economic disruption. Without accurate hurricane forecasts, emergency managers are unable to take necessary decisive action to save lives and mitigate economic loses. The expected outcomes of the HFIP are to provide higher quality information with associated probabilities on high impact variables, such as wind speed, precipitation, and storm surge; and to extend the lead time beyond five days, and reduce the length and duration of watches and warnings.

Operational Needs

Operational needs expressed by the tropical cyclone operations centers (National Hurricane Center (NHC), Central Pacific Hurricane Center, and the Joint Typhoon Warning Center) are detailed in the OFCM report, *Interagency Strategic Research Plan for Tropical Cyclones—The Way Ahead.* These operational needs support the

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[2] Willoughby, H. et al., "Hurricane Forecasting: The State of the Art," *National Hazards Review* © ASCE, August 2007, pp. 45–49.

[3] *http://www.nibs.org/MMC/MitigationSavingsReport/Part1_final.pdf*

[4] *Hurricane Warning: The Critical Need for a National Hurricane Research Initiative,* National Science Board NSB–06–115, January 12, 2007.

[5] *http://www.ofcm.noaa.gov/p36-isrtc/fcm-p36.htm*

[6] Pielke, R.A., Jr., J. Gratz, C.W. Landsea, D. Collins, M. Saunders, and R. Musulin, 2007: Normalized Hurricane Damages in the United States: 1900–2005. Accepted for publications in the *Bull. Amer. Met. Soc.*

overarching goal to produce improved wind speed, precipitation, and storm surge analysis and forecast information and to provide associated probabilities, as well as the uncertainty in the forecasts, to emergency managers and other decision-makers. To meet these operational needs, critical steps to ensure the future success of the Nation's hurricane forecast and warning program include: focused applied research and transition efforts to improve computer models; advanced observations and observational strategies; improved processing capabilities to include those data into the models; expanded forecaster tools; and properly applied human and infrastructure resources. Furthermore, extensive collaboration with social scientists is also needed to help ensure the information presented to the public can be understood in clear terms by non-meteorologists.

NOAA's mission-oriented requirements for operational system development, implementation and sustained operations guide us toward attaining a specific set of short-term forecast goals, related applied research focus areas, and infrastructure investments. Within this mission-oriented context, the research and transition activities needed to improve operational forecasts are accomplished with the aid of testbeds strategically aligned with the needs of the forecast centers. In general, testbeds are a collaborative environment for conducting integrative research, testing new ideas in an end-to-end fashion under the rigors of operational constraints (real and simulated), and facilitating the deployment into operational practice of knowledge gained in research (NSB Report 2007).

Testbeds, such as the Joint Hurricane Testbed in Miami, the Developmental Testbed Center in Boulder, and the Joint Center for Satellite Data Assimilation in Maryland, are oriented toward improving operational hurricane forecasts and guidance. These testbeds provide evolutionary pathways to coordinate applied model and technology advancements to specific forecast requirements and focus on identifying and effecting the transition of research and technologies capable of providing immediate and justifiable improvements to operational hurricane forecasts.

Bridging across the OFCM and NSB reports, the NOAA HFIP plan involves evolutionary and transformational pathways that require coordination between key federal and academic leaders in order to properly support the required research and development and to improve the operational hurricane track and intensity forecasts.

Building Off the Nation's Interagency Strategic Research Plan

Within our HFIP, we are working to build upon recent planning efforts of the NSF, NSB and OFCM[7] to engage the broader research community in improving hurricane forecasts. The HFIP's goals include improving the accuracy, reliability, and extending the lead time of hurricane forecasts and increasing confidence in those forecasts by customers and decision-makers, especially those in the emergency management community. These goals were also echoed by the NOAA Science Advisory Board's Hurricane Intensity Research Working Group.

Within the framework of operational hurricane forecast improvements, NOAA seeks a partnership among the federal and academic communities to align the broader science and engineering community with the operational community to realize the greatest benefits for the country. This broader partnership is critical to effectively address HFIP goals and for NOAA to transition new research and technology into operations.

NOAA Strategy to Align with the Larger Community

The key to success in improving hurricane prediction is leveraging the capabilities of all partners: federal, State, local, academic, and private sector. Communication between federal partners and the external community on operational needs and associated research focus areas is necessary to achieve both immediate successes and scientific research advances that hold promise for the future. A highly visible and independent oversight activity will be identified. An annual interagency program review with a significant external (to NOAA) role is being planned with the Interdepartmental Hurricane Conference, as a possible venue. This conference leads up to an annual summit attended by agency, academia, and private sector research leadership.

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[7] —Office of the Federal Coordinator for Meteorology (OFCM) P–36, 2007; *Interagency Strategic Research Plan for Tropical Cyclones—The Way Ahead.*

—National Science Board, 2007; *Hurricane Warning: The Critical Need for a National Hurricane Research Initiative.*

—National Oceanic and Atmospheric Administration Science Advisory Board, Hurricane Intensity Research Working Group Majority Report.

NOAA is working with the NSF to formally establish the National Hurricane Research Alliance to ensure coordination across the broad spectrum of activities from observations to data assimilation to modeling to basic research. The Alliance will include key federal agencies, including NSF, the National Aeronautics and Space Administration (NASA), and the Navy (including the Office of Naval Research). This Alliance will leverage existing federal hurricane coordination efforts, including those from the OFCM Services and Supporting Research, to manage overall roles and responsibilities to improve overall accuracy and reliability of hurricane forecasts. Through this Alliance, NOAA and NSF will work with other federal agencies to maximize the use of the considerable non-federal assets in conducting much of the hurricane research and development described in the *National Hurricane Research Initiative Act of 2007,* and in developing and disseminating related products and services.

Federal Investments

NOAA needs to ensure new breakthroughs in hurricane research and technology can be accelerated into operational forecasting systems. The importance of addressing operational forecast requirements and related research focus areas requires sufficient investments that include:

- Easy access to current and planned observing systems;
- Increased high performance computing capacity and capability to allow for higher resolution models;
- Institutionalized and transition research to operations to ensure an efficient process to incorporate demonstrated research results in modeling and observing systems;
- A plan for sufficient operations and maintenance resources; and
- Enhanced interactions with the broader science and engineering community to provide increased understanding of hurricanes while using all available resources.

Therefore, a sustained and broad hurricane research initiative would make the best use of these capabilities and improve our understanding of and ability to predict hurricanes.

Hurricane Forecast Improvement Project (HFIP)

NOAA established the Hurricane Forecast Improvement Project (HFIP) to develop a unified 10-year plan to improve our one to five day tropical cyclone forecasts, with an emphasis on rapid intensity change. The goal of HFIP is to improve the accuracy and reliability of hurricane forecasts and warnings and to increase the confidence in those forecasts to enhance mitigation and preparedness decisions by emergency management officials at all levels of government and by individuals.

The scope of the HFIP plan (Figure 2) encompasses research and development:

- To improve understanding, with emphasis on the phenomena related to predictability of rapid intensity[8] change and secondary eyewall phenomena;
- To improve observations and observational strategies for the hurricane and its environment;
- To uncover novel methods for data assimilation, to utilize the diverse range of existing and new observations;
- To advance high-resolution numerical prediction and ensemble predictions systems for hurricane forecast guidance; and
- To accelerate the transfer of research results into operational forecasting.

While NOAA is developing its level of involvement in the broader spectrum of issues identified in the NSB report, NOAA focused HFIP on the research and development issues identified by operational needs that will lead to improved hurricane forecast guidance and tools. HFIP aims to reduce and quantify the uncertainty in all forecast guidance, including high spatial/temporal resolution gridded wind speed, precipitation, storm surge analysis and forecast information. Our efforts will focus on improved track forecasts, improved intensity forecasts, improved rapid intensity change forecasts, and improved lead time.

Below are four examples of our metrics:

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[8] Rapid intensification is defined at a 30kt increase of sustained maximum winds in 24 hours or less.

1) Reduce average track error by 50 percent for Days 1 through 5 (Figure 3)

Based on input from emergency managers at all levels, the forecast of the location or track of the tropical cyclone is most important. Over the past couple of decades the hurricane community has put most of its effort and resources into reducing the track error. While the limits of predictability for track error are not fully understood, NOAA will seek to reduce the track error by 50 percent over the next decade, which is the same level of improvement as NOAA was able to achieve between 1990 and the present. More accurate information on the location of the storm will allow emergency managers to focus on a more precise coastal area at landfall and avoid unnecessary evacuations.

2) Extend the lead time for hurricane forecasts out to Day 7 (Figure 4)

In 2001 the NHC extended the lead time of its forecasts from three to five days. However State and federal emergency managers have expressed that five days is not enough time to prepare certain areas, due to population growth, infrastructure, resources, etc. Extending the forecast out to seven days would help address their concern and need for longer lead times to ensure those impacted (the public, businesses, etc.) have sufficient time to prepare for, and evacuate from, an approaching hurricane.

3) Reduce average intensity error by 50 percent for Days 1 through 5 (Figure 5)

The current hurricane 48-hour official forecast intensity error is ~14 knots or roughly the wind speed range for one category on the Saffir-Simpson Hurricane Scale. Due to the uncertainty in today's intensity (strength of storm) forecast, NHC suggests that emergency managers prepare for one category above the NHC official intensity forecast (e.g., if NHC forecasts a Category 3 hurricane at landfall, emergency managers should prepare for a Category 4). A 50 percent reduction in intensity error will allow emergency managers to better focus their preparedness efforts. Reducing the uncertainty in the hurricane intensity forecasts will also support evacuation decisions by identifying the coastal and inland areas of greatest concern for wind and associated storm surge.

When the impacts of the 50 percent improvement in track and intensity errors are combined for the Gulf Coast, forecasts provided to the emergency managers will be a more confined area of concern with a more precise wind estimate (Figure 5).

4) Increase the accuracy of rapid intensity change forecasts

Rapid intensity change presents a great challenge to hurricane forecasters during the life of a storm and a serious problem for emergency managers when it occurs just prior to landfall. Rapid intensity events constitute an approximate two-category change within one day, and have a significant impact on preparedness and evacuation actions for emergency managers.

While improving the accuracy of rapid intensity change forecasts within one day of landfall is a high priority, given the uncertainty in track forecasts of landfall and the need by some to make decisions on protective actions more than one day before landfall, these improvements are needed at all lead times over the entire life of the storm. Increasing the forecast accuracy of rapid intensity change events can lead to greater confidence in forecasts. Emergency managers and the public will be able to make decisions and take appropriate action. Today, emergency planning is based on a storm one category higher than what is predicted. More accurate rapid intensity change predictions, will allow for more efficient evacuations and preparedness.

Key Strategies for HFIP

I will now briefly describe key strategies outlined in our Hurricane Forecast Improvement Project plan to implement the activities needed to improve hurricane forecasts, with an emphasis on rapid intensity change. Full HFIP details are available at *http://www.nrc.noaa.gov/plans_docs/HFIP_Draft_Plan-1.pdf*.

Engage the expertise of the operational tropical/hurricane numerical prediction and research community, including stakeholders

NOAA recognizes the broad scope of the scientific challenges associated with understanding and predicting hurricanes. Addressing these challenges and improving forecasts of hurricane track and intensity will involve increased interaction with the external research community to leverage and coordinate research activities. NOAA plans to broaden the base of expertise in the tropical cyclone operational numerical prediction and research communities and broaden our interaction with the research

and development community by improving our efforts through workshops, symposia, and conferences to:

- Improve computer modeling of hurricanes;
- Improve the use of data;
- Better coordinate with our federal, academic, and private sector partners of needs and opportunities;
- Increase grants; and
- Support additional education and outreach activities.

Optimize observing systems for research and operations

The advancement of observational capabilities for tropical cyclone analysis, forecasting, and numerical weather prediction is a vital component of the HFIP. These observational capabilities extend from exploratory scientific research conducted with new types and new generations of advanced instruments and platforms, to proven operational systems used for analysis and forecasting. Over the past four decades, satellite and airborne observing systems developed and flown by NASA, NOAA, NSF, and the Department of Defense have made major contributions to the operational tropical cyclone forecast systems. With several new observational platforms and sensors meant to enhance observing capabilities for hurricane forecasters, and hurricane numerical prediction systems potentially available in the next several years, NOAA will evaluate the usefulness of these data to ensure investment decisions are made to select the optimal systems/platforms for improvements in hurricane forecasts.

Define and build the next generation hurricane forecast framework, including the Hurricane Forecast System/Global Forecast System

The next generation hurricane forecast framework is a multi-model suite containing both high resolution and ensemble forecasts produced by NOAA and other numerical prediction entities on the national and international scales. Within this framework, a next-generation Hurricane Forecast System/Global Forecast System will also be defined and constructed to accurately represent the physical processes responsible for rapid intensity change through research and development activities within NOAA and the broader research community. This strategy builds upon NOAA's long-standing operational numerical prediction capabilities and related research efforts to improve understanding of the physical processes that lead to track, intensity/structure, and precipitation changes in hurricanes. This plan focuses on developing a capability to accelerate numerical modeling developments to drive improvements in the hurricane forecast guidance through enhanced research between NOAA and the larger research community.

The need for an ensemble approach for all forecast applications, including hurricane forecasting, was highlighted by a 2006 National Research Council Report.[9] The report states, as one of their nine major recommendations, "NOAA should develop and maintain the ability to produce objective uncertainty information from the global to the regional scale."

Institutionalize and transition research to operations

The transition of research to operations—referred to by the OFCM and defined by the Board on Atmospheric Sciences and Climate, National Research Council as "bridging the valley of death"—requires robust interaction between the research and operational communities, as well as a strong interface with the user community. Also required is a healthy infrastructure for the transition, including resources and processes for evaluation and demonstration, operational implementation and operations and maintenance.

Increase High Performance Computing and Information Technology capacity and capability

High quality hurricane forecasting will require a 5000 fold increase in high performance computing and information technology capabilities. The framework of combining information from different forecast centers involves virtual grid computing as the system leverages and relies on computing capability across the numerical prediction centers, but may also require significant enhancements in telecommunication. In addition, each center, including the NOAA computing centers, will

[9] *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts,* National Research Council of the National Academies, ISBN 0–309–66261–3, 2006.

produce higher-resolution analyses and forecasts by running the numerical models on massively parallel processors, including NOAA's supercomputer. Therefore, increases in NOAA's high performance computing capability and capacity are required to enable and support advancements in the NOAA Hurricane Forecast System/Global Forecast System, including ensemble capabilities.

Conclusion

NOAA applauds the Committee's broad perspective of hurricane impacts and the need for research in areas including storm structure, rapid intensity change, ocean-atmosphere interactions, storm surge, rainfall and inland flooding forecasts. However, the Administration is concerned that the bill's funding levels are significantly higher than current funding levels. NOAA's HFIP already addresses a path forward for many of the items outlined in the *National Hurricane Research Initiative Act of 2007*. HFIP efforts are currently focused on improved track and intensity forecasts, wind fields, and storm surge, as well as the accompanying need for improved observations and computing capability. We agree the most effective role is for NOAA and NSF to co-chair a committee to oversee and coordinate federally funded hurricane research efforts to ensure successful work can be incorporated into the operational forecast and warning environment with the overall goal of improved hurricane forecasts and services. The key to success in improving hurricane prediction is leveraging all available national assets and capabilities to address this national need. I thank the Committee for the opportunity to speak about this challenge and we look forward to working with the Committee as this legislation moves forward.

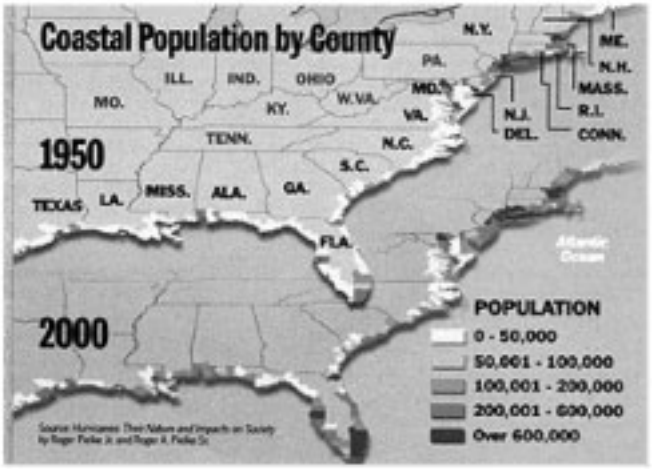

Figure 1. Coastal population by county. Source *Hurricanes: Their Nature and Impacts on Society*, by Roger Pielke, Jr. and Roger A. Pielke, Sr.

Figure 2. Scope of the NOAA Hurricane Forecast Improvement Project (HFIP).

Figure 3. The panels above are examples of the NHC track forecast (cone graphic). The black line denotes the NHC forecast track for the center of the storm over a 5 day period The cone is calculated such that the center remains within it two-thirds of the time based on official forecast errors over the previous 5 years. The panel on the left shows what the NHC hurricane cone graphic would look like today. The panel of the right shows the same storm with a 50% reduction in track error, the first goal of the HFIP.

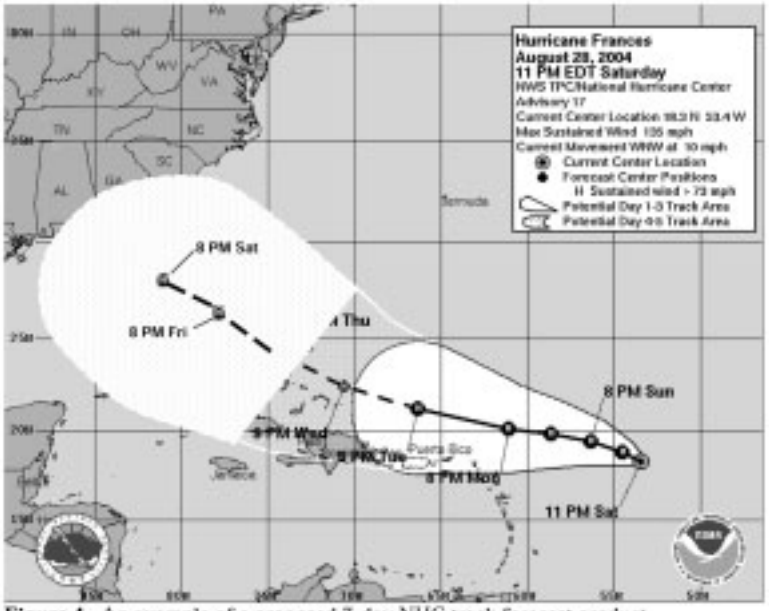

Figure 4. An example of a proposed 7-day NHC track forecast product.

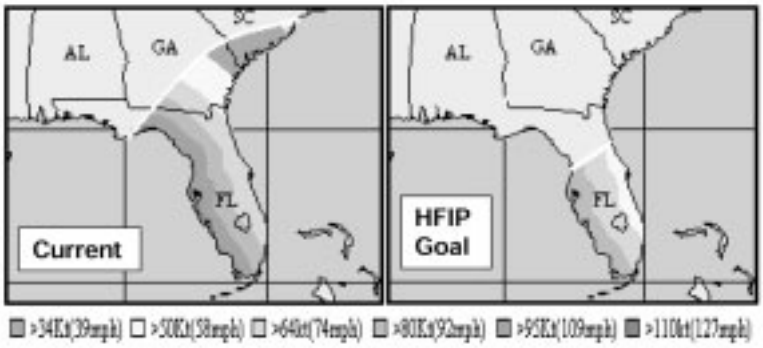

Figure 5: A depiction of a 50% improvement in intensity and track for the Gulf Coast. The HFIP goal (on the right) will allow a more focused effort by the emergency managers for their preparedness and evacuation activities.

BIOGRAPHY FOR JOHN L. "JACK" HAYES

John L. "Jack" Hayes is the NOAA Assistant Administrator for Weather Services and National Weather Service Director. In this role, he is responsible for the day-to-day civilian weather operations of 122 local Weather Forecast Offices, 13 River Forecast Centers, nine National Centers for Environmental Prediction, and 21 Aviation Weather Service Units in the United States, Puerto Rico, Hawaii, and Guam.

The National Weather Service (NWS) provides daily weather forecasts and warnings to the American media, emergency managers, fire land managers, commercial weather partners, and the general public for weather and natural hazards such as hurricanes, tornadoes, severe thunderstorms, flash floods, winter storms, extreme fire weather conditions, tsunamis, and solar flares.

Dr. Hayes rejoined the National Weather Service after serving as the Director of the World Weather Watch Department at the World Meteorological Organization (WMO), a specialized agency of the United Nations located in Geneva, Switzerland. In that position, he was responsible for the global observing, global telecommunications, and global data processing and forecasting systems that provide the foundation for operational weather forecasting and warning services for 188 WMO member countries worldwide. During this period, he led the development of the WMO Strategic Plan which was approved by WMO's 15th Congress in May 2007.

Before joining the WMO, he served in several senior executive positions at NOAA. As the Deputy Assistant Administrator for NOAA Research, he was responsible for the management of research programs. As Deputy Assistant Administrator of the National Ocean Service (NOS), he was the chief operating officer dealing with a multitude of ocean and coastal challenges, including NOS's response to the Hurricane Katrina disaster in August 2005. As Director of Office of Science and Technology for the NWS, he was responsible for the infusion of new science and technology essential to weather service operations; he was recognized as one of the Federal Government's Top 100 IT Executives for his leadership of programs to improve information processing and dissemination supporting NWS's weather forecast and warning mission.

Dr. Hayes was also an executive in the private sector and the military. He was general manager of the $500 million Automated Weather Interactive Processing System program at Litton-PRC from 1998 through 2000. AWIPS is the interactive computer system utilized by all weather service forecasters. From 1970 through 1998, he held a variety of meteorological positions with the United States Air Force, beginning as a weather forecast officer in 1970 and culminating his career as Commander of the Air Force Weather Agency and Air Force Global Weather Center.

He received both his Ph.D. and Master of Science degrees in meteorology from the Naval Postgraduate School in Monterey, California. He is a graduate of Bowling Green State University, with a Bachelor's degree in mathematics. He is a Fellow in the American Meteorological Society.

Chairman LAMPSON. Unfortunately, it seems to be no different with medicine. We seem to be putting our resources after the fact, trying to treat those effects rather than trying to prevent them.

Dr. HAYES. Yes, sir.

Chairman LAMPSON. Or that occurrence. Thank you very much, Dr. Hayes.

Dr. Droegemeier, you are recognized for five minutes.

STATEMENT OF DR. KELVIN K. DROEGEMEIER, PROFESSOR OF METEOROLOGY, UNIVERSITY OF OKLAHOMA; MEMBER, NATIONAL SCIENCE BOARD; CO-CHAIR, NATIONAL SCIENCE BOARD TASK FORCE ON HURRICANE SCIENCE AND ENGINEERING

Dr. DROEGEMEIER. Thank you, Mr. Chairman. Good morning to everyone. I thank you very much, Chairman Lampson. Also Chairman Baird, Ranking Members Ehlers and Inglis and other Members of the two Subcommittees for the opportunity to speak with you today. My name is Kelvin Droegemeier. I am a Professor of Meteorology at the University of Oklahoma. I am also a member of the National Science Board and am appearing before you today in my role as Co-Chair of the National Science Board's Task Force on Hurricane Science and Engineering. The final report of that task force, which was published in January 12 of 2007, served, as you heard earlier, as a blueprint for H.R. 2407. Dr. Kenneth Ford, who directs the Institute for Human and Machine Cognition in

Florida actually, is my fellow NSB member and also was the other Co-Chair.

You have heard a lot of statistics this morning, but I would like to highlight one area of vulnerability for our nation that is particularly relevant today, and that is the immense energy infrastructure in the Gulf of Mexico. That infrastructure transports some 30 percent of our nation's domestically-produced oil and gas from offshore wells to onshore refineries, and more than 100 of the 4,000 offshore platforms in the Gulf of Mexico were destroyed in Hurricanes Katrina and Rita alone. And a full nine months later 150 million barrels of oil and 730 billion cubic feet of gas remain unavailable to our nation.

Motivated in part by the sorts of vulnerabilities I just mentioned, the National Science Board undertook a very intensive effort to frame the hurricane science and engineering research challenges and recommend a national imperative to address them. The most important aspect of this strategy is that it engages not only the atmospheric sciences but also disciplines such as engineering, social and behavioral sciences, economics, computer science, ecology, and hydrology in a truly integrated fashion.

We often tend to think of hurricanes as a weather problem, but in reality they are a weather-driven, social science, human behavior, physical science and engineering problem as Dr. Baird correctly mentioned a few moments ago. The recommendations of the Board report strongly reflected H.R. 2407, and for that we owe all of you a debt of gratitude.

You might ask where are we today. As the Nation's principle agency for funding basic science and engineering research and education, the National Science Foundation's support for hurricane-related research in fiscal 2007, was $12.44 million across all the topic areas outlined in H.R. 2407. NSF awarded 106 small grants for exploratory research related to Hurricane Katrina alone, and the total budgets of those grants were about $7.5 million.

NSF has long been an active participant in the U.S. Weather Research Program, which focuses on the physics of hurricanes and their prediction. NSF and NOAA, the two lead agencies in H.R. 2407, already collaborate in many ways, and a wonderful example of that with regard to hurricanes is a new joint research solicitation on the topic of communicating hurricane information. It focuses on the important social science problem of how warning information is communicated, interpreted, and then acted upon.

H.R. 2407 provides an opportunity to coordinate and enhance that type of research along with physical science and engineering research in a truly integrative manner, which is truly the necessary path forward if we hope to improve our nation's resilience and resistance.

Additional opportunities in the National Science Board report that are worth mentioning this morning include the use of National Super Computing Centers funded by NSF for running operational NOAA forecast models in time of national need; in fact other models as well—as well as exploring university curricula that look at hurricanes not just from an atmospheric scientist's point of view but from a multi-disciplinary perspective to make sure that our next generation of hurricane researchers is adequately educated.

In closing, I would like to note that the NSB report on which H.R. 2407 is based, I have a copy here, the title says, Hurricane Warning, and it truly is an urgent call to action on a very, very important challenge for our nation. On behalf of the National Science Board and our Chairman, Dr. Steven Beering, I want to thank the Science Committee and the two Subcommittees who sponsored this hearing for recognizing urgency of this important topic. We at the National Science Board stand ready to assist you in whatever ways might be most beneficial.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Droegemeier follows:]

PREPARED STATEMENT OF KELVIN K. DROEGEMEIER

I thank Chairman Lampson, Chairman Baird, Ranking Members Ehlers and Inglis, and the other Members of the two Subcommittees for the opportunity to speak with you today. My name is Kelvin Droegemeier and I am a Professor of Meteorology at the University of Oklahoma. I also am a member of the National Science Board and am appearing before you today in my role as Co-Chair of the National Science Board's Task Force on Hurricane Science and Engineering. The final report of this Task Force was published on January 12, 2007, and I understand that it largely served as the blueprint for H.R. 2407 as introduced in the House of Representatives. Dr. Kenneth Ford, Director of the Institute for Human and Machine Cognition and fellow NSB member, served as my Co-Chair.

I needn't tell you that every year, hurricanes pose a threat to life, property, and the very economic vitality of our nation. Yet impact of hurricanes extends well beyond a given storm, often for many years, as we've seen in recent storms such as Katrina and Rita. Among all weather hazards in the U.S., hurricanes account for over half the total damage inflicted, and annual economic losses average approximately $10 billion in constant 2006 dollars. Of course, the 2005 hurricane season was notably destructive, with Katrina losses exceeding $130 billion. Remarkably, 50 percent of the U.S. population lives within 50 miles of a coastline and that some 80 percent of our population resides within 200 miles of a coast. The $3 trillion of physical infrastructure in the Gulf and Atlantic coastal regions continues to grow at a rapid pace, and thus we as a nation are increasingly vulnerable to hurricanes. Of particular relevance today is the immense energy infrastructure located in "hurricane alley"—33,000 miles of pipeline that transports some 30 percent of our nation's domestically-produced oil and gas from offshore wells to onshore refineries. According to the U.S. Department of the Interior, some 3,000 of the Gulf's 4,000 platforms, and 22,000 of the 33,000 miles of the Gulf's pipelines, were in the direct paths of Hurricanes Katrina and Rita. A total of 115 offshore platforms were destroyed, 52 were damaged, and 535 pipeline segments were damaged. Considerable destruction occurred to onshore facilities—for example, refineries and supporting infrastructures in and around Lake Charles, Louisiana. More than nine months later, 22 percent of federal oil production and 13 percent of natural gas production remained unavailable, resulting in the loss of 150 million barrels of oil and 730 billion cubic feet of gas from domestic supplies.

Motivated in part by recent hurricanes, the National Science Board decided to undertake an intensive effort to frame the hurricane science and engineering research challenges and recommend a national imperative to address them in a holistic manner. We did so by engaging the academic, government and private sector communities in a series of workshops; by evaluating previous studies of hurricanes and other natural disasters; and by obtaining input from the public on a draft version of the report.

As you well know, we spend billions of dollars on rescue and recovery after hurricanes occur. But can we better anticipate and react to hurricanes ahead of time to avoid loss of life, property, vital infrastructures, and disruptions in our economy? The answer from our study is yes. Are we using existing knowledge effectively? The answer from our study is no. Is the research now being done adequate and properly coordinated? The answer from our study is no. In fact, research in hurricanes appears to be a modest, loosely coordinated enterprise. Although of high quality, this research is generally conducted within the boundaries of traditional disciplines—stovepipes like meteorology, hydrology, engineering, computer science and ecology—with insufficient integration. And the engagement of social, economic, behavioral sciences is inadequate. In short, the hurricane is perhaps one of the best examples

of a problem—vital to society—which must be studied in a multi-disciplinary fashion if we hope to lessen our vulnerability.

H.R. 2407 reflects very closely the recommendations made in our report. This truly is a wonderful testimony of Congress responding quickly to recommendations of the broad community and using existing frameworks (such as OSTP and the *National Windstorm Impact Reduction Act*) to deal with a profoundly important problem. Given that you are familiar with the bill, I wish to highlight just a few key points.

First, strong collaboration between NSF and NOAA is vital to the success of this effort, as is the involvement of other agencies, as articulated in the bill. Second, it is important to note that the hurricane is not a weather problem alone but rather a weather-driven problem that must be studied in a multi-disciplinary fashion. It is for this reason that the components of the research agenda described in the bill—including, for example, hurricane intensity change, assessment and response of structures to wind and waves, ecosystem impacts, and economic and societal impacts—are important and must be performed in a coordinated manner. Third, the national infrastructure data base is important for hurricanes but also for numerous other uses, ranging from earthquakes to homeland security. Fourth, the National Hurricane Research Model—which in our report was referred to as a testbed and involves all relevant disciplines of the research program—is essential for bringing together the research components and moving them to operational practice.

On behalf of the National Science Board and our Chairman, Dr. Steven Beering, I want to thank the Subcommittees for the important work they do for U.S. scientific research, education, and training. We appreciate your attention to the recommendations of the Board and stand ready to assist in whatever ways might be most beneficial.

BIOGRAPHY FOR KELVIN K. DROEGEMEIER

Kelvin K. Droegemeier earned a B.S. with Special Distinction in Meteorology in 1980 from the University of Oklahoma, and M.S. and Ph.D. degrees in atmospheric science in 1982 and 1985, respectively, from the University of Illinois at Urbana–Champaign under the direction of R. Wilhelmson. He joined the University of Oklahoma in September, 1985 as an Assistant Professor of Meteorology, and was tenured and promoted to Associate Professor in July, 1991, and promoted to Professor in July, 1998. Dr. Droegemeier was co-founder in 1989 of the NSF Science and Technology Center (STC) for Analysis and Prediction of Storms (CAPS), and served for five years as its Deputy Director. He then directed CAPS from 1994 until 2006, and today CAPS is recognized around the world as the pioneer of storm-scale numerical weather prediction. Dr. Droegemeier is now Director Emeritus of CAPS. In 1998, Dr. Droegemeier was named a President's Associates Presidential Professor at the University of Oklahoma, and for two years, beginning in summer 1999, wrote a daily weather science column for the *Daily Oklahoman* newspaper, which is Oklahoma's largest. He was awarded a Regents' Professorship at OU in fall, 2001, which is a life-long title. In 2003, Dr. Droegemeier co-founded the NSF Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) and currently serves as its Deputy Director. He is the only person in the Nation to have co-founded an NSF Science and Technology Center and an NSF Engineering Research Center. In 2004, he was awarded the Roger and Sherry Teigen Presidential Professorship and became the first OU professor to receive two Presidential Professorships. In 2005, he was named the Weathernews Chair in Applied Meteorology at the University of Oklahoma and also the Director of the Sasaki Institute, a nonprofit organization that fosters the development and application of knowledge, policy, and advanced technology in the government, academic and private sectors. In 2004, Dr. Droegemeier was appointed by President George W. Bush to a six-year term on the National Science Board, the governing body of the National Science Foundation that also provides science policy guidance to the Congress and President. In 2005, Dr. Droegemeier was appointed Associate Vice President for Research at the University of Oklahoma.

In 1987, Dr. Droegemeier was named a Presidential Young Investigator by the National Science Foundation. As Director of the CAPS model development project for five years, he managed the creation of a multi-scale numerical prediction system that has helped pioneer the science of storm-scale numerical forecasting. This computer model was a finalist for the 1993 National Gordon Bell Prize in High Performance Computing. In 1997, Dr. Droegemeier received the *Discover Magazine* Award for Technology Innovation (computer software category), and also in 1997 CAPS was awarded the *Computerworld* Smithsonian Award (science category). Droegemeier

also is a recipient of the NSF Pioneer Award and the Federal Aviation Administration's Excellence in Aviation Award.

Dr. Droegemeier has been a major force behind the development and application of high performance computing systems both at OU and across the U.S. In 1989 and 1990, he chaired the OU Computing Advisory Committee and was the lead author on a five-year strategic plan. He has served on numerous NSF High Performance Computing and Communication panels and is a member of the NCSA User Advisory Committee. In 1995 he created as principal investigator, and now directs, a $1.4 million NSF/OU project known as the Environmental Computing Applications System. He served on the National Science Foundation's Blue Ribbon Panel on Cyberinfrastructure, and is a member of the Board of Directors of the OU Supercomputer Center for Education and Research (OSCER), which he helped establish. Dr. Droegemeier is now a member of the Advisory Committee for the National Center for Computational Sciences and the Computer Science and Math Division at Oak Ridge National Laboratory.

Dr. Droegemeier is a national leader in the creation of partnerships among academia, government and industry. He initiated and led a three-year, $1M partnership with American Airlines to customize weather prediction technology for commercial aviation, and this resulted in him founding a private company, Weather Decision Technologies, Inc., located in Norman, that is commercializing advanced weather technology developed by the University of Oklahoma and other organizations. The success with American Airlines also played a role in the establishment in Oklahoma of the Aviation Services Division of Weathernews, the world's largest private weather company. Dr. Droegemeier led a $10.6M research alliance with Williams Energy Marketing and Trading Company in Tulsa, which is the largest such partnership between a university and a private company in the field of meteorology. He initiated and led the Collaborative Radar Acquisition Field Test (CRAFT), a national project directed toward developing strategies for the real time delivery of NEXRAD radar data via the Internet. CRAFT won two awards from the National Oceanic and Atmospheric Administration, and its success led the National Weather Service to adopt its Internet data delivery strategy. As a follow-on to CRAFT, Droegemeier established Integrated Radar Data Services (IRaDS) at OU, which is a National Weather Service-designed top-tier provider of NEXRAD radar data to private industry.

Dr. Droegemeier's research interests lie in thunderstorm dynamics and predictability, variational data assimilation, mesoscale dynamics, computational fluid dynamics, massively parallel computing, and aviation weather. He has served as an associate editor for *Monthly Weather Review* for six years served on the UCAR University Relations Committee, the last two as Chair. Elected to the UCAR Board of Trustees in 2002 and as its Vice Chairman in 2003, he became Chairman of the Board in 2004. Dr. Droegemeier has served as a consultant to Honeywell Corporation, American Airlines, the National Transportation Safety Board, and Climatological Consulting Corp. Dr. Droegemeier has graduated 27 students and served on the committees of numerous others. He has served on the Advisory Committee for the Geosciences Directorate at the National Science Foundation and the NSF Advisory Committee for the Computer Information Science and Engineering Directorate.

In his 23 years at the University of Oklahoma, Dr. Droegemeier has generated over $40 million in external research funding. For over a decade, he has been among the top five faculty at the University of Oklahoma in external research grant funding, averaging over $2 million per year. Dr. Droegemeier has been an invited speaker at or organizer of several international conferences and symposia on meteorology, high-performance computing, and computational fluid dynamics in the U.S., England, Japan, Australia, Korea, and France, notably the series of Joint US-Korea Workshops on Storm and Mesoscale Weather Analysis and Prediction, which he initiated in the mid 1990s. He has authored and co-authored more than 60 refereed journal articles and over 200 conference publications, and is a former Vice President of the Central Oklahoma Chapters of the American Meteorological Society and National Weather Association. He is a former Member of the Board of Directors of the Norman, OK Chamber of Commerce and chaired the Weather and Climate Team for Governor Brad Henry's EDGE (Economic Development Generating Excellence) Program. He is a Fellow of the American Meteorological Society, and served as a Counselor from 2005–2008.

Chairman LAMPSON. Thank you, Dr. Droegemeier.

At this time we will recognize Dr. Chen for five minutes.

STATEMENT OF DR. SHUYI S. CHEN, PROFESSOR OF METEOROLOGY AND PHYSICAL OCEANOGRAPHY, ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCES, UNIVERSITY OF MIAMI

Dr. CHEN. Chairman Baird, Chairman Lampson, and Members of the two Subcommittees, thank you for the opportunity to speak with you today on the need for advancing hurricane research. My name is Shuyi Chen. I am a Professor at Rosenstiel School of Marine and Atmospheric Sciences of the University of Miami. It is an honor for me to testify on the National Hurricane Research Initiative. I would also like to thank Congressman Hastings and Congresswomen Ros-Lehtinen for their leadership in introducing H.R. 2407.

The U.S. has become increasingly vulnerable to hurricanes, not only because of the uncertainty of hurricane response to a warming climate, but also rapid growth of coastal population. The average annual cost for hurricane-related losses have increased to more than ten billion, not to mention the loss of life and human suffering as seen in the case of Katrina.

As a scientist it was particularly devastating and heartbreaking for me to watch the disaster caused by Katrina, the 2004 hurricanes in Florida, and the recent hurricanes worldwide. The time for us to have better integrated hurricane forecasting and a response system is now, not some time in the future.

The research required to address these challenges require a transformative agenda that stimulates new directions in research including a collaborative and multi-disciplinary approach. The prediction of rapid intensity-changing hurricanes has been stagnant over the last fifteen years. We need new, truly integrated hurricane forecasting response system. This is outlined in the written testimony.

At the center of this integrated system are accurate forecasts of extreme wind, rain, storm surge, severe weather, floods, at and after landfall, and the seamless information flow from forecasts to risk assessment, emergency response, and ultimately mitigation of hurricane damage. Universities will play a critical role in building the integrated system, not only providing the basic research in science and technology but also training the next generation scientists, engineers, forecasters, and government managers with fresh knowledge of innovative tools for hurricane prediction and impact mitigation.

These young people will continue the effort to improve the system into the future. We are confident that with the requests and support, the research community will meet the scientific and engineering challenges in collaboration with the government agency. We will develop and implement such an integrated system of operations in the coming decade.

It is impossible to put a price tag on the value of such a challenging problem facing the Nation. The investment we needed to make to build the integrated system is a cost-effective approach. The request investment is dwarfed by the cost of a single disaster like in Katrina, which was more than 130 billion and unnecessary loss of life.

H.R. 2407 represents a cost-effective investment that will help prepare the Nation to deal with the future disaster like Katrina. It is overall a preventative plan for saving lives and reducing economic losses that would occur in many hurricanes we can expect in the coming decades.

In conclusion, improving hurricane forecasts and response to save lives and reduce economic losses must be a national priority. The investment in science and technology gives us an unprecedented capacity and opportunity to develop an integrated system that will support risk assessment, emergency management by reducing warning areas and providing forecasts with longer lead time. The legislation, H.R. 2407, if passed, will represent a real opportunity for the Nation to effectively meet the challenge before us.

I urge the Committee to give the highest priority to the passage of the *National Hurricane Research Initiative Act,* as this presents an excellent plan to improve hurricane forecasts that will ultimately reduce hurricane damage.

Thank you.

[The prepared statement of Dr. Chen follows:]

PREPARED STATEMENT OF SHUYI S. CHEN

Introduction

Chairman Baird, Chairman Lampson, and Members of the two Subcommittees, thank you for the opportunity to speak with you today on the need for advancing hurricane research. My name is Shuyi Chen and I am a Professor at the Rosenstiel School of Marine and Atmospheric Science at the University of Miami. It is an honor for me to testify on the *National Hurricane Research Initiative Act of 2007.*

My research and professional service have centered on understanding and improving prediction of tropical weather systems, especially hurricanes. I served as an Editor for *Weather and Forecasting* of the American Meteorological Society from 2004–2007. I currently serve on the American Geophysical Union Committee on Cloud and Precipitation and the National Science Foundation Science Steering Committee on Coastal Ocean Processes. I lead a research group at the University of Miami that has developed a next-generation high-resolution coupled atmosphere-wave-ocean model to better understand hurricane structure and intensity and to improve hurricane prediction. I am a principal investigator for two recent major hurricane research programs. One is the National Science Foundation supported Hurricane Rainbands and Intensity Change Experiment (RAINEX), which used three Doppler radar aircraft and collected unprecedented in-situ data in Hurricanes Katrina, Rita, and Ophelia during the 2005 Hurricane Season. The other is the Coupled Boundary Layer Air-Sea Transfer (CBLAST)–Hurricane sponsored by the Office of Naval Research, which aimed to better understand the role of air-sea interaction in hurricane structure and intensity change. These research results have been published in *Science*[1] and *BAMS.*[2] Currently I am a lead scientist for a large international program to study the tropical cyclones in the West Pacific.

The U.S. has become increasingly vulnerable to hurricanes, not only because of the uncertainty of hurricane response to a warming climate, but also the rapid growth of the coastal population. The averaged annual cost for hurricane-related losses has increased to more than $10 billion in recent years, not to mention the loss of life and human suffering as seen, for example, in the case of Hurricane Katrina. The devastating landfall hurricane events in 2004–2005 have led to four major national reports calling for action to substantially improve hurricane forecasts

[1] Houze, R.A., S.S. Chen, B. Smull, W.C. Lee, M. Bell, 2007: Hurricane intensity and eyewall replacement. *Science,* 315, 1235–1239.

[2] Chen, S.S., J.F. Price, W. Zhao, M.A. Donelan, and E.J. Walsh, 2007: The CBLAST–Hurricane Program and the next-generation fully coupled atmosphere-wave-ocean models for hurricane research and prediction. *Bull. Amer. Meteor. Soc.,* 88, 311–317.

(AGU,[3] NSB,[4] NSAB,[5] and OFCM[6]), particularly the rapid intensity change of hurricanes threatening the U.S. Accurate and timely forecasts and warnings can help to avoid unnecessary loss of life and reduce economic losses related to land-falling hurricanes. Recent advance in science and technology gives us hope for optimism. Meeting the challenges put forward by the NSB, AGU, NSAB and OFCM can only be accomplished through fundamental research to increase our understanding of hurricanes as an integrated science and engineering problem, and to use this understanding to improve our ability to predict hurricanes, mitigate their impacts, and react to an impending landfall.

The key to success is development of an integrated hurricane forecasting system that substantially improves upon the current 1–5 day forecasts of intensity and track, and extends it to include detailed forecasts of extreme winds, rain, storm surge, and severe weather such as tornadoes and inland flooding, which are critical for emergency response to hurricane impacts. There is also a need to extend the forecast horizon to a time scale of weeks, which requires making probabilistic forecasts of hurricane genesis, that would provide extremely valuable for emergency planning and preparedness. The bill H.R. 2407, if passed, will represent a real opportunity for the Nation to effectively meet the challenge before us. *I urge that the Subcommittees give the highest priority to the passage of the H.R. 2407, as this presents an excellent plan for improving hurricane forecasting that will ultimately reduce the damage of these dangerous storms.*

Deficiencies in the Current Forecast System

Hurricane track forecasts and warnings have improved over the past 20 years due mostly to improved computer models, global observations from satellites, and methods of assimilating many observations into models. These improvements have undoubtedly saved countless lives and billions of dollars in property damage. However, hurricane intensity forecasts have shown little improvement. The lack of skill in present forecasts of hurricane structure and intensity, especially rapid intensity change, are attributed in part to deficiencies in the current prediction models: insufficient grid resolution, inaccurate model physics, lack of full coupling to a dynamic ocean, and inadequate observations and data assimilation of hurricane structures.

Current operational forecast models are not adequate for predicting hurricane wind and rain structure and intensity change, as highlighted by the report of the NOAA SAB Hurricane Intensity Research Working Group. Recent research results[2] Chen et al. (2007) have demonstrated the impact of increasing model grid resolutions on forecasting of hurricane structure and intensity change (Fig. 1). Clearly the lower resolution models are incapable of predicting critical details in the hurricane core region controlling the rapid intensification of a hurricane. A research experiment carried out during RAINEX in Hurricane Katrina (Fig. 2) shows the potential capability of high-resolution models in forecasting rapid intensification. The required computer power increases by 5–10 times for each halving of the grid spacing, so this requires a substantial investment in high performance computing. Moving to high resolution also requires an investment in research to further our understanding and our ability of reproducing in forecast models the manner by which air-sea interactions and cloud development are incorporated. Improvement in computer models, high performance computers, innovative observations and data assimilation of the hurricane structure will have to be achieved in concert to guarantee substantive progress in predicting hurricane intensity change.

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[3] American Geophysical Union, 2006: *Hurricanes and the U.S. Gulf Coast: Science and Sustainable Rebuilding. www.agu.org/report/hurricanes/.*

[4] NOAA Science Advisory Board, 2006: *Majority Report, Hurricane Intensity Research Working Group, www.sab.noaa.gov/Reports/HIRWG_final73.pdf*

[5] National Science Board, 2007: *Hurricane Warning: The Critical Need for a National Hurricane Research Initiative.* National Science Foundation, Arlington, Virginia, *www.nsf.gov/nsb*, 36 pp.

[6] Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2007: *Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead,* FCM–P36–2007. Silver Spring, Maryland, www.ofcm.gov/p36-isrtc/pdf/entire_*p36_2007.pdf*

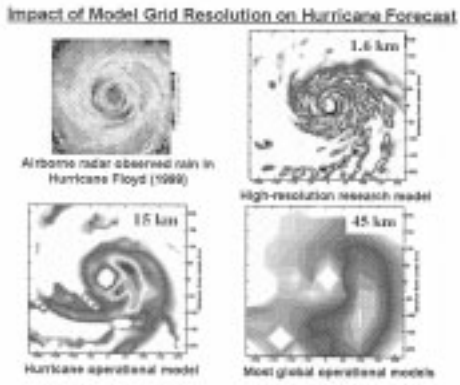

Figure 1. The top left is a radar observation for Hurricane Floyd (1999). The other panels (in clockwise order) are forecast precipitation patterns obtained from a high-resolution (1.6 km) research model, from the typical resolution used by current hurricane models (15 km), and from current global operational models (45 km). The top right-hand corner of each panel shows the scale of the model grids relative to the hurricane.

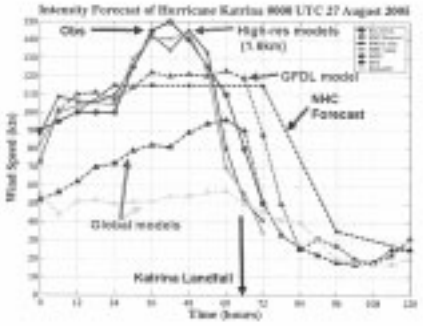

Figure 2. Observed storm intensity (the best track in black), the NHC official forecast made ~70 hr before landfall (dashed black line), and forecast made by computer models with various grid resolutions. Vertical axis is max wind speed and horizontal is time in hours. Current operational global models have no skill, the best current operational hurricane model by the GFDL (magenta) did not capture the rapid intensification, and two high-resolution research models (WRF and MM5 with 1.6 km grid spacing, brown and red) were able to forecast the rapid intensification.

The Next-Generation Hurricane Forecast System

A key to improving forecast of hurricane intensity and landfall impact is to develop computer models that are capable of resolving the inner core structures (eye and eyewall) and rainbands in a hurricane and realistically representing the physical processes governing rapid intensity change, such as the transfer of heat, moisture, and momentum at the air-sea interface and the phase changes of water vapor in the atmosphere. The next-generation prediction models must be able to resolve features on a horizontal scale of ~1 km or less to capture the gradients across the eyewall boundaries and the interactions between the inner core and rainbands. Furthermore, the intensification and decay of a hurricane largely depends upon two competing processes at the air-sea interface: 1) the heat and moisture fluxes that fuel the storm and 2) the dissipation of kinetic energy associated with wind stress on the ocean surface. Figure 3 shows an example of the high-resolution coupled models developed at the University of Miami in collaboration with NCAR capable of capturing the detailed structure of rain, wind, ocean surface waves, sea surface temperature and currents. These detailed forecast fields can bridge the gap between the traditional forecast of track and intensity and realistic hurricane impacts at landfall.

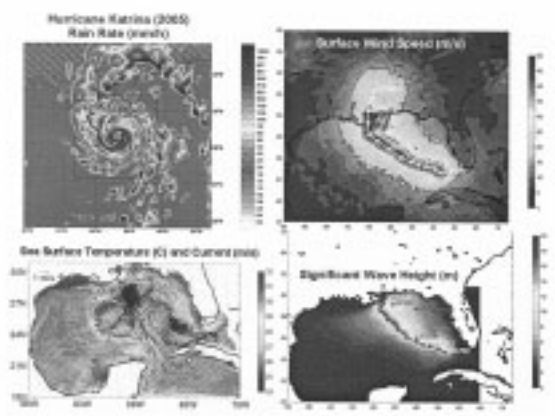

Figure 3. High-resolution coupled forecast of rain rate (top-left), surface wind speed (top-right), sea surface temperature and ocean current (bottom-left), and significant wave height (bottom-right) in Hurricane Katrina from 0000 UTC 27 Aug – 0000 UTC 30 Aug 2005.

Furthermore, the success of forecasting hurricane intensity change will depend on the ability of assimilating new observations and ensemble-based probabilistic forecasts using the high-resolution atmosphere-wave-ocean coupled models. A better understanding of the predictability of fine scale features in the extreme wind and rain fields associated with hurricanes is also critical. The NSB report and the H.R. 2407 Section 3 have highlighted these urgent needs as high-priority for the research community to address.

A further issue in increasing the fidelity of hurricane intensity and track forecasts, especially for increasing the forecast horizon beyond five days, is improved global weather predication models that provide the large-scale forcing for the high resolution storm-scale forecasts. The resolution and number of ensemble members of the NOAA NCEP Global Forecasting System are significantly lower than that of the European Centre for Medium Range Weather Forecasting (ECMWF). The higher resolution ECMWF model is being used as the basis for extended range hurricane forecasting, and the synergy of the higher resolution global weather model having a large number of ensemble members with the high-resolution coupled atmosphere-wave-ocean storm-scale model provides the foundation for a substantially improved hurricane forecasting system with improved accuracy, more specific information regarding impacts, and an extended time horizon for the forecasts.

An Integrated Approach for Improving Hurricane Forecast and Emergency Response

To improve preparedness in response to hurricane impacts, a new integrated approach in hurricane forecasting and warning is sorely needed. This system should be capable of:

- Providing accurate forecast of high-resolution wind, storm surge, rain, and flood on the short lead time of days to hours, and potential hurricane genesis and track on extended lead time of weeks;
- Assessing potential hurricane impacts on human lives (fatalities and suffering) and broad-range economy loss (property and infrastructure damage, power outage, insured losses) based on the forecast of wind, surge, rain, and flood;
- Communicating with federal and local government to optimize the utility of the forecast and assessment products in emergency response;
- Rapidly transferring research products to NOAA and other operations;
- Training the next-generation scientists and forecasters with innovative tools for hurricane prediction and impact mitigation;
- Educating vulnerable residents on the application value of the new information coming out of the integrated forecast system on short and long lead times.

The ultimate goal of this integrated system is to improve risk assessment and mitigation over the U.S. coastal regions so lives will be saved and economic loss reduced.

Conclusion

The research required to address these challenges requires an ambitious, transformative and risky research agenda that stimulates new directions and styles of inquiry in research including collaborative, cross-disciplinary and interdisciplinary approaches. New centers and partnerships between university researchers, government agencies and the private sector are needed to meet these challenges. The academic hurricane research community is ready to lead an ambitious and transformative interdisciplinary research agenda required to lay the foundations for development of an integrated hurricane forecast and response system that will help mitigate hurricane damage. The envisioned research agenda will advance our ability to collect accurate observations from the atmosphere, air-sea interface, and the ocean and to assimilate such observations for hurricane forecasting, to improve prediction models, to use forecast products for better risk assessment, and ultimately to mitigate hurricane damage. There is critical need for the involvement of the NSF to support the ambitious and risky interdisciplinary research agenda, in ways that go beyond what is feasible in individual mission oriented government agencies. The development and operation of such an integrated hurricane forecast and response system requires collaboration and coordination among many research disciplines and among the research community and government and impacted sectors. Further, successful implementation of such a system requires the education of a new generation of scientists, technicians, forecasters, government managers, and be guaranteed with a smooth transition from research to NOAA operations.

In closing, it is of no doubt that improving the hurricane forecast and response to save lives and reduce economic loss should be a national priority. The rapid advancement of science and technology presents us with an unprecedented capability and opportunity to develop the integrated hurricane forecast and response system that will support risk assessments and emergency management by reducing warning areas and providing forecasts with longer lead time. There is no reason for further delay of full-scale support for such development, which is long over due. We are confident that with the requested fiscal support the hurricane research community will meet the scientific and engineering challenges and in collaboration with the relevant government agencies will develop and implement such an integrated hurricane forecast and response system for operations in the coming decade.

BIOGRAPHY FOR SHUYI S. CHEN

Shuyi S. Chen is a Professor of Meteorology and Physical Oceanography at the Rosenthal School of Marine and Atmospheric Science (RSMAS) of the University of Miami (UM). Professor Chen is a widely published author whose research interests include tropical weather systems and hurricanes, air-sea interactions, high-resolution coupled atmosphere-wave-ocean modeling of tropical cyclones, and numerical weather prediction. She served as an Editor for *Weather and Forecasting* of the American Meteorological Society and currently serves on a number of science committees on atmospheric and ocean processes including the AGU and NSF. Professor Chen leads a research group at RSMAS/UM that has developed a high-resolution, fully coupled atmosphere-wave-ocean, vortex-following, nested-grids model for hurricane research and prediction. These efforts contribute directly to the development of the next-generation hurricane forecasting modeling systems. Professor Chen is a lead scientist and principle investigator for the Coupled Boundary Layer Air-Sea Transfer (CBLAST)–Hurricane modeling team sponsored by the Office of Naval Research, which is one of the first comprehensive research programs to study the impacts of ocean surface waves, sea surface temperature and upper ocean circulation on hurricane intensity changes. She is also a principal investigator for the National Science Foundation supported Hurricane Rainbands and Intensity Change Experiment (RAINEX), which used three Doppler radar aircraft and collected unprecedented in-situ data in Hurricanes Katrina, Rita, and Ophelia during the 2005 Hurricane Season. Currently she is a lead scientist of a large international program to study the tropical cyclones in the West Pacific. Her research has received broad national and international recognition. She has given many invited lectures on hurricanes and was invited by the National Academy of Engineering as a Keynote Speaker at the Indo-U.S. Frontiers Symposium in 2006 and was a Keynote Speak at the First U.S.–China Symposium on Meteorology in 2008. In 2006, Professor Chen was awarded the NASA Group Achievement Award. Professor Chen served on a panel of experts for the Congressional Staff Briefing on *"A National Hurricane Research Initiative: Meeting Society's Needs"* at the U.S. House and Senate in July 2007. Dr. Chen received her Ph.D. in Meteorology from the Pennsylvania State University in 1990.

Chairman LAMPSON. Thank you, Dr. Chen.

Dr. Prevatt, you are recognized for five minutes.

STATEMENT OF DR. DAVID O. PREVATT, ASSISTANT PROFESSOR, DEPARTMENT OF CIVIL AND COASTAL ENGINEERING, UNIVERSITY OF FLORIDA, GAINESVILLE

Dr. PREVATT. Chairman Baird, Chairman Lampson, and honorable Subcommittee Members, my name is David Prevatt, and I am a Professional Engineer and Assistant Professor of Civil and Coastal Engineering at the University of Florida. I appreciate, really truly appreciate the opportunity to speak to you on this bill.

Your own bipartisan support for this bill, the collective voice from the State of Florida Representatives, underscores the importance that hurricane mitigation plays in our lives in that State. Increasing national support for hurricane research is of critical importance if we are to reduce the enormous economic losses from hurricanes.

Funding for research to address damage to buildings and infrastructure, which by far dominates the economic impact of hurricanes, is under-represented in the current budget, as it has been for decades. In my testimony I have suggested several categories in this bill that probably should be considered for reprioritization.

Preparation for hurricanes. This begins long before landfall, long before the 24-hour window. It begins when we first construct our buildings. It begins when we first retrofit the existing infrastructure we have today. Nearly 40 years ago the National Bureau of Standards reporting on Hurricane Camille damage noted that most failures in rural homes were to roofs and that proper anchorage was non-existent. That same concern was voiced by me and by others after Hurricanes Francis, Charlie, Ivan in 2004, Wilma in 2005, and Katrina.

Sadly, ladies and gentlemen, the situation is not much different now than it was in 1969, with regard to hurricane resistance of buildings and our infrastructure. The fact is nearly 90 percent of all homes, those built before 1994 building code changes, have inadequate connections, and they risk significant damage from hurricanes.

Therefore, there is an urgent need to harden those homes to reduce hurricane losses. And currently we must address how to ensure the adequate performance of future homes. These are the issues which really reduce the economic loss and the disruption to people. Consequently, the highest priority, I believe, should be placed on reducing the damage and minimizing economic losses.

Some of the issues that should be at the forefront of the research agenda to reduce wind damage to buildings and storm surge damage to buildings and infrastructure. One, a need to improve our knowledge of the special variability of surface level winds that impact buildings, a need to understand how a hurricane is attenuated as it makes landfall, a better understanding of how and at what loads do our existing buildings fail, and how can we really apply this knowledge to the new construction coming on-board.

We need an intense program to study the ways of identifying weaknesses in this existing infrastructure and ways to provide practical retrofit techniques to ameliorate these problems.

Further, we need to quantitatively understand the storm surge and wave loading on coastal structures, on bridges, and how coastal structures also respond to these loads.

And finally, a need for robust support of academic infrastructure that generates basic science and technology research and provides increased availability of trained faculty and researchers and trained engineers to implement these improved practices.

While the loss of life in hurricanes has dropped dramatically over the past decades due to improved warning and forecasting, the amount of damage, the amount of economic loss—it continues to spiral upward at an exponential rate. This trend is projected to continue as more properties, more wealth is concentrated in the vulnerable coastal areas that we have heard about today.

It is only through mitigation that we have any hope of reducing the increases, much less begin to reduce the losses when major events occur.

Strong consideration should be given to increasing support for severely under-funded areas, i.e., the performance of buildings and infrastructure under hurricane loads. In this way we will see the most immediate, tangible benefits from our increased research and infrastructure improvement.

I believe improved forecasting by itself will not have a significant impact on loss reduction, however, we develop cost-effective ways to harden the 80 to 90 percent of homes built before recent code improvements, our widespread vulnerability will remain.

Investing in creation of new knowledge and in more-effective ways of using the existing knowledge that we have is the only way to change current trends. Improving the resilience of civil infrastructure and houses can significantly reduce economic losses of hurricanes. I admit, many unanswered questions remain regarding the construction of new facilities, and the problems of existing construction has hardly begun to be addressed. However, a sustainable, federally-supported long-term research program in this area envisioned by this bill and others can, indeed, make a difference.

[The prepared statement of Dr. Prevatt follows:]

PREPARED STATEMENT OF DAVID O. PREVATT

1. INTRODUCTION

Chairman Baird and Chairman Lampson and Honorable Subcommittee Members, my name is David Prevatt, and I am a professional engineer and Assistant Professor of Civil and Coastal Engineering at the University of Florida. The faculty of the Department of Civil and Coastal Engineering (CCE) is very active in multiple aspects of hurricane hazards research and the design of hazard resistant infrastructure. Our research focuses on understanding the hurricane effects (wind, rain, storm surge) on buildings and infrastructure in hurricane-prone coastal regions in order to increase their resilience. Our combined expertise includes:

- Building and infrastructure design against surge and wind hazards
- In-field measurement and characterization of hurricane winds and wind loads
- Evaluation of structural capacity to resist wind loads and the efficacy of retrofits
- Prediction and modeling of storm surge, wave, and coastal flooding
- Remote sensing of high resolution ground elevation and bathymetry (ocean depth contours)
- Lifeline protection and restoration
- Transportation issues for emergency evacuation
- High performance computing and data warehousing/mining.

It is clear that there are several common areas of interest for H.R. 2407 and the wind and civil engineering research community. I applaud this increased emphasis on understanding and predicting the nature and impact of hurricanes. However, the proposed research efforts, while they address important goals, do not do much to reduce the damage or economic losses from hurricanes. Funding for research to address damage to buildings and civil infrastructure, which by far dominates the economic impact of hurricanes, is under-represented in the current budget. We believe emphasis of several categories in this bill and the National Science Board (NSB) report of 2007 should be re-prioritized.

1.1 Background

Nearly 40 years ago, the National Bureau of Standards reporting on Hurricane Camille damage noted that the most common failure in homes was to roofs and that proper anchorage was non-existent. These same concerns have repeatedly been voiced by researchers over the ensuing years (Table 1), who also noted recurring widespread structural damage due to loss of roof sheathing, failure of load transfer at joints and connections. Sadly, the situation today is not much different, wherein roof failures and improper anchorage still account for the majority of building damage from hurricanes.

Table 1: Main finding and recommendation of various hurricanes over the years

Hurricane/ Year	Main Finding/ Recommendation	Report
Camille (1969)	• Most common failures were roofs. • "... proper anchorage....."	(Dikkers et al. 1970)
Alicia (1983)	• Most structural damage was due to loss of roof sheathing. • "Total collapse of timber-framed houses was a common scene."	(Kareem 1985)
Gilbert (1988)	• Most of the damage due to anchorage deficiencies • Continuous load path is needed	(Adams 1989; Allen 1989)
Hugo (1989)	• Roof loss with subsequent collapse of walls. • Most damage was roof and wall cladding failures resulting in extensive rain damage.	(Sparks 1990)
Andrew (1992)	• Excessive negative pressure and/or induced internal pressure • Correct methods for load transfer are needed	(FEMA 1992)
Iniki (1992)	• Overload on roof systems due to uplift forces. • Load path must be continuous from the roof to the foundation.	(FEMA 1993)
Georges (1998)	• Tile shingle damage resulted in extensive water penetration and subsequent damage.	(FEMA 1999)
Charley (2004)	• High internal pressure due to window failure was the major cause of roof loss. • Load path needs to be continuous.	(FEMA 2005a; FEMA 2005c)
Ivan (2004)	• Structural damage was due to sheathing loss. • ....ensure a complete load path for uplift loads.	(FEMA 2005b; FEMA 2005c)
Katrina (2005)	• Structural failures limited to roof sheathing loss & roof-to-wall connection failure. • A continuous load path must be present.	(FEMA 2006)

It is estimated that 50 percent of the U.S. population now lives in hurricane prone coastal areas (Alvarez 2000). Hundreds of miles of once empty coastlines are now major population centers with trillions of dollars of buildings and infrastructure exposed to the risk of hurricane damage. The vast majority of residential structures (over 80 percent) in these areas were constructed before recent improvements to building codes that occurred after Hurricane Andrew. Therefore there is an urgent need to harden those homes to reduce annual hurricane losses. It must be recognized that hurricanes are just one of the several sources of damage and loss due to extreme winds and that tornadoes, down-bursts and frontal winds also contribute to large annual losses that could be reduced through better connections and development of continuous load paths.

Civil engineers and particularly wind engineers are critically aware of factors contributing to high failure rates of buildings and infrastructure and we have been intimately involved in the effort to improve the knowledge base to reduce hurricane impacts. Indeed many of us have previously testified before Congressional Subcommittees (Bienkiewicz 2004; Levitan 2005; Prevatt 2005; Reinhold 2005) and our members have supported related legislation H.R. 3940, the *National Windstorm Impact Reduction Act of 2004*.

Hurricanes, tornadoes, thunderstorms, and associated phenomena cause an excessive level of property losses and human suffering in the United States. With the exception of Hurricane Katrina, loss of life has been significantly reduced through warnings about hurricanes and the loss of life in tornadoes and other extreme wind events typically average less than 100 per year. Consequently, the highest national

priority should be placed on reducing the damage and minimizing economic loss. With the exception of strengthening building codes in some hurricane prone regions, our success in reducing losses has been poor over the past 40 years. This is due in large part to the limited research and technology transfer support that is focused on strengthening the existing built infrastructure and in the development of cost effective retrofit and mitigation measures.

1.2 Effects of Recent Hurricanes on Buildings and Infrastructure

The 2004 and 2005 hurricane seasons were a real-time laboratory for evaluating the performance of our buildings. Several of our faculty were deployed during the storms and collected perishable damage data immediately after the events. There were several areas of concern regarding performance of buildings and infrastructure:

- Small breaches in the building envelope, especially in the roofing systems, can provide paths for water leakage that result in extensive water damage to the interior walls, ceilings, and to building contents. Minor roofing failures (loss of asphalt shingle and underlayment) to one Pensacola house resulted in water damage to about 80 percent of all interior finishes on the ceiling and walls. The cost of drying out water-soaked buildings and removal of mold has been a growth industry since these hurricanes. Less durable materials, insulation, gypsum sheathing and acoustic ceiling tiles cannot be dried out and must be removed and replaced. The gutting of houses and businesses contributes tons of debris and toxic substances to our landfills.
- Numerous engineered buildings suffered little damage, and retrofitted non-engineered houses also performed satisfactorily. In Charley, a major success story was the good to excellent performance of newer manufactured homes that were built in accordance with 1994 HUD guidelines. Most of these survived with minimal damage, while adjacent older manufactured homes that did not have wind-resistant construction were destroyed.
- Failure of building envelope systems caused significant disruption to hospitals and critical facilities during these storms. From Mobile, AL to Ft. Myers, FL, more than a dozen hospitals were damaged or were evacuated due to the 2004 hurricanes. Charlotte Regional Hospital in Port Charlotte and the Navy Hospital in Pensacola both sustained damage to their roofing systems, and windows. One hospital damaged in Hurricane Frances in 2004, suffered further damage as Hurricane Jeanne passed through the area just three weeks later.
- Several fire stations and hurricane evacuation shelters were not able to maintain function throughout or after the storms. The Turner-Arcadia Civic Center in Central Florida suffered a masonry wall and roof collapse while sheltering 1,200 persons from Hurricane Charley.

These poor and variable performances are examples of a larger problem related to buildings and infrastructure.

1.3 Research Priorities to Improve the Resilience of Structures

Specifically some of the factors that are important to reducing loss and wind damage to buildings and infrastructure are:

- A need to improve our knowledge of surface level winds and their spatial variability during extreme wind events.
- A need to better understand the potential loadings on structures through a comprehensive program of boundary layer wind tunnel testing and validation using field observations.
- A better understanding of how and at what level of loading existing structures fail and the application of this knowledge to new construction.
- An intense program to study various ways of identifying weaknesses in existing infrastructure and practical retrofit techniques to ameliorate these problems.
- Comprehensive testing of full scale structures to learn how to economically improve wind and hazard resistant construction and associated water penetration and damage.
- A need to improve the techniques to assess the economic impacts of different design decisions for both new and retrofit applications.
- A need to quantitatively understand the surge and wave loading on coastal structures and how the coastal structures respond to loading.

- A need for a new robustness in the supporting academic infrastructure to generate improved basic supporting science and technology, to improve the availability of trained new university faculty/researchers, and trained engineers to implement improved practices and planning.

In this era of limited funds, it is necessary to set realistic expectations and to give priority to initiatives that have the greatest chance of reducing the hurricane impact. Consideration should also be given to increasing support for the most severely under-funded areas, that of civil infrastructure. In their comment on the draft NSB report, the Weather Coalition stated that *"Hurricanes are complex and violent systems. Even the best research initiative will only improve forecasts, not perfect them."* However, the focus should be to improve performance of buildings and infrastructure, and we will see the most immediate and tangible benefits from increased research on infrastructure improvement. Improved forecasts will not have a significant impact on loss reduction.

2. COMMENTS ON NATIONAL SCIENCE BOARD 2007 REPORT

The University of Florida faculty experts in hurricane winds and storm surge recommend changes to the proposed budget distribution, as well as a re-prioritizing of subjects within the three investment categories. Comments and suggestions are delineated below by the following subsections of the NSB document: investment category, recommendations, and appendix.

The purposes of the National Hurricane Research Initiative shall be to set research objectives based upon the findings of the January 12, 2007, National Science Board report entitled *Hurricane Warning: The Critical Need for the National Hurricane Research Initiative,* to make recommendations to the NSB and NOAA science Advisory Board and to assemble expertise and pursue multi-entity research in three areas:

1. improving hurricane and other severe tropical storm forecasting capabilities, including formation, track, and intensity change
2. durable and resilient infrastructure; and
3. mitigating impacts on coastal populations, the coastal built environment, and the natural coastal environment, including but not limited to, coral reefs, wetlands, and other natural systems that mitigate hurricane wind and storm surge impacts.

For the sake of clarity, the comments below follow the structure of the NSB report. General comments are provided on the overall document, followed by comments on specific sections in the report and delineated herein.

2.1 General Comments on the NSB Report

The NSB Report identifies for Investment categories (#1, Understanding and Prediction, #2, Impacts, #3 Preparedness and Response Measures, and #4 Cross-cutting Activities), and it provides recommendations for action and budget of approximately $300 million. H.R. 2407 proposes that $285 million be authorized for this effort for each of the fiscal years 2008 through 2018.

We recommend that a working group be assigned with direct links among the four investment categories, so that R&D will not be performed independently, but that resources be assigned to address those issues that can be shown to have the most significant impact.

We recommend that the initiative be developed within a defined interagency group, comprising of NSF, NOAA, FEMA and NIST.

Appendix C: Proposed Strategic Investment in the National Hurricane Research Initiative—pg. 29

Problem: Funding to address damage to civil infrastructure, which by far dominates the economic impact of hurricanes, is under-represented in the current budget. Given the weighting of expertise represented on the NSB panel (only 10 out 55 panel members were civil engineers), this priority received less attention than warranted. Consequently, the proposed NHRI budget is directed to already heavily funded NSF programs, while research areas that represent the highest potential gains in risk reduction are not well funded.

We recommend that funding support the core high-priority research areas that are currently most severely under-funded.

We recommend against redistributing NHRI funding to already heavily funded NSF programs, such as cyberinfrastructure ($492M in FY 2005), networking and information technology R&D ($811M in FY 2005) and climate change ($197M in FY 2005). Rather, an increase in the current (and very modest) annual expenditures on engineering and the built environment would provide far greater immediate benefit, given the dominance of infrastructure damage on economic loss. The table below reflects our suggested reprioritizing of strategic investments.

NHRI Research Program	NSB Report ($millions per year)	Modification ($millions per year)
Power, Communications and Remote Access Systems	$60 →	$30
Structure and Behavior of Hurricanes	$40 →	$60
Engineering and the Built-Environment	$40 →	$60
Risk Assessment, Communication and Response	$20	
Biological and Ecosystem Dynamics	$20 →	$10
Economic and Societal Impacts	$20	

Investment Category #1: Understanding and Prediction, pages 13–15

HIGH PRIORITY: Predicting hurricane intensification and size, and reducing the uncertainty associated with where and when hurricanes will make landfall—pg. 13

Problem: Existing hurricane models do not have adequate parameterization to represent the dissipation effects of land on hurricanes.

We recommend that an additional HIGH PRIORITY item be established to focus research to understand the effect of land roughness on hurricane intensity decay.

HIGH PRIORITY: predicting storm surge, rainfall and inland flooding from hurricanes and tropical storms—pg. 13

Problem: One key to limiting the loss of life in both coastal and inland flooding is having high resolution topographic maps with sufficient spatial resolution to identify where constricted flow is likely to cause flash flooding. The U.S. is well behind when it comes to producing high quality, one foot contour topographic maps. During the past decade many European nations have used airborne laser swath mapping (ALSM, also known as LiDAR) and ground based laser scanning to map their entire nations. In the U.S. only a few states have launched programs to obtain high resolution digital terrain maps and contour maps suitable for comprehensive flood planning, using airborne and ground based laser scanning. The U.S. should have digital elevation models adequate to support one foot contour maps across the Nation. The highest priority should be given to areas at risk for flash floods. The combination of airborne and ground based laser scanning is the method of choice for collecting the necessary observations.

Suggestion #1: Emphasize the importance of high resolution topographic maps to predict both coastal and inland flooding and limit loss of life and economic loss.

Suggestion #2: Research is needed to fully understand and predict the effect of waves on storm surge, coastal inundation, and loading on coastal infrastructures, including houses, bridges, levees, and power plants. Wave loading is much more destructive for coastal infrastructures than storm surge alone.

Suggestion #3: For more accurate and cost effective mitigation and evacuation planning, high resolution street-level forecasts are needed. Current hurricane and storm surge forecasts by the U.S. Government have much lower spatial resolution (hundreds of meters) than the LiDAR data. Street-level forecasts are needed to enable more accurate and cost-effective mitigation and evacuation planning. To enable street-level forecasts, it is more prudent to adopt more efficient forecast models than to increase computational capability.

Suggestion #4: Research is needed to fully understand the flow-structure interaction during hurricanes. Storm surge and coastal flooding is strongly affected by such manmade or natural structures as levees, wetlands, marshes, coral reefs, and beach dunes.

HIGH PRIORITY: Improved in situ observations—pg. 13

Problem: Direct measurement of the hurricane is a necessary underpinning of virtually every other investment category enumerated in this document. Prevention of infrastructure damage to winds must be based upon detailed knowledge of dynamic wind loads, which can only be gathered via direct measurement. A historical dearth of direct observation of ground level wind speeds during landfalling hurricanes is among the biggest obstacles in the design against extreme wind loads. Additionally, all remote sensing is ultimately dependent upon direct measurement for refinement, validation and calibration.

Suggestion: Emphasize the importance of observations of data at surface level winds and its interactions (pressure generation) on structures.

Investment Category #2: Impacts and Interactions, pages 15–16

HIGH PRIORITY: Interaction of hurricanes with engineered structures—pg. 15

Problem: Current codes (except for perhaps earthquake effects) do not adequately incorporate dynamic loading (e.g., wind, vessel impact, surge, waves) for foundation/soil interaction or foundation/water interaction for cyclic or surge loading. We have the system characterization capabilities, and the mechanics/computational abilities to account for dynamics, but we sorely lack experimental research to calibrate and validate our analysis systems, particularly at full-scale. With the advent of Network for Earthquake Engineering Simulation (NEES) at NSF, we now have the experimental equipment capable of full-scale experiments. We now need the funding to pursue this research.

Suggestion #1: Add an additional HIGH PRIORITY item that addresses the need for full-scale experimentation to capture the effects of dynamic wind/rain/surge loads on the infrastructure, which as of today is poorly incorporated in building codes. Current practice focuses on the performance of individual components in isolation, but the most often observed failures are a result of interaction among multiple components (system response). We sorely lack research to evaluate system performance issues via full-scale experiment.

Suggestion #2: Add an additional HIGH PRIORITY item that addresses retrofitting of existing structures. Retrofitting of critical infrastructure in hurricane prone regions is urgently needed to protect the public and life-line services. Ninety percent of existing residential homes were built before building code improvement modifications that occurred after Hurricane Andrew. As with earthquake prone regions, retrofitting of existing structures will result in lower damage and fewer lives lost. This, combined with a tightening of the existing building codes, should be a substantial emphasis.

Problem: Recent hurricane seasons have clearly demonstrated that highway bridges which are key components of infrastructure lifelines, at risk of failure due to the combined effects of wind, storm surge, and vessel impact loading. During Hurricanes Ivan (2004) and Katrina (2005), major interstate bridges along critical lifelines were destroyed by storm surge loading. Additionally, Hurricane Katrina demonstrated that barges, ships, and floating structures such as drill rigs, can break loose during storms and collide with bridge structures and levee walls, thus generating significant impact loads and damage.

Suggestion #3: As with earthquake prone regions, retrofitting of critical infrastructure in hurricane prone regions is urgently needed to protect the public and lifeline services. This should be addressed in the draft.

Suggestion #4: Development of procedures for evaluating (both pre- and post-event), and improving, the resistance of infrastructure components under the combined effects of wind, storm surge, and vessel impact needs to be a high priority item. The approach taken must account not only for structural aspects of bridge performance under these conditions, but also the statistical probabilities that such combined multi-hazard loading conditions occur simultaneously.

Investment Category #3: Preparedness and Response Measures, pages 16–18

HIGH PRIORITY: assessing and improving the resilience of the built environment—pg. 16

Problem: The massive economic impact of hurricanes is in many ways a direct result of engineering designs mandated by building codes. For a large majority of the existing infrastructure, extreme events associated with hurricanes (e.g., wind & wave loading, tidal surges, bridge scour, etc.) are simply a secondary consideration. For example, current bridge design specifications only address wind induced forces,

with no recognition of wave loading, even when more than 15 bridges were lost from waves/surge during Katrina. In addition, much of the existing infrastructure involving geotechnical related issues (i.e., levees, dams, bridge foundations, etc.), were designed using the "allowable stress" procedure that incorporates a global factor of safety. However, no consideration for the degree of risk or probability of failure of said systems has ever been undertaken. Moreover, even though some of the newer codes are moving towards incorporating risk assessment, i.e., (Load and Resistance Factor Design (LRFD), with associated load and resistance factors developed through research, the majority of geotechnical infrastructure (dams, levees, building foundations, etc.) load and resistance factors have never been established.

Suggestion: Emphasis needs to be placed on research toward the efficacy of the current design practice in light of recent infrastructure failures. The NSB report calls for the investigation of damage due to non-compliance, *but the majority of damage is clearly the result of adequate compliance with inadequate codes.*

HIGH PRIORITY: Disaster response and recovery—pg. 17

Problem: Getting victims out of and relief services into an affected area is critically dependent on the condition of the roadway network in the area. Aerial based technologies need to be developed and/or evaluated for their ability to provide a survey of critical roadway infrastructure items (e.g., passable roads, navigational signage condition, and status of traffic control devices). This information can be used with Geographic Information Systems to develop usable transportation routes into and out of the area.

Suggestion: A prioritization of critical links in the highway system should be developed, based on anticipated origin-destinations in disaster response conditions (for example, to and from shelters, hospitals, etc.)

Investment Category #4: Cross-Cutting Activities

MEDIUM PRIORITY: Computational Capability—pg. 18

Problem: With the well-recognized scarcity of funding, it is not prudent to divert funds to well-funded and generic research that will advance full-force with no funding from a hurricane mitigation-specific program. This is an important but not well-funded item.

We recommend removal of this priority item: Computational capability is an important, but is already well-funded through existing programs.

MEDIUM PRIORITY: Training and education programs related to hurricane impacts—pg. 18

Problem: Education and training already receives $844M annually from NSF. This falls under the category of "important but heavily funded elsewhere.

Suggestion: Remove or de-emphasize the funding for this priority.

General Implementing Recommendations, pages 19–21

Leadership—pg. 20

Problem: Although considerable progress has been made on arriving at improved loading standards and on some methods of improving constructed facilities many of these improvements are based on an existing information base that is over 30 years old. Unfortunately support for these efforts has not continued at a level that encourages basic research. What is needed now is new research capabilities to supplement current efforts and generate fundamental knowledge from which next generation buildings and retrofit techniques can emerge. The emphasis of these activities resides in understanding buildings and infrastructure.

Suggestion: Designate the National Science Foundation as the custodian for all funding. This research belongs in the hands of the federal agency primarily tasked to supported basic research conducted by our colleges and universities. Operational agencies (meaning those organizations responsible for exploration, prediction, monitoring, response, and recovery) should carry a supporting role, but not share parallel responsibilities.

Maintaining dialogue with the broad community—pg. 20

Problem: Progress will be made by engaging all stakeholders responsible for construction and retrofit of buildings and infrastructure, including legislative bodies, academic researchers, and building professionals.

Suggestion: Use conferences already in existence. Stage the meetings/presentations from the annual Interdepartmental Hurricane Conference held by the Office of the Federal Coordinator of Meteorology. It is the most reputable and well-attended by government stakeholders.

Suggestion: The panel is recommended to seek input from civil engineers through the existing associations who work to protect buildings and infrastructure from hurricanes. We recommend that the American Association for Wind Engineering and the American Society of Civil Engineers be consulted within the process, since those organizations combined nearly a decade ago to initiate the initial legislation that will expire in November 2008.

3. SUMMARY

The cost of hurricanes is something that we bear as a society. The losses and disruptions have profound and widespread impacts to the social structure of communities and to the ecological systems upon which we depend. While the loss of life in hurricanes has dropped over the past decades due to improved warning and forecasting, the amount of damage and economic loss continues to spiral upward at an exponential rate. This trend is projected to continue upward as more properties and wealth are concentrated in vulnerable coastal areas. It is only through mitigation that we have any hope of reducing the increases much less begin to reduce losses when major events occur.

Investing in the creation of new knowledge and in more effective ways of using existing knowledge is the only way to change the current trends. The research to improve the resilience of civil infrastructure and houses can significantly reduce the enormous economic costs of hurricanes. Many unanswered questions regarding the design and construction of new facilities remain, and the problems of existing construction have hardly been addressed. However, a sustainable, federally-supported, long-term research program can indeed make the difference.

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BIOGRAPHY FOR DAVID O. PREVATT

Born in Nassau, Bahamas and growing up in Trinidad and Tobago, Dr. David O. Prevatt has lived in hurricane-prone regions for most of his life. In 1985, Prevatt graduated from the University of the West Indies (UWI), Trinidad with a BSc (Honours) degree in Civil Engineering. He worked as a structural engineer in Trinidad until 1990 when he joined an IDRC-funded research project on Caribbean Cyclone-Resistant Housing at UWI's Civil Engineering Department. Prevatt came to the United States in 1993 to pursue his Ph.D. at Clemson University, working at the Wind Load Test Facility. His research on evaluating the wind uplift capacity of various mechanically attached commercial roofing systems sought to assess the validity of industry-standard test methods and compare these with roof behavior subject to true spatial and temporally varying wind loads. After earning his Ph.D. in 1998, Dr. Prevatt worked as structural engineer with the Boston-based ENR500 consulting engineering firm, Simpson Gumpertz & Heger Inc., from 1998 through 2004, concentrating in the design, performance and investigation of building enclosure systems. His expertise is in structural engineering, wind engineering and the performance of building envelope systems, and forensic engineering. Dr. Prevatt is a professional engineer registered in the Commonwealth of Massachusetts and in Trinidad and Tobago with over 15 years consulting experience in structural engineering and building investigations.

In May 2007, Dr. Prevatt joined the faculty at the University of Florida as an Assistant Professor in the Department of Civil and Coastal Engineering. Dr. Prevatt's research continues to focus on the mitigation of hurricane damage, particularly to low-rise construction. His current research involves experimental investigation and analytical modeling of the structural load paths in wood-framed structures, and the wind uplift testing of building cladding components. Prior to this appointment, Dr. Prevatt was on the faculty of Clemson University where he was an Assistant Professor and served as Director of the Wind Load Test Facility, conducting wind engineering research using a boundary layer wind tunnel to quantify wind loading on residential structures, to compare and validate field wind pressures collected during the 2004/2005 hurricanes. Dr. Prevatt is a member of the American Society of Civil Engineers, the American Association for Wind Engineering, and the UK Wind Engineering Society.

Chairman LAMPSON. Thank you, Dr. Prevatt.

Dr. Leatherman, you are recognized for five minutes.

STATEMENT OF DR. STEPHEN P. LEATHERMAN, CHAIR PROFESSOR AND DIRECTOR, INTERNATIONAL HURRICANE RESEARCH CENTER & LABORATORY FOR COASTAL RESEARCH, FLORIDA INTERNATIONAL UNIVERSITY

Dr. LEATHERMAN. Thank you very much, Mr. Chairman, and all the other distinguished Members of Congress and especially to Congressman Diaz-Balart, who I had the pleasure of working with over the years.

Today I would like to show you a few slides. We are very happy to the have the National Hurricane Center located on the FIU campus, and we are pleased to have built a strong working relationship with them over time to support our hurricane agenda. We are presently building a $15 million building, supported by the State of Florida, that will be next to the National Hurricane Center. That is under construction shortly.

In terms of H.R. 2407, the key elements in general terms that need increased funding to make a real difference in saving lives and property, and lowering property damage actually has been stated before, very few people are actually killed directly by hurricanes. The big problem really is the incredible losses which are not sustainable. If we get another Andrew-type hurricane that hits Miami or the Tampa area, it would be between $100 and $150 billion in losses. This will really cause an insurance meltdown none of us even want to think about. So that is one of the big things we need to work on right now is lowering damage.

There are actually four different types of hazards from hurricanes. The International Hurricane Research Center is a multi-disciplinary center that addresses these different hazards. We have already heard earlier about social science research. Indeed, it is very key. We looked at the evacuation problem. Hurricane Floyd in 1999, in North Carolina, the problems there, also South Carolina. More recently Hurricane Rita in 2005, in Texas, the evacuation was the disaster in this case. I am pleased to report that we are now developing the first quantitative model, it is under development, that will help us, a quantitative evacuation model. And so we haven't seen this before, and we have been having it vetted by the National Hurricane Center, and with more funding I think we can bring this to help us solve this problem and better evacuate our communities and districts.

We are also working on the insurance industry itself. In fact, we developed the first public catastrophe model. You have heard about these CAT models that are used to set insurance rates. Presently there are five black box models. We developed an open model. That means you can see our assumptions, our code, and it has been adopted by the State of Florida and certified.

Now we would like to exercise this model to really show us how to do mitigation right. What are the economic advantages of various things you do rather than just try to do something. We need to know what to do to lower the damage. In fact, this model says that we can expect to reduce our damages by as much as 50 percent. That is huge if you think about the damages we have had.

Our coastal laboratory, which I brought down from the University of Maryland, College Park, when I was there years ago, has been working very much on storm-surge modeling. We have been

well served by NOAA's storm-surge model for decades, however, now new models are being developed. We developed a new model at FIU which correctly predicted the 30-foot storm surge that Katrina hoisted upon coastal Mississippi. A lot of the other models came in only at 15 to 20 feet, and so we know we need to go to these more high-resolution models, which have no algorithms and new technologies to make them much more accurate.

Another area, wind-engineering research. Huge opportunities here. For the first time ever we are doing full-scale testing. Keep in mind in the past we have just been working with wind tunnels. When houses are reduced down to the size of a bird house, you can learn a lot, but you cannot really understand how things fail. We are now doing that. Those are shingles. Actually, those are clay tiles flying off a house under category three winds. I hate to see this photograph myself, because I have this kind of house here in Miami, so this hurts me dearly.

We really feel that with this kind of work we can; really, our goal at the International Hurricane Research Center is to make it so we can survive a category three hurricane with little to no damage. Now, that would solve about 85 percent of the hurricane damage problem if you can get through a category three hurricane. Keep in mind, Hurricane Wilma in 2005, was barely a category two, and produced $16 billion in damage, much of it roof damage. We've got to do better, and we can do better, and in fact, we at FIU, we developed the first hurricane simulator. We call it the Wall of Wind. It was actually a two-fan model. We now have this six-fan model. It is sponsored and built by Renaissance Reinsurance Company for us on the campus. You can see we are getting up to 135 mile an hour. That is a category three. Actually, it is category four winds. There is water and debris injection, as well as the wind field itself. Recently, this is the first of its kind in the world, and now the University of Florida also, of course, has a hurricane simulator as well, and we are working with them.

We just won a $10 million Florida Center of Excellence Competition to really push this technology. We have 70 industry partners, including 3M and DuPont. The DuPont people were just down from Wilmington, Delaware, so things are happening, testing is under way.

We are now building the ultimate hurricane simulator. We just recently ordered 12, 500-horsepower electric fans. We are working with Florida Power and Light, because if we turn it on, the lights would dim in Miami if we turned this thing on. So FP&L has assured us that fortunately there is enough power coming out from the Turkey Point Nuclear Power Plant and an open slot, so we can work this simulator. This huge array of fans will allow us to generate category five wind, rain, and debris, and assault a full-size house in this aircraft hangar building, which is now being completed, under controlled and repeatable testing conditions. The first time ever we have been able to do that. We are literally bringing the hurricane into the laboratory.

These are exciting times in hurricane research. We have great capabilities now to make a difference. Real progress is being made that has real world applications with practical applications that will significantly reduce the damage in the near future.

Finally, I would like to say that FIU is very proud to be the leader of the Florida Hurricane Alliance, of the nine public universities in the State of Florida, including UF, Florida State, USF, FAMU, and others. This is funded by NOAA, and we are the lead institution on that.

Again, I thank you very much for your time and attention.

[The prepared statement of Dr. Leatherman follows:]

PREPARED STATEMENT OF STEPHEN P. LEATHERMAN

Florida International University (FIU) in Miami, Florida supports H.R. 2407, the *National Hurricane Research Initiative Act,* introduced by Rep. Alcee L. Hastings and co-sponsored by 18 other members of the Florida Delegation. Similar legislation, S. 931, introduced by Florida Senators Mel Martinez and Bill Nelson, is pending before the Senate Committee on Commerce, Science and Transportation.

FIU appreciates the recognition by our Florida leaders for the need for additional hurricane mitigation research and commends the Committee for holding this hearing. We strongly concur with the findings of the September 29, 2006, National Science Board Report (NSB) entitled *"Hurricane Warning: The Critical Need for National Hurricane Initiative,"* which outlines the urgent national need for strategic action with respect to hurricanes. FIU applauds our Florida leaders for taking the lead on this national imperative and for introducing legislation which implements the recommendations of the National Science Board. We are pleased that 40 Members of the House have co-sponsored H.R. 2407 and hope that FIU's statement will help convince the Committee and remaining Members of Congress of the need to make passage of this legislation one of the Chamber's highest priorities.

Florida International University—Miami's public research university—established in 1972, has more than 38,000 students, almost 1,100 full-time faculty and more than 124,000 graduates, making it the largest university in South Florida and placing it among the Nation's 25 largest colleges and Universities. FIU offers more than 200 baccalaureate, Master's and doctoral degree programs in 21 colleges and schools. Research is emphasized as a major component of its mission. The University is ranked as a Research University in the High Research Activity category of the Carnegie Foundation's prestigious classification system. FIU's College of Law received full accreditation in 2006, and it led all universities in the State with the highest pass rate of 94.4 percent on the 2007 stateside Florida Bar Examination. In the Fall of 2009 we will be welcoming our first medical school class.

FIU's International Hurricane Research Center is the statewide center for hurricane mitigation research in Florida. We also lead the Florida System-wide Hurricane Mitigation Alliance, comprised of nine of the eleven Florida public universities.

Before commenting on the NSB report and H.R. 2407, I will briefly acquaint you with the work that we do at the International Hurricane Research Center and explain why we believe it is in the national interest, and the interest of the Federal Government, to support the development and implementation of a rational research strategy focusing on the reduction of potential hurricane damage. I will conclude by providing FIU's thoughts as they pertain to the NSB report and then comment on the provisions of H.R. 2407.

International Hurricane Research Center

The International Hurricane Research Center (IHRC) at Florida International University (FIU) conducts basic and applied multi-disciplinary scientific research to reduce the potential for damage from hurricane impacts to the human, natural and built environments in vulnerable communities throughout the United States and in other countries. It was established by the private sector in the aftermath of Hurricane Andrew.

As Florida's center for hurricane research, education and outreach, the IHRC offers a solid record of interdisciplinary and collaborative research, both basic and applied, focusing on the full spectra of hurricane impacts and the methods and techniques for hurricane loss reduction. The work of the IHRC has largely involved Florida and the larger Caribbean and Gulf basin, where most of the North Atlantic hurricanes make landfall.

The knowledge and findings resulting from the work of the IHRC, and the complementary education and outreach methodologies benefit not only Florida and specific countries in the Caribbean and Latin America, but every hurricane vulnerable community in the USA and abroad. These capabilities clearly allow the IHRC to

support federal strategic objectives and priorities, providing increased assistance to international partners while concentrating on the domestic front.

In fulfillment of its mission, the IHRC has engaged in a wide-ranging research agenda that includes the following areas:

- *Research and development of effective and credible hurricane loss reduction methods and techniques for housing in Florida.* This involves the testing of various building components and assemblies, development of improved building design criteria, and the analysis of various architectural and structural elements and their role in modifying the performance of buildings under hurricane conditions. IHRC researchers have developed an innovative full-scale structural testing facility—the Wall of Wind—to determine inherent weaknesses of structures when subjected to hurricane-force winds and rain. This research facility, the first-of-its-kind, will revolutionize our building construction and retrofitting practices. (Funded by Florida Department of Community Affairs, Florida Division of Emergency Management, National Science Foundation, Florida Sea Grant, Renaissance Reinsurance Holdings, Ltd, AIR Worldwide.)
- *Development of a public domain hurricane loss model to assess risk and estimate potential losses.* This integrated model is particularly useful to insurers, re-insurers, regulators as well as the financial and housing industries. The model includes newly-developed knowledge databases and an updated wind field model. (Funded by Florida Office of Insurance Regulation.)
- *Implementation of a windstorm simulation and modeling.* This project focuses on the use of high-resolution data acquisition with airborne LIDAR technology and IHRC-developed algorithms, enhanced storm surge modeling, computer simulation and visualization complemented by public education and outreach programs. (Funded by the Federal Emergency Management Agency, National Oceanic and Atmospheric Administration.)
- *Assessment of beach erosion, sea level rise impacts and coastal vulnerability.* Quantification and assessment of erosion resulting from hurricanes and long-term sea level rise through the use of airborne LIDAR technology. This project uses high-resolution elevation data and local geomorphology features to assess coastal vulnerability at specific locations. (Funded by National Oceanic and Atmospheric Administration, The Andrew W. Mellon Foundation.)
- *Assessment of social consequences and the human impact of hurricanes.* Evaluation of how various social factors such as demographics, socioeconomic strata or education may affect perceptions and attitudes influencing critical issues such as hurricane evacuation and the use of mitigation measures. (Funded by the National Science Foundation, National Oceanic and Atmospheric Administration, Florida Division of Emergency Management.)

To complement its research program, the IHRC also engages in efforts of education and outreach to transfer critical knowledge and findings to potential users and policy-makers in various fields. This includes the *Developing a Culture of Mitigation through Education* project focusing on K–12 students, their parents and teachers, and the community at large.

The Need for a National Hurricane Research Agenda

Hurricanes have shredded every ounce of public belief and trust in the safety and resiliency of community life by not only destroying people's homes, but everything else they need in their daily lives—businesses, schools, hospitals, gas stations, and places of worship.

It is hard to identify any other societal need or engineering problem as challenging, recurring, and multi-disciplinary as hurricanes. Among weather hazards, hurricanes account for over half of the total damage inflicted.

The National Oceanic and Atmospheric Administration's National Hurricane Center, located on FIU's campus, predicts the six-month 2008 hurricane season which began June 1st has a 65 percent probability of being above normal, with 12 to 16 named storms, including six to nine hurricanes and two to five major hurricanes with winds in excess of 111 mph. William M. Gray, a noted hurricane expert from Colorado State University, in April predicted a "well above-normal" season with 15 named storms, eight of them becoming hurricanes when they grow to 74 mph or more, and four developing into major-hurricane intensity.

FIU believes the following provide compelling evidence of the critical need for prompt congressional enactment of a national hurricane research initiative:

- Hurricanes represent 65 percent of insured losses by natural hazards in the U.S., with the potential to affect every state from Maine to Texas.
- In 2004 the value of insured coastal properties in the 18 East Coast and Gulf states exposed to hurricanes totaled $6.9 trillion, or 16 percent of insurers' total exposure to loss in the U.S.
- In 2005 alone, hurricane losses surpassed $80 billion and caused more than 1,800 fatalities.
- Analyses of the top 40 most costly insurance losses worldwide for 1970–2005 indicate that $147 billion in worldwide insured losses were associated with hurricanes compared to $25 billion for earthquakes. Over the last five years, actual economic losses from U.S. hurricanes alone are estimated to be $179 billion (in constant 2006 dollars).
- If a hurricane of the same category as Hurricane Andrew which hit South Florida in 1992 would hit Miami directly, it could be a $100+ billion disaster, comparable to the physical damage New York suffered as a result of 9/11.
- Fifty percent of the U.S. population lives within 50 miles of the coastline, where the physical infrastructure in the late 1990s was valued at about $3 trillion in the Gulf and Atlantic regions alone.
- If a hurricane caused permanent closure of only one percent of businesses in South Florida, 13,500 jobs would be lost in addition to $1.8 billion in sales and $414 million in lost payroll. By comparison, Hurricane Andrew permanently closed 10 percent of the businesses in the area. We believe similar losses would occur in other densely populated areas along the Gulf Coast and Atlantic Ocean.
- In Florida, estimates show that only 35 percent of small and mid-sized businesses have a disaster recovery plan in place, and less than 10 percent have contingency, business recovery and resumption plans, despite studies that show that 40 percent of companies that were shut by a disaster for three days failed within 36 months.
- FIU has a Wall of Wind test facility that enables development of innovative, high performance building systems and structures capable of withstanding hurricanes as intense as Category 5 and performance-based evaluation of two-story buildings, including residences, low-rise commercial buildings, schools, power lines, traffic signals, gas stations, commodity stores, focusing on issues of sustainable community and business continuity.
- In advance of Hurricane Katrina's landfall a 29-foot storm surge in Mississippi was predicted by FIU researchers. The CEST storm surge model, currently under development, proved highly accurate and will continue to be a major asset to vulnerable regions as emergency managers will have additional tools to predict flooding potential. University of South Florida and University of West Florida have recently joined the Hurricane Mitigation Alliance and aid in this research effort.
- IHRC researchers developed the first dynamic model of hurricane evacuation behavior. This multi-period model can address questions such as how levels of evacuation might be affected by an improved three-day vs. two-day forecast, extended hurricane warning, reduced costs of evacuation, and reduced benefits of evacuation.
- Real-time hurricane track forecasts were made available through the FIU-led Hurricane Mitigation Alliance to the National Hurricane Center by Florida State University using their super-ensemble model.
- The University of Florida and FIU team of wind engineers used meteorological towers to intercept landfalling hurricanes during the 2004 and 2005 hurricane seasons. This real-time, surface data characterizes the winds that actually cause damage. A highlight of the 2004 season was first-ever recording of surface wind during passage of the hurricane eyewall, and forecasters at the National Hurricane Center based advisories upon these data.
- FIU scientists, working with colleagues at NOAA's Hurricane Research Division, formulated a new analytical model of hurricanes' horizontal structure based upon aircraft observations. This research will lead to more realistic assessment of windstorm underwriting risk and more accurate storm-surge forecasts.
- University of Central Florida has built building virtual models of the effects of hurricane wind forces on residential houses as funded through FIU-led Hurricane Mitigation Alliance. The models include visualization of different

types of damage to different types of structures (for example concrete block vs. wood frame structures), which will be used in educational programs.

Adoption and adequate funding of the NSB plan can result in as much as a 50 percent reduction in costs of hurricanes.

FIU's Comments on the NSB Report, "Hurricane Warning: The Critical Need for National Hurricane Initiative"

FIU and its Alliance colleagues have been vocal critics of the woefully inadequate attention that hurricane science, research and education have received at the federal level. The university wholeheartedly agrees with the NSB that "The present federal investment in hurricane science and engineering research relative to the tremendous damage and suffering caused by hurricanes is insufficient, and time is not on our side." We concur with the NSB that hurricane-related research has been conducted, for the most part, as a relatively modest, loosely coordinated enterprise, but we leave to others to determine the amount of annual funding necessary to implement a meaningful, successful program to reduce the enormous public outlays, loss of life, and the associated societal disruption caused by hurricanes.

FIU also agrees with the NSB that any legislative National Hurricane Research Initiative be a "focused activity, with well defined metrics for success, effective assessment mechanisms and a clearly articulated pathway from research to operations." Finally, we share the NSB's conclusion that time is not on our side with respect to the federal investment in hurricane science and engineering, as hurricanes are an inevitable part of our future. Our nation simply cannot afford the status quo. Added to the huge financial cost is the intolerable and unnecessary loss of life associated with hurricanes.

FIU has carefully reviewed the "Research Imperatives" identified as priorities in the NSB report and have the following comments noted in black type with respect to level of urgency given by the NSB. Also provided are areas not addressed in the NSB report that we believe are essential and should be included in H.R. 2407, the *National Hurricane Research Initiative.*

Investment Category #1: Understanding and Prediction

- *High priority. Predicting hurricane intensification and size, and reducing the uncertainty associated with where and when hurricanes will make landfall.* **FIU's recommended level of priority: Highest**
- *High Priority. Understanding air-sea interactions.* **FIU's recommended level of priority: Medium**
- *High Priority. Predicting storm surge, rainfall and inland flooding from hurricane and tropical storms.* **FIU's recommended level of priority: Highest**
- *Medium Priority: Understanding the relationship between hurricanes and climate.* **FIU's recommended level of priority: Medium**
- *Medium Priority. Improved observations.* **FIU's recommended level of priority: Highest**
- *Medium Priority. fundamental hurricane predictability.* **FIU's recommended level of priority: Medium**
- *Medium Priority. Hurricane modification.* **FIU's recommended level of priority: Low**

Investment Category #2: Impacts and Interactions

- *High Priority. Interaction of hurricanes with engineered structures.* **FIU's recommended level of priority: Highest**
- *High Priority. Economic and social impact of hurricanes and mitigation measures.* **FIU's recommended level of priority: Highest**
- *High Priority. Technologies for disaster response and recovery.* **FIU's recommended level of priority: Highest**
- *Medium Priority. Interaction of hurricanes with natural ecosystems.* **FIU's recommended level of priority: Medium**

Investment category #3: Preparedness and Building Resiliency

- *High Priority. Assessing and improving the resilience of the built environment.* **FIU's recommended level of priority: Highest**

- *High Priority. Human behavior and risk planning.* **FIU's recommended level of priority: High**
- *High Priority. Evacuation planning.* **FIU's recommended level of priority: High**
- *Medium Priority. Computational capability.* **FIU's recommended level of priority: Medium**
- *Medium Priority. Training and educational programs related to hurricane impact.* **FIU's recommended level of priority: Medium**

FIU's Specific Comments on H.R. 2407

FIU applauds this bill, which is comprehensive and addresses key research priorities. In addition, this legislation should include socioeconomic research and implementation, such as public and governmental adoption of mitigation measures and linking disaster recovery to mitigation. Our specific comments are as follows wherein we give the highest priority ratings to those areas which have the greatest potential for breakthrough science and return on investment in terms of mitigating losses:

- Predicting hurricane intensity change—**Highest** priority
- Understanding ocean-atmosphere interactions—**Medium** priority
- Predicting storm surges and inland flooding—**Highest** priority
- Improved hurricane observations—**High** priority
- Assessing vulnerable infrastructure—**Medium** priority
- Understanding hurricane and structural interaction—**Highest** priority
- Assessing hurricanes and climate change—**Medium** priority
- Improving response and recovery technologies—**Medium** priority
- Evacuation planning—**Medium** priority
- Computation capability—**Low** priority

Conclusions

FIU strongly believes in the need for coordinated programs at the federal level to reduce the impacts of hurricanes and other windstorms. As such, FIU has been a lead advocate of the 2004 *National Windstorm Impact Reduction Act* and strongly urges Congress to reauthorize the Act this year, before its 2008 authorization expiration. We are heartened, thanks to the efforts of Reps. Debbie Wasserman Schulz (FL) and Dennis Moore (KS) that the FY '08 Commerce, Justice Science appropriation Conference Report includes $11.3 million to implement the bill. We are disappointed that neither the National Oceanic and Atmospheric Administration, the National Institute of Standards and Technology, and the National Science Foundation has chosen to fund the Act, presumably due to budget shortfalls and different priorities. FIU strongly urges the Committee to advise these agencies of the importance of the *National Windstorm Impact Reduction Act* and to make implement of the 2004 Act a high agency priority.

If a hurricane of the same category as Hurricane Andrew (which hit South Florida in 1992) would hit Miami directly, it would be a $100+ billion disaster, comparable to the physical damage New York suffered as a result of 9/11. While the size of the national hurricane mitigation research program that the National Science Board outlined is significant, it only represents one percent of the present value of the damage caused by Hurricane Andrew. Our research shows that funding for a strong, coherent and united research agenda, such as that embodied in H.R. 2047, could lead to significant loss reductions—in lives saved and structural damage incurred.

BIOGRAPHY FOR STEPHEN P. LEATHERMAN

Education

Ph.D., Environmental (Coastal) Sciences, University of Virginia, 1976

B.S., Geosciences, North Carolina State University, 1970

Publications

16 books and National Academy reports, including *Hurricanes, Sea Level Rise: History and Consequences, and Barrier Island Handbook.*

Over 200 journal articles and technical reports authored, including articles in both *Science* and *Nature*

Expert testimony for the U.S. Senate and U.S. House of Representatives ten times.

On-screen host and co-producer, "Vanishing Lands" film, 1992, winner of three international film awards, including the Golden Eagle.

Professional Presentations

Over 200 speeches at national and international scientific conferences including Antigua, Argentina, Bahamas, Brazil, Canada, China, Denmark, Egypt, England, France, Hong Kong, Iceland, Ireland, Italy, Japan, Mexico, Micronesia, Netherlands, Norway, Puerto Rico, Thailand, Venezuela and Wales.

DISCUSSION

Chairman LAMPSON. Thank you, Dr. Leatherman. I am sure that Mr. McNerney would be happy to work with you to see if you couldn't just generate some windmills that would capture some of that excess wind that is blown over there and generate a little bit more electricity to pay for that operation.

At this point we will open for our first round of questions, and the Chairman will recognize himself for five minutes.

And I would like to start with Dr. Hayes. H.R. 2407 establishes a National Hurricane Research Initiative to improve hurricane forecasting and preparedness. Which areas of this research initiative in the bill is NOAA not addressing yet, and are there ways that this bill can be improved?

Dr. HAYES. Well, Mr. Chairman, I think all the weather-related or hurricane-related pieces we are attempting to address right now. I think we are stronger in some areas than others. I think clearly our expertise is operational weather prediction, and I would think that those aspects associated with operational prediction we are addressing, and we are trying to address those in partnership. I think where we recognize certainly a need for help, it is in the social science area. NOAA has a Science Advisory Board, which has a Social Science Subcommittee. They did a study approximately three, maybe four years ago, and they are updating that at the present time. And I think the remarks I heard this morning indicate that while we produce improved forecasts and warnings, if we can't translate that into something that the American public, that the emergency managers can use to effectively accomplish actions, then we have not taken the challenge far enough. So I guess if there is an area where I think we would need help it is there.

On the research side we have our lapses, as I mentioned in my testimony. I think that we are working with the National Science Foundation, with NASA, with the Office of Naval Research, all federal agencies that have an interest in tropical cyclone research. And where we could use help is making that alliance a reality, and it is just a resource investment to all federal agencies involved in that part of the problem.

Thank you.

Chairman LAMPSON. I understand that there is a need for better research and understanding hurricane activity, so what are some of the roadblocks that exist to better hurricane forecasting? And would better national coordination between the federal agencies as

you were just talking about help to break down some of those roadblocks?

Dr. HAYES. Well, Mr. Chairman, I think certainly better observations. If one looks, our, my testimony talks about rapid intensity change. One of the challenges scientifically that we face is that you have processes going on in the center of a storm between the ocean and the atmosphere, inside the eye wall of a hurricane, if you will, that we are not even observing. So I think certainly observations.

NOAA flies aircraft in at safe altitudes, but getting an unmanned aerial system in may be at a level that we couldn't safety fly a human in, and I am talking here maybe 100, 200 feet off the surface of the ocean, would see some of the dynamics going on in the storm.

So observations is an area that I think we could work better and the Committee could help us with funding to improve observations of the storms.

I think also it is creating an infrastructure that allows rapid transition of what the university community is doing. We have several in the United States that are involved in tropical cyclone research. We run our models at the National Centers for Environmental Prediction, one of the constraints we have is that it doesn't exist in the research community, is a need to meet production deadlines for emergency managers, for the American public. And that requires a very operationally tuned environment, and there are differences between what exists in our national centers and what exists in the Nation's research facilities.

And so helping us with planning and transitioning that research to operations. I think funding is, should be targeted toward that transition step.

Thank you.

Chairman LAMPSON. What areas of forecasting is NOAA best equipped, most equipped to handle, and what areas are covered by other federal agencies?

Dr. HAYES. Well, I, again, I think it is from an operational perspective it is observations, operational modeling, detecting the presence of storms using our satellites, our radars, our aircraft, translating those observations into meaningful operational forecasts the public can use, and then the warnings that emergency managers and the public could use. So, I think those are our strengths, Mr. Chairman.

Chairman LAMPSON. I recognize Mr. Inglis, Ranking Member, for five minutes.

Mr. INGLIS. Thank you, Mr. Chairman.

Dr. Hayes, I suppose that the weather predictions have an impact on the social behaviors surely because, having grown up in a hurricane area at the coast in South Carolina, you feel silly when you pack up and leave and then you come home and there is nothing that happened, and so then people decide to stick out the next one, until they get a big one and then they forever more leave even if it is a small one coming.

And so that feedback loop, I guess, is, if you leave and nothing happened, there is not nary a piece of moss in the yard when you come home, you know, you decide not to leave the next time.

So, I guess it is essential to try to better the forecast, but there will be some limits on that. Right? I mean, there, I suppose we will get better and better, but there still is some limit on the ability to accurately forecast and narrow the cone, as Ms. Ros-Lehtinen was talking about.

Dr. HAYES. Mr. Inglis, I think if you look at our, what we have done over the past say 15 to 20 years, we have improved the hurricane track forecasts, reduced error by a factor of two. I think with finer-scale models, we run our models today at 10 kilometers, and if we were able to get that modeled down to say a kilometer in resolution, I have great confidence that, using our global models and our regional models, we could achieve that in the next 10 years, and that is what our plan calls for.

What that is going to require is probably, well, not probably, approximately an increase of about 1,000 or more times the high-performance computing capacity that we have at the National Centers. Earlier speakers talked about having a partnership with the research community to leverage high-performance computing in the universities, and we are prepared to do that. The unfortunate challenge that we face in trying to do that is, as I mentioned earlier, our operational modeling structure is designed to work in real time, and we have optimized it, and we have developed I would say probably over a billion dollar investment in our National Centers, and it is a certain way. Our research institutions, by virtue of their mission to do basic research, don't operate under those constraints, and so it is how would we transition our—what we have in operations to exploit that.

We are prepared to work with the university community to try and do that. It is not going to be an easy task. We are also, we have ongoing discussions with Department of Energy. They have in Oak Ridge high-performance computing assets, which we think we might be able to leverage in both, primarily a research capacity, and other federal agencies.

So, I think, Mr. Inglis, that is our, one of our big challenges, and then I have one final comment. From a fundamental science perspective, I don't think we know what causes rapid intensity change, and by rapid intensity change I mean a hurricane intensity jump by Saffir-Simpson Scale of over one category in a 24-hour period. Last September we had Hurricane Humberto, that was a tropical depression in the early afternoon, and within 18 hours it became a hurricane. Right off the coast of Louisiana and Texas. I heard firsthand from the folks in Texas about how the energy community, the oil community scrambled. And the thing that was luckiest for us was that it only reached minimal hurricane strength, 65 knots, before it moved to shore.

My fear is something like that happening a little bit further out in the Gulf and then picking up some speed and come crashing ashore and then have another Katrina where we have a category or a two-category jump in 24 hours.

Fundamentally, research is required to understand what is causing these storms to increase in intensity so rapidly, and then on the flip side it was mentioned that we, and you mentioned that we lose credibility when we over-warn the public. I can remember in the earlier part of this decade where we hit and nailed a tropical

storm coming into the coast of Louisiana. The unfortunate thing is we said it is going to be a category three, and by the time it got to Louisiana it was a category one. People then begin to say, they are not right often enough, so I don't need to take any action.

So, I think hurricane intensity and rapid intensity change is a tough scientific problem where we need the research community.

Mr. INGLIS. And you, the funding here that I mentioned earlier, $4.17 billion over 10 years, that is a lot of money, and so I wonder if you have any thoughts about how much assistance you get in those goals you were just describing by the additional funding?

Dr. HAYES. Well, I think that my focus in the Weather Service is to orient our architecture, our work processes. I think we truly believe this is a national problem, and I think my commitment isn't, and I think NOAA's commitment is not to necessarily say we invented it. It is to say where it can help America, we are prepared to use it operationally, and I think that is my commitment to this committee and to the American public.

Mr. INGLIS. Thank you. Thank you, Mr. Chairman.

Chairman LAMPSON. Thank you, Mr. Inglis.

Dr. Baird, you are recognized.

Mr. BAIRD. I thank the Chair.

I want to follow up on the theme raised by my friend, Mr. Inglis, a second ago, and that is the funding aspect of this bill, the requested amount is pretty large. And I would ask each of you, if you had to prioritize the most important areas, if you had some extra funding, where do you think the most important areas are in order to reduce and do it fairly quickly for us, and I will just go from Dr. Hayes on down to each person. Very quickly. The most important areas where we should allocate funding. In other words, without duplicating what is already being done, et cetera.

Dr. HAYES. Mr. Baird, I think if we are looking for rapid impact, I mentioned we run our models at ten kilometers, if I had significantly more operational high-performance computing, then it is a matter of taking the models I have and then just changing the code, which can be done fairly quickly to run, and right now that is a constraint that I have. For every time you increase the resolution by a fact or two, you increase your high-performance computing requirements by a factor of about ten. So, that is where I got the 1,000 times to get from ten to one kilometer.

Dr. DROEGEMEIER. I believe really the best investment would be two-fold. One is in terms of applying the current engineering practices that we have and in studying new ones but also the communicating information to the public. The social science research agenda is very, very important.

I agree completely with Dr. Hayes that we need to be doing more in the area of meteorology, but I think that the forecasts are quite good now, and I think we could get a quick benefit if we actually understand how to better communicate the information, get people to respond appropriately, and help them actually get out of harm's way. In fact, in Katrina and Rita a lot of the loss of life was people simply were immobile for a variety of reasons. And so I think those are very important, again, not to diminish any other elements of the components of the effort. But as you say, the priorities, I think, for a quick return would be those.

Mr. BAIRD. Thanks, Dr. Droegemeier. Dr. Chen.

Dr. CHEN. I would like to emphasize a point, we refer to the rapid intensification forecast that has been stagnant over the last 15 years for the reason the complexity that you need basic research. The research community have developed the next generation forecast model and kilometer resolution already, and that technology can be explored and moving over to operations more effectively. And that also relates to the forecasts, not only the location of where landfall occurs but a detailed forecast of extreme winds and rain. That will help the mitigation and the many other areas, risk assessment.

So this new generation model in research community really needs to be, continue to be supported and then translation to operation. That is a very urgent area that we can help.

Mr. BAIRD. Dr. Prevatt.

Dr. PREVATT. I believe the two areas, social interactions and so on, but most importantly it is improving our performance of our existing buildings and our existing structures. How do structures interact with wind, how do structures interact with storm surges and inland flooding? Preparation begins not when we have 24-hours notice. Preparation begins what we put down in the ground today, what we do about what is existing and improving those things.

There is no reason why we should have a situation in which people have to be scared for their homes in a category one hurricane. We know how to build it. It is a matter of actually doing that, getting the research that allows us to improve our civil infrastructure.

Mr. BAIRD. Dr. Leatherman.

Dr. LEATHERMAN. I think the full-scale testing as we just heard in terms of making our houses stronger. We have got to do that. We can do that right away, and it has got to be the first investment I think we have got to make, because after all, the wind is doing so much damage. Every hurricane is a billion dollar event plus. Most people are saying now they are five billion a piece or more. The last, 2004, 2005, those hurricanes now are on the top ten list most of them. So what are we saying? Just the damages are going out of sight.

Secondly, I think that we can make big improvements to the storm surge models and actually run in a suite of models, storm surge models as the National Hurricane Center runs a suite, a forecast model. They presently use 15 models, which they use to look at and make their determination where the best track. Right now we are relying upon one storm surge model that was developed by Chester Jalanski, a great model, some 20, 30 years ago. And that is really, we are way behind on that.

And finally, I think the social science, I mentioned one aspect of that is a quantitative model that was recently being developed where we could understand why people make decisions in a quantitative sense, and it is a numerical model, which I think it fits in perfectly and meshes with the storm surge model, because after all, as we say, you hide from the wind, and you run from the water. And that is where people drown is in the water. That is where people are really killed, and that is what we need to know, and we need to mesh that new high resolution storm surge models with

this quantitative evacuation model. And that is how we can save lives, but most of the damage, sparing New Orleans, what happened with the break in the levees, was, in fact, and is wind damage to our houses and buildings, and that is just out of sight.

So we've got ways now to do the full-scale testing and know how to build better, and not only that, retrofit the 99 percent of the existing houses that are out there in cost-effective ways such as the new technologies that Dupont and 3M and other countries are developing, but it has to be tested and shown to work.

Thank you.

Mr. BAIRD. Very helpful. It seems that what we need is some combination of factors where we improve our prediction and then you can translate that to individual buildings and homeowners with their location and say, this is what we predict is about to happen. This is the risk you face, this is the preparedness of your building or structure that you are in, and then somehow communicate that in a meaningful way so that they can, the average individual can do something about that in a responsible way, both well beforehand as Dr. Prevatt said, but then base their immediate real-time decisions on what they have done and what, the threats they face.

Thanks for the succinct answers. I yield back. Thanks.

Chairman LAMPSON. Thank you, Dr. Baird.

Dr. Ehlers, Ranking Member Ehlers, you are recognized for five minutes.

Mr. EHLERS. Thank you, Mr. Chairman. A number of my questions have been answered, but a few I would like to follow up on.

Years ago we sustained very substantial amounts of earthquake damage in this country. We instituted earthquake modeling programs, lots of research. We strengthened the building codes. Today we can take a very substantial earthquake with not a great deal of damage.

Similar in the Midwest where I live, this same thing with snow loads, straight wind problems, and so forth. We have changed all the building codes, and we really have fairly minor damage unless a tree falls on the house.

I have been surprised every time we read about the hurricanes, people talk about, well, we need better building codes, and the insurance companies say, we are not going to give you insurance unless you have better building codes. And they don't seem to happen.

Is my outsider's perception wrong, or is there just too much delay on strengthening the building codes, or do people simply not know enough about what to do in the building code?

Dr. Prevatt, I think you are the engineer who has dealt with this. What are your comments? And then anyone else can jump in, too.

Dr. PREVATT. You hit the nail on the head there, because it is the tremendous investment that we have placed in research and in the earthquake engineering environment that has improved our work and the success of large earthquakes. We learned a lot since 1989.

In our case wind engineers, civil engineers have been working since Hurricane Camille in 1969, and we have been saying and saying over and over that we don't understand the dynamics, how a

dynamic wind effect affects a structure. We do not understand the basic engineering, even of a simple light-frame wood structure. And these are the issues that we need to focus on to improve the building codes.

My testimony did indicate that there is a lot of work to be done for us to really have a building code that is probabilistically based on that which we can rely on. A lot of the construction that we use today is based on traditional construction practice.

What I learned from my dad and what he learned from his dad. And this has been, you know, in our codes today. What we do need, in fact, is to get the engineering, the actual forces, we need structural testing that simulates not just an individual window component or a door component, but as Dr. Leatherman says, we need to put all components together in a holistic, three-dimensional test situation and see what happens at the interfaces of those.

Mr. EHLERS. Dr. Leatherman, do you want to add something?

Dr. LEATHERMAN. Yes. I totally agree with him. I mean, if you look at buildings, they are very complicated, and how do things fail? You can test an individual window or a door, but really the structure fails in a holistic way, as a whole, and we never had that capability before. So, if you talk about building codes, there is a problem because what do you do now? What is, where is the emphasis going to go, and a lot of times we don't know. Now we can say, oh, everybody should live in a bunker or live in a cave, a fortified fortress, but, you know, people aren't going to do that, it is too expensive, and so there is that ultimate solution you might say, and that, and there is also how we are living today.

And we have got to find something that makes sense economically for people to do, because after all, in terms of building stock, it is 98, 99 percent out there and built. We got to find a way to retrofit those existing buildings in a cost-effective way so we can bring them up to withstand at least a category three hurricane. And I think that is what we are trying to do.

And so, and of course, improve the new structures that are going up.

Mr. EHLERS. Don't you already know enough to at least get this building code process started? I was struck, I think it was Hugo, but I am not sure, when I saw the photograph of a number of houses without roofs and right next to them or mixed in with them a number of houses with roofs. And the ones that still had the roofs had been built by Habitat for Humanity volunteers, and the others had been built by builders who used the guns, when you can't always tell whether you are actually getting it into the rafter or not.

I mean, that is a fairly simple thing to correct. Can't you start somewhere? Or do you really have to build a complete model first before you can really change the buildings?

Dr. PREVATT. I think we have started. We definitely have started, but in addition to the engineering part of it, there is the enforcement part of it. However, if we have a situation where your structure is dependent on a hit or miss situation of you getting these things, perhaps we are dealing with the wrong type of structure for a significant risk of damage. And those are the issues. The issues that I face is trying to convince people when they are re-roofing their homes to put in, you know, another set of nails. Increasing

the number of nails that you have in your roof from a twelve-inch spacing to a six-inch spacing will significantly increase the sustainability of your home.

However, if you do that without looking at the entire load chain where the roof fits on the wall, where the wall fits onto the foundation, you are still going to be in jeopardy, and my research has been trying to retrofit existing homes in the Port Orange area, and we have done some other homes in Bartow, Florida, and other places. What you find is you cannot just do one part of the problem. You have to address it all the way through. And without that you risk keeping the roof on but then you lose the entire roof structure itself.

Mr. EHLERS. Dr. Leatherman.

Dr. LEATHERMAN. If I may also add to that, we saw in the 2004 hurricanes that hit Florida, even when the roofs stayed on with category two and three hurricanes, still significant damage to the water coming in, going through the soffits, going through the water barriers, so-called water barriers. Once that water gets in, the ceilings saturate, they collapse. The walls fill up, the drywall has to come out, the furniture, the clothes are all destroyed. You have a total loss. You have to gut that house, even if the roof stayed on.

So, this is a lot more complicated than people think, and most of these soffits, as you know, are underneath the overhang, which is really more of a cosmetic feature. We got to find a way to make those things, at least in hurricane alley, so they don't blow out or at least they limit the water. We are working on that, but that is not as simple as it seems, because we need the air to get in underneath there so the roof doesn't get so hot. This is important in terms of energy conservation and also the longevity of your roof.

So, there is a lot of, it is a real balancing act here. It all sounds very simple in one sense, but then you get down to the details, the devil is in the details you might say. And so these are the things that we are working on, and we are now learning things through the full-scale testing, but we are not there yet. But we can see we can get there through adequate type of funding and attention.

Thank you.

Mr. EHLERS. Thank you very much.

Chairman LAMPSON. Thank you, Dr. Ehlers.

Dr. Bartlett, you are recognized for five minutes. Less if possible.

Mr. BARTLETT. Thank you very much.

In a former life among other things I was a home builder, and I think that we have some real opportunities for changing these homes after a hurricane, and you have to take off the drywall and so forth, because then you can do the kinds of things that are quite impossible with an intact home. And you can't go up and put hurricane ties between the rafters and the upper plate in an intact home very well. But once you have torn off all the drywall, why, you can do that.

Another thing that occurred to me is that for homes in hurricane-prone areas we maybe ought to be looking at different kinds of materials. There is nothing worse than a wet vat of fiberglass insulation. It just stays that way almost forever, and it may be that we need to insulate those houses differently. There are insulations

which will not wet. A lot of cellular foams and so forth that it will not wet so that they will dry out almost immediately.

So, there are a lot of things we can do, not just in the way we build the houses, but in the materials we use for houses. It costs very little more, for instance, to use treated materials in building a house. The differential in costs on a grand scale is not all that much. I know there is the potential for some out-gassing problems. You better seal your home on the inside anyhow, because there is a lot of out-gassing from OSB and things like that with the glues that are used.

I have one technical question since Dr. Ehlers said most of the questions I would have asked have already been asked. That is one of the advantages of being late in the queue. I have a technical question. For every reaction there is a reaction, and Dr. Hayes, you mentioned the difficulty of predicting these very short surges going from a category one to a two just very quickly.

Where does all this energy come from? To every action there is a reaction, and could we do a little better in understanding how we get this enormous increases in energy? And I hear that for every few minutes in a hurricane the energy released is equivalent of a hydrogen bomb going off. So, there are huge amounts of energy there.

What is the reaction to this action of the hurricane?

Dr. HAYES. Well, Congressman, I think there are a complex set of forcing functions that cause these rapid changes. I think we know conceptually that the heat or the heat content in the lower part or in the upper part of the ocean, because that is what really drives hurricane intensity. It is the evaporation, when you evaporate, and you convert that into heat, that drives intensity change.

There are just complex dynamics and thermodynamics inside the eye wall itself or the center of circulation if we are talking a tropical cyclone, and I think that scientifically we just don't understand those, and I think when you talk the amount of energy, I think certainly a nuclear weapon, but when you think the breadth of some of these storms, we are talking hundreds of nautical miles, and I would venture a guess that it is probably well in excess of a nuclear weapon. And what controls the rapid change? I don't think scientifically we know yet.

Mr. BARTLETT. Evaporation cools, of course.

Dr. HAYES. Yeah. The surface of the ocean. Yes. Yes. But when you condense that evaporation inside, you have processes, thermodynamic processes which convert that energy into heat, which drives the convection inside the store.

Mr. BARTLETT. Yeah, but you get it all back when it condenses, of course.

Dr. HAYES. Yes.

Mr. EHLERS. Isn't it a fact, I think water has an incredibly high latent heat of fusion——

Dr. HAYES. Right.

Mr. EHLERS. And so it is an immense force.

Dr. HAYES. Yes.

Mr. EHLERS. Immense amount of energy.

Mr. BARTLETT. I fortunately live in an area that kind of benefits from hurricanes. When it is dry, why we kind of look for the tail

end of a hurricane which will bring us some water. In Maryland we don't often get one that hits our shore, so we are kind of a beneficiary of hurricanes rather than a victim of hurricanes, because many times our crops are saved by a late season hurricane that brings a lot of rain and very little wind and so forth.

But I remember Agnes, which caused in excess of 100-year flooding in our area, and so we can be affected by hurricanes, but we didn't have the wind force. It was just rain, rain, rain that we got.

And is most of the damage in a hurricane done by the wind or the water? From an insurance perspective.

Dr. HAYES. If you are addressing me, Congressman, I would say it is the storm surge, and it is that wall of water that is going to come crashing ashore.

Mr. BARTLETT. But if you are not on the shore, what is the biggest——

Dr. HAYES. Inland it would be inland flooding.

Mr. BARTLETT. Is it water or wind?

Dr. HAYES. It is water. It is water, I think.

Mr. BARTLETT. It is still water.

Dr. HAYES. I think so.

Mr. BARTLETT. Even when you are inland, it is still water. Yeah. The wind does the damage and then makes it possible for water to get in, then water does the primary damage.

Dr. CHEN. Mr. Chairman, if I may, I would like to add a point there. The damage caused by hurricanes not only onshore, also the offshore for instance, the energy oil wrecks in the Gulf and many of these been pushed down by Katrina and Rita. And a part of, because not only the highest wind and also gusts. The process we are talking about here right now, it is not currently in the operational model but it is coupled, modeled that in the research mode we are looking at very detailed ocean impact and the winds.

And these are down to meter scales now that we are hoping to transition to operations that can address exactly the problem we are looking at, the intensification, the wind, and wind damage.

Dr. PREVATT. I don't believe, I believe Hurricane Andrew, for instance, was the dramatic cost of that was wind damage, and Hurricanes Charlie, they damaged buildings as far inland as Orlando, we do recall Civic Center, evacuation center, which actually had its roof collapse due to the wind.

So, the wind damage itself cannot be underestimated.

Dr. LEATHERMAN. Yes. I would like to amplify that point. Hurricane Andrew was $30 billion in damage in 1992. It was 90 percent wind damage. There was a surge, but it was limited in terms of the damage it did, even though it was, it came up to about 17.5 feet at Burger King's International Headquarters.

But, still, it was 90 percent more was wind damage, and also the hurricanes of 2004. The hurricanes that hit Florida, except for Ivan, they were mostly all wind damage. There was beach erosion, there was some local flooding, but, again, they were mostly all, I think Katrina was probably the exception because the New Orleans levies broke. That is when you got so much damage from the flood waters and the fact of the 30-foot storm surge swept inland from Mississippi for about 1,000 feet until it hit the railroad tracks and stopped. And that is why you had so much damage there.

Mr. BARTLETT. Thank you, Mr. Chairman.

Chairman LAMPSON. Yes. Mr. Diaz-Balart, you are recognized for five minutes. We got eight minutes left.

Mr. DIAZ-BALART. Thank you, Mr. Chairman. I will be——

Chairman LAMPSON. Six minutes left.

Mr. DIAZ-BALART.—very brief because, again, most of the things that I was thinking about also were answered, but I wanted to thank all of you for being here.

Just briefly, when we talk about, you know, strengthening structures, what reasonably, if you have an idea, what is reasonable to expect, that people could expect to be able to strengthen a building, a home with reasonable cost? Are we looking at a home being able to withstand a category three, category four? Is there any way to, without building a bunker be able to withstand a category five? Or is, you know, so what is reasonable to expect in some time in the future?

Dr. PREVATT. I think reasonably we should expect whatever we have in the code, which is 140 mile-per-hour wind in the Miami, 150 Miami, 130 further up. We should expect homes to withstand that, and that is not just from the problems with the code that they have been developed primarily from a life-safety standpoint. What we are trying to address here now is building codes need to also address economic losses, the losses that occur well below 100, 130, 140 miles per hour. We have to address how does the water damage affect things. By using a secondary water byway installed in your home you can reduce significantly the amount of water damage that occurs.

By developing better test methods for looking at the interface between a window and the wall structure itself. We can also develop better methods for developing those windows which have a water penetration resistance, air resistance, as well as it stops the impact of missiles, two by fours, and so on.

So, my sense is that currently we should be able to do the things for the category three hurricane with no problem. The problems we face, however, is like me, I have just moved to Florida. I have a 1973 home. I know I don't have a hurricane-resistant home, but, you know, when I ask my wife, well, should we buy a stove or should we put in hurricane ties, you know who is going to win. And so those are the issues. Ninety percent of our homes are built this way. How do we address that, and that is where the research needs to address.

Mr. DIAZ-BALART. And if I may, and Dr. Leatherman, I don't know, because, you know, I am thinking of, I am now thinking locally now. Homes that were built even after the strengthened code, are they built to really withstand a hurricane, or is it just, you know, fortifying some? You all were saying a little while ago that you have to have, it has got to be a holistic approach. You can have a strong roof but still lose the entire home.

Are they built, were they really strengthened to the point of being really hurricane protected, or is it just that we can kind of feel better that we are not going to lose a roof, but we are going to get flooded? I mean, where are we with the current codes, strengthened codes?

Dr. LEATHERMAN. Well, you are absolutely right. The codes have been strengthened in South Florida and now moving throughout the State of Florida, the building code and hopefully the Nation, and they say South Florida has the best building code in the Nation, and yet we saw $16 billion in damage from barely category two Wilma.

So, yes, we have built them stronger, but we still have a lot of problems with the way we put roofs on. It turns out there was defect in the way those ridge tiles were put on the clay tiles, and I can tell you, I had to put a new roof on my house about five years ago and got supposedly the best roofer in South Florida because that is, the lawyers told me that who sue roofers. But any rate, and yet with these category, with Wilma, I lost some ridge tiles, and I talked to my builder, and I said, what in the world is going on here? I was up there every morning when he was working, and I was there every afternoon when I got off from work, and I did my own inspection. Okay. And I said, what is going on? He says, well, the code didn't ask for the ridge tiles to have mechanical fasteners. I said, well, I would have paid you if you told me at the time that is what we needed. He said, well, you know, it just wasn't in the code. I was like, wow, you know. It was a learning situation for me, and this was before we started the Wall of Wind, the full-scale testing. If I had had all that going on, believe me, we would have put up a two by four or some other thing so we could have, you know, screwed down into that member on the ridge line, because once those ridge lines go, it kind of opens up the structure.

So, yes, we have done better, but, gosh, there is some glaring mistakes in omissions and the code is not what it should be, and again, people thought, well, this is good enough.

Now, the other thing you mentioned is I said before, you can still get water, even if the roof stays on. People are going to aluminum roofs, which are actually better. These metal roofs are doing better. But the water can still get underneath and get in your house, and you got a total loss from your insurance point of view if everything is saturated. You have to strip it out to studs. That is a total loss. Even if your roof is perfectly in tact.

So we have got to address these issues, and I think we have the capability now to do them.

Mr. DIAZ-BALART. We have got a long way to go it seems.

Thank you, Mr. Chairman.

Chairman LAMPSON. We do indeed. It is fascinating, and I have got more questions. I know others have more questions as well, but we also have votes that are pending, and we have got a minute and a half to get to the Floor to cast those votes.

I at some point in time want to even know about whether or not we have the capability of changing the temperature of water enough that might impact a storm or the intensity of that storm. We can talk about it.

Let me just thank you all for appearing here before the Subcommittees today. Under the rules of the Committee the record will be held open for two weeks for Members to submit additional statements and any additional questions that they might have for the witnesses.

This hearing is now adjourned. Thank you.

[Whereupon, at 11:41 a.m., the Subcommittees were adjourned.]

Appendix:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by John L. "Jack" Hayes, Assistant Administrator for Weather Services; Director, National Weather Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce

Questions submitted by Chairman Brian Baird

Q1. As you and many of the witnesses stated in their testimony, social science research plays a crucial role in better understanding and improving hurricane preparedness and response. What areas of social and behavioral science research do you consider to be the highest priority areas? How are the results of such research being translated into operational practice? Have you encountered, or are you aware of any impediments to applying the findings from social and behavioral sciences to disaster planning, recovery and response activities? If so, do you have any suggestions as to how these impediments could be addressed?

A1. NOAA has focused on improving communication of information to support hurricane preparedness and response as a priority area within social and behavioral science. Through the American Meteorological Society, we are engaging the entire weather and climate enterprise to determine the best way to communicate our information to ensure people understand the information and can make informed decisions, resulting in appropriate response to the hazard. We are engaging the social science community as we develop the next level products and services to help prioritize areas of research and ensure the public understands the information we provide—especially our forecasts and warnings—and will be able to make appropriate life saving decisions.

NOAA is also collaborating with the National Science Foundation (Engineering Directorate and Social, Behavioral and Economic Sciences Directorate) on a joint solicitation on Communicating Hurricane Information. This joint solicitation is an outcome of a three-year development of a Hurricane Forecast and Warning Social Science Research agenda involving the social science research community and the hurricane research and operational communities. The research results from the solicitation will inform NOAA on improving the understanding by emergency managers and the public of its hurricane forecast and warning products.

Q2. In his testimony Dr. Prevatt stated that increased support for research on strengthening the existing built infrastructure and developing cost effective retrofit and mitigation measures would be the most effective way to reduce damage and economic losses from hurricanes. Would you comment on what priority you would assign to such research and development efforts within the context of a national hurricane research program?

A2. NOAA would continue to work with our partners in academia, the private sector, and other appropriate federal agencies to prioritize research and development efforts in areas of strengthening existing infrastructures and retrofit and mitigation measures. NOAA participates in the National Windstorm Impact Reduction Program (NWRIP), enacted in 2004 (42 USC 15703 et seq.), which seeks to improve meteorological understanding of windstorms, quantify windstorm impacts, and identify and promote cost-effective measures to reduce windstorm impacts. NWRIP identifies the National Institutes of Standards and Technology as the lead within the Department of Commerce.

Questions submitted by Representative Mario Diaz-Balart

Q1. There are a number of reports that speak to the urgency for improved hurricane forecasts. Your own statement points out the needs for such research. But this kind of research is quite costly. The NSB report lists appallingly low numbers given the importance of the research. If the Administration is aware of the urgency for the research, why does it not request more funds from Congress?

a. What was the level of funding for hurricane research in the President's FY09 budget request? What was it in FY08?

b. Do you believe that the budget requests reflect the sense of urgency that you describe in your testimony?

c. The authorizations set forth in this bill are total amounts. So, how should the money be divided between NSF and NOAA to carry out the initiative? Are other "coordinating" federal agencies to receive part of the funding as well? Should they?

A1. Improving hurricane forecasting is a top priority for the Administration and NOAA is implementing this commitment with an emphasis in its hurricane prediction and research. NOAA spends over $300 million a year for hurricane warning and forecast efforts. Reflecting a sense of urgency for improved information, the FY 2009 President's Budget includes a new increase of $19.5 million for modeling improvements, research, and operations across NOAA. In the FY 2008 President's Budget, NOAA requested $10 million for hurricane research. To further expedite these efforts, the Administration recently submitted to Congress a FY 2009 budget amendment for $13 million to support the Hurricane Forecast Improvement Project.

The National Science Foundation and NOAA are formulating a cooperative agreement to improve hurricane forecasting, and to ensure the expertise and facilities of academic and research institutions, and other non-governmental organizations nationwide, are leveraged to address this national-scope challenge. Funding would be allocated in alignment with these enterprise priorities.

Q2. You admit that the hurricane track forecast accuracy has increased by 50 percent since 1990, but that the accuracy of intensity forecasts has not kept pace.

a. Is there a particular reason why the community did not invest time and expertise in intensity tracking?

b. Was figuring out where the hurricane was going considered more important back then compared with the ability to determine the intensity of the hurricane once it hit?

A2. It is critical to first know where the hurricane will go and then determine other aspects of the storm. While complex in its own right, improving track forecasts was an aggressive but attainable goal given the state of the science and computing capacity. We are just now beginning to understand some of the physical processes occurring within a hurricane as it changes in intensity. Complex atmospheric and sea interactions occur on a much smaller scale than can currently be incorporated into operational models. Our priority is to leverage development activities in the research community to understand and forecast hurricane intensity and incorporate successful research into our operations. Additionally, the $13 million provided for NOAA in the recently transmitted budget amendment will accelerate planned improvements in both hurricane track and hurricane intensity forecasts.

Q3. Many different offices within NOAA have experienced similar difficulties of transitioning research to operations. Is that the intent of the Joint Hurricane Testbeds? What do you think is necessary to facilitate cooperation between the research communities and the operations communities in order to reap the benefits of the investment this bill proposed to spend on hurricane research?

A3. The intent behind the Joint Hurricane Testbeds is to facilitate the transfer of research to operations. Testbeds provide a quasi-operational environment of tools, techniques and models, along with the infrastructure to facilitate the transfer of research applications into the operational arena. To better reap the benefits of hurricane research, we believe it is critical to have a coordinated federal, academic, and private sector effort, with the goal of incorporating demonstrated improvements into operations. Testbeds are one component of this coordinated effort and the following are relevant to improve hurricane forecasting:

- NOAA's Joint Hurricane Testbed that is funded through the U.S. Weather Research Program. The Joint Hurricane Testbed supports the testing and transfer of research to operations by the Hurricane Research Division of NOAA and the Tropical Prediction Center/National Hurricane Center in Miami.
- The Developmental Testbed Center, also known as the Weather Research and Forecasting Model testbed, supports the testing and transfer of research to operations of numerical weather prediction of the Earth's atmosphere, including tropical cyclones.
- The DOD–NASA–NOAA Joint Center for Satellite Data Assimilation supports critical efforts to improve our models by improving our ability to provide large amounts of high quality satellite observational data for them, resulting in the best analysis of atmospheric conditions. Developing the best model analysis of the initial state of the atmosphere, including cyclone structure, results in the best model predictions of the atmosphere and better hurricane predictions.

Q4. Are there currently any interagency collaborative efforts between NSF, NOAA and any other agencies on hurricane research? If so, please explain the nature

of these collaborations. How well do NSF and NOAA work together in this regard?

A4. The National Science Foundation (NSF) and NOAA are formulating a cooperative agreement to improve hurricane forecasting and to ensure the expertise and facilities of academic and research institutions and other non-governmental organizations nationwide are leveraged to address this national challenge. NSF is focused on basic research. NOAA has an operational research focus with near-term payoff for improved operational forecasts. In addition to specific coordination of NSF and NOAA research programs, the Federal Coordinator for Meteorological Services and Supporting Research coordinates Federal Hurricane Operations and Research efforts across responsible federal agencies. Other federal collaborative efforts supporting the overall hurricane research effort include the National Ocean Partnership Program and the U.S. Weather Research Program.

Q5. You state in your testimony that in the past year, NOAA has developed the Hurricane Forecast Improvement Project to focus your efforts on improved forecasts of track, intensity, wind fields, and storm surges. Considering that many of these improvements require significant research, not all of which will or should be done in house at NOAA, did you collaborate with other agencies in the development of the project?

A5. The Hurricane Forecast Improvement Project incorporates the planning efforts of: the NOAA Science Advisory Board Hurricane Intensity Research Working Group; the 2006 report of the National Science Foundation (NSF) National Science Board—*Hurricane Warning: The Critical Need for a National Hurricane Research Initiative;* the 2007 report issued by the Office of the Federal Coordinator of Meteorological Services and Supporting Research (OFCM)—*Interagency Strategic Research Plan for Tropical Cyclones—The Way Ahead.* These three elements represented a cross-agency collaboration and incorporated academic vision as well.

NOAA is currently engaging with other key federal agencies, including NSF, the National Aeronautics and Space Administration, the Department of Energy, and the Navy (including the Office of Naval Research) to develop a National Hurricane Research Alliance. This alliance will leverage existing federal hurricane coordination efforts, including those from the OFCM, to manage overall roles and responsibilities (including those of the broader academic community funded by NSF, NOAA, and others), and priorities of the broad set of activities necessary to improve overall accuracy and reliability of hurricane forecasts. Through this Alliance, NOAA will work with the other agencies to maximize the effective use of these considerable non-federal assets in conducting the Initiative's fundamental research, and in developing and disseminating related products and services.

Q6. I notice that the NOAA testimony does not mention the collaboration between NSF (Engineering Directorate and Social, Behavioral and Economic sciences directorate) and NOAA on the joint solicitation on Communicating Hurricane Information. Could you please speak to this new initiative?

A6. This joint solicitation is an outcome of a multi-year discussion between NOAA and NSF. The solicitation is funding research that advances basic information about how people and organizations understand and use warning messages. The testbed for this research is hurricane warnings. The effort is jointly led by NOAA and NSF and is largely funded by NSF. The first awards were made in early July. The joint solicitation required there be at least one investigator from the physical, natural, or engineering sciences and one from the social sciences to ensure cross disciplinary collaboration.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Kelvin K. Droegemeier, Professor of Meteorology, University of Oklahoma; Member, National Science Board; Co-Chair, National Science Board Task Force on Hurricane Science and Engineering

Questions submitted by Chairman Nick Lampson

Q1. Does NOAA's Hurricane Forecasting Improvement Plan address the concerns in the National Science Board Report? If not, what else needs to be done to improve NOAA's Plan?

A1. The NOAA Plan focuses on one of a broad range of concerns—hurricane forecasting—articulated by the Board as needed in a comprehensive National Hurricane Research Initiative. However, there are many areas outside of atmospheric and oceanic sciences that need to be addressed, particularly in the social, behavioral, and economic sciences. Other areas of concern raised in the National Science Board's report include: (1) Impacts—interaction of hurricanes with engineered structures, economic and social impacts of hurricanes and mitigation measures, and interactions of hurricanes with natural ecosystems; (2) Preparedness and Response Measures—assessing and improving the reliance on the built environment, disaster response and recovery, human behavior and risk planning, and evacuation planning; (3) Cross-cutting Activities—computational capability, and training and education programs related to hurricane impacts.

Questions submitted by Chairman Brian Baird

Q1. As you and many of the witnesses stated in their testimony, social science research plays a crucial role in better understanding and improving hurricane preparedness and response.

Q1a. What areas of social and behavioral science research do you consider to be highest priority areas?

A1a. High priority research areas of social and behavioral science identified by the Board include: economic and social impact of hurricanes and mitigation measures, disaster response and recovery, human behavior and risk planning, and evacuation planning.

Q1b. How are the results of such research being translated into operational practice?

A1b. As a most telling example, following Hurricanes Katrina and Rita, NSF supported more than 100 grants. Results from some of these studies have provided emergency planners, responders, and others with key findings ranging from how disasters inflict physical damage to the impact of social factors on evacuation and long-term emotional effects.

Q1c. Have you encountered, or are you aware of any impediments to applying the findings from social and behavioral sciences to disaster planning, recovery and response activities? If so, do you have any suggestions as to how these impediments could be addressed?

A1c. The Hurricane Initiative itself, and, most importantly, the Hurricane Test Bed, could provide a framework for collaboration among traditionally disparate disciplines. The Board notes that communities often are overwhelmed with sometimes conflicting information regarding risk planning and procedures for action. Additionally, training and outreach activities, involving policy- and decision-makers, are needed to ensure that research efforts are appropriately applied, thus meeting the societal demand for protection of life and property and responsible management of resources. Finally, the social impacts of human-induced changes to coastal and offshore vulnerability—ranging from land use development and practices that drastically modify the fate of precipitation runoff to social demographics of communities and their mobility—must be better understood and effectively incorporated into societal decision-making.

Q2. In his testimony Dr. Prevatt stated that increased support for research on strengthening the existing built infrastructure and developing cost effective retrofit and mitigation measures would be the most effective way to reduce damage and economic losses from hurricanes. Would you comment on what priority you would assign to such research and development efforts within the context of a national hurricane research program?

A2. The Board, in its recent report, has assigned a high priority to research on improving the resilience of the built environment. Resiliency of physical and social infrastructure is enormously important for successful disaster response and recovery operations. The establishment and sustainability of lifelines to victims remains one of the greatest challenges following the failure of transportation, power, and communication infrastructures. Research is needed to provide such lifelines, as well as design infrastructures that gracefully degrade, rather than fail indiscriminately, during extreme conditions. A requirement exists for a national engineering assessment of coastal infrastructure and efficacy of current design practice—including levees, sea walls, drainage systems, bridges, water/sewage, power, and communications—to ascertain the associated level of vulnerability to hurricanes. Studies are needed to identify and prioritize the most cost-effective improvements and to develop a national loss reduction strategy that addresses inevitable degradation of built infrastructure. Careful attention also should be paid in infrastructure research to existing building codes and the extent to which recent damage has been a result of noncompliance. Research also is needed to understand coastal erosion and resilience, particularly in relationship to the built environment.

Q3. You note in your testimony the importance of a multi-disciplinary approach to hurricane research and point out that current research tends to be stovepiped. Has the National Science Board taken any action since the release of its hurricane report to address this problem within NSF's hurricane research activities? Overall, what has been the response of NSF thus far to the recommendations of the NSB report?

A3. In recent years NSF has placed a high priority on research related to hurricanes. In FY 2007, NSF awarded approximately $12,400,000 to projects dealing with the geophysical, social, and engineering aspects of hurricane processes and the resultant impacts on society and the environment. This research has included the study of the physical genesis and life cycles of hurricanes, the development of new simulation and forecast models of hurricane processes, the effect of land-falling hurricanes on ecosystems and the natural environment, the impacts on social systems in hurricane impacted areas, the engineering and structural aspects of damage resistant practices in areas prone to hurricane exposure, and damage assessment of facilities and infrastructure in hurricane impacted areas.

Question submitted by Representative Vernon J. Ehlers

Q1. How could the hurricane initiative help encourage development and adoption of necessary building codes?

A1. The Board notes in its report that engineered structures are vulnerable to damage from wind, precipitation, and storm surge, though the impacts are not well understood, particularly at the scale of individual structures. Research therefore is needed to better understand fluid-structure interactions at fine spatial scales, with the coupling of atmospheric and land-surface/built infrastructure models being essential for guiding the creation of improved building designs and construction codes in particularly vulnerable locations. Developing a better understanding of how the land-atmosphere interface impacts hurricane morphology is also needed. Operational risk prediction models, some of which are highly parameterized, should be updated to accommodate the detailed characterization of four-dimensional atmospheric structures that are possible with today's advanced forecast models.

Questions submitted by Representative Mario Diaz-Balart

Q1. Even with better interagency coordination, how do you avoid the stovepipe situation you discuss that is created by the boundaries of the traditional disciplines?

A1. The Hurricane Initiative provides a framework, and the potential outcomes provide an incentive, for collaboration among traditionally disparate disciplines. In FY 2008 NSF and NOAA issued a joint announcement calling for proposals to advance fundamental understanding of the communication of hurricane outlooks, forecasts, watches, and warnings both to decision-makers (i.e., emergency managers, elected officials) and to the general public.

The Board encourages interdisciplinary research, and NSF is experienced at supporting research that crosses disciplinary boundaries. The Hurricane Research Testbed itself is designed specifically to bring multiple disciplines together. The Board's Hurricane Task Force found in our roundtable discussions with the science and engineering community that researchers from multiple disciplines are eager to

work with one another. Workshops and symposia can help bring different groups together, and, accordingly, NSF regularly supports both.

Q2. How are we not using existing hurricane research knowledge effectively, as you say the NSB study finds? You state that current research is of high quality, but it is not adequate. Is this purely a funding issue or is there some major research hurdle standing in the way?

A2. Despite advances made during the past decade in meteorological understanding and prediction, we still know relatively little about the most important aspects of hurricanes from an integrative perspective, including their internal dynamics and interactions with the larger-scale atmosphere and ocean; methods for quantifying and conveying uncertainty and mitigating hurricane impacts; associated short- and long-term consequences on the natural and built environment; and the manner in which society responds before, during and after landfall. Billions of tax dollars have been provided for rescue, recovery, and rebuilding *after* hurricanes strike. Also important is investment in the creation of new knowledge, and *more effective application of existing knowledge* to reduce those enormous public outlays, loss of life, and the associated societal disruption caused by hurricanes. Recognizing the many vital challenges associated with hurricanes in the broader context of natural disasters, the National Science Board has engaged the Nation's experts in science and engineering from government, academia, and industry in an intensive study to identify priorities in fundamental research and complementary applied or mission-driven research, which can improve our Nation's ability to become more resilient to hurricane impacts. The result is "an agenda for action—a National Hurricane Research Initiative—that will provide urgently needed hurricane science and engineering research and education that engages relevant agencies across the Federal Government; involves industry, academia, and other levels of government; establishes highly focused priorities; strengthens disciplinary research; creates multi-disciplinary frameworks for studying the hurricane in an integrative fashion; and stimulates the efficient transfer of research outcomes to operational practice." [1]

Q3. Are there currently any interagency collaborative efforts between NSF, NOAA and any other agencies on hurricane research? If so, please explain the nature of these collaborations. How well do NSF and NOAA work together in this regard?

A3. Yes. The Federal Coordinator for Meteorological Services and Supporting Research (OFCM) coordinates Federal Hurricane Operations and Research efforts across the responsible federal agencies. Additionally, federal agencies, including NOAA, NSF, NASA, and the Navy (including Office of Naval Research) are working to develop a National Hurricane Research Alliance. This Alliance will leverage existing federal hurricane coordination efforts, including those from the Office of the Federal Coordinator Meteorological Services and Supporting Research, to manage overall roles and responsibilities (including those of the broader academic community funded by NSF, NOAA, and others). Through this Alliance, NOAA and NSF will work with the other entities to maximize the effective use of considerable non-federal assets in conducting hurricane research.

Many of the hurricane research efforts conducted to date have had narrow foci and limited coordination across disciplines. This makes it difficult to engage the more challenging questions, the answers to which are not obtainable with short-duration studies. The bottom line is that many of the disciplines for whom hurricanes are an important research challenge (e.g., physical science, engineering, social science, behavioral science, and economics) do not regularly interact, resulting in a myopic view that limits the effectiveness by which problems are formulated and research outcomes can be translated into operational practice. NSF needs to continue to support work and communication across disciplinary boundaries through workshops and by supporting interdisciplinary research approaches.

NSF currently supports merit-reviewed, highly interdisciplinary research and coordinates activities with other relevant agencies, including the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA). NSF is discussing with other agencies their interests and how coordination can be improved, taking into account the priorities related to hurricanes under development by the Disaster Reduction Subcommittee of the National Science and Technology Council's Committee on Environment and Natural Resources Research.

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[1] National Science Board, *HURRICANE WARNING: The Critical Need for a National Hurricane Research Initiative,* (NSB–06–115), Arlington, VA: National Science Foundation, 2007. *http://www.nsf.gov/nsb/publications/index.jsp*

NSF and NOAA, while having different agency missions, do serve to accomplish a common goal related to physical hurricane research—increasing forecast accuracy in order to protect life and property. To that end, NSF and NOAA have recently collaborated to conduct a major field campaign studying internal hurricane dynamics. This project, called the Hurricane Rainband and Intensity Change Experiment (RAINEX), took place in 2005. NSF and NOAA sponsored aircraft were able to sample hurricanes, including Katrina and Rita, in unprecedented detail by using coordinated flights. The results from this work will likely have an impact on understanding rapid intensification periods in hurricanes, which are one of the most crucial aspects of forecasting.

An interagency and international project that will be taking place in August and September 2008 is the THORPEX (The Observing Research and Predictability Experiment) Pacific Asian Regional Campaign (T–PARC). This NSF/DOD/international collaborative effort will follow tropical systems from their formation, through maturity, to their eventual recurvature and downstream effects.

Another main unresolved question about tropical systems is why only a small number of tropical waves and disturbances actually organize and intensify into tropical storms and hurricanes. To further research this topic, NSF, NOAA, DOD, and NASA are discussing a field experiment in the Atlantic Ocean that will study these pre-storm disturbances. While any one of the agencies could approach this topic on their own, the collaboration between them greatly increases the likelihood that the data collected will be sufficient to make large steps forward in our understanding of the topic.

In addition to these observational campaigns, NSF and NOAA researchers have also collaborated on the next generation numerical weather forecasting models for hurricane research. Called the HWRF, or Hurricane Weather Research and Forecasting model, this new model includes significantly increased amounts of data and is run at a much finer scale than previous operational models. Finally, NSF and NOAA recently issued a joint announcement for funding proposals on Communicating Hurricane Information (CHI).

Q4. Assuming a budget that remains flat, where would you suggest the NSF and NOAA cut funding in order to fund their share of the $285 million per year authorized in the H.R. 2407 for this research? And where would you suggest they make cuts in order to fund the $20 million per year for the database requirements?

A4. The Board encourages NSF and NOAA to consider this recommendation in setting priorities for future budgets. NSF establishes its budget priorities through a process that integrates broad-based input provided by the science and engineering community with the overall strategic direction set by the Foundation's leadership through interactions with the Board, OMB, OSTP, Congress, and NOAA and other R&D agencies and institutions.

Q5. The authorizations set forth in this bill are total amounts. So, how should the money be divided between NSF and NOAA to carry out the initiative? Are other "coordinating" federal agencies to receive part of the funding as well? Should they?

A5. In its study, the Board found investments in science and engineering research related to hurricanes and earthquakes were funded by a range of federal agencies (see attachment, Appendix A of the Board's report). The Board proposed new investments in essential areas of science and engineering research for the National Hurricane Research Initiative without reference to federal department or agency funding source.

Attachment

Appendix A

Federal fiscal year budget investments for science and engineering research related to hurricanes and earthquakes by various Federal agencies.* Budget investments are presented in constant 2006-dollar increments of $1,000. Operation costs of satellites, ship and aircraft that may be supporting research are not included. Endnotes provide more detailed explanation on data sources and calculation methods.

U.S. Hurricane and Earthquake Research Funding (2001-2006)
(Thousands, 2006 constant dollars)

	Hurricane							Earthquake	
	NSF	US Navy[a]			NIST	NOAA	USG	NSF	USG
Fiscal Year	Total[1]	ONR Funding[2]	CBLAST Funding[3]	NRL Funding[4]	Total	Total[5]	Estimated Total[6]	Total[8]	Total[9]
2001	4,952	N/A	1,715	1,715	2,567	N/A	228,678	67,858	N/A[10]
2002	5,498	1,800	1,688	N/A	4,711	N/A	225,124	64,918	N/A
2003	4,808	N/A	1,651	N/A	2,989	6,120	228,119	51,594	N/A
2004	4,527	N/A	1,688	N/A	2,482	6,873	214,408	46,259	N/A
2005	9,266	N/A	1,555	N/A	698	8,226	207,381	56,361[7]	127,857[7]
2006	15,050	850	1,000	400	737	8,557	200,800	53,778[7]	118,681[7]
Annual Average[11]	**7,186**	**1,326**	**1,536**	**1,058**	**2,347**	**7,444**	**215,952**	**56,785**	**122,869**

*NSF National Science Foundation
ONR Office of Naval Research
CBLAST Coupled Boundary Layers Air-Sea Transfer Defense Research Initiative
NRL Naval Research Laboratory
NIST National Institute of Standards and Technology
NOAA National Oceanic and Atmospheric Administration
USG U.S. Government-wide

ANSWERS TO POST-HEARING QUESTIONS

Responses by Shuyi S. Chen, Professor of Meteorology and Physical Oceanography, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami

Questions submitted by Chairman Nick Lampson

Q1. There are four major reports on improving hurricane research and forecast mentioned in your testimony. Is there anything different in these other reports from the National Science Board report? Are there things in these other reports that need to be addressed in H.R. 2407?

A1. They all strike the same main point: hurricane research must be a national priority. The reports are similar, but have slightly different emphases given the primary missions of each agency and organization. They all agree that improvement in forecasting requires better understanding and modeling of rapid intensity changes and storm genesis (formation). Consistent with their mission, NOAA HIRWG report placed the prediction of rapid intensity change as the highest priority, which is mostly based on the fact that NOAA's primary responsibility is forecasting, whereas the National Science Board report put emphases on integrating physical science and engineering as well as social science to study hurricane forecasting and response in its entirety. The AGU report focuses on science-based strategy in rebuilding the U.S. Gulf coast after the 2005 hurricane disasters. The OFCM report is mainly concerned with the coordination of operational forecasting, warning, and emergency response. H.R. 2407 covers the whole range of hurricane research.

Q2. What are the current major gaps in research to better forecast hurricanes? Does the proposed legislation H.R. 2407 and NOAA's Hurricane Forecasting Improvement Plan address these needs?

A2. The major gaps in research to better forecast hurricanes are: 1) The fundamental understanding of the predictability of hurricanes and factors limiting the current prediction of hurricane genesis and rapid intensity change; and 2) The effective transfer of knowledge and technology from the research to operations. The NSF-supported basic research at academic institutions is best suited to fill the first gap. The NOAA Hurricane Forecasting Improvement Plan mainly addresses the second.

Questions submitted by Chairman Brian Baird

Q1. As you and many of the witnesses stated in their testimony, social science research plays crucial role in better understanding and improving hurricane preparedness and response. What areas of social and behavioral science research do you consider to be highest priority areas? How are the results of such research being translated into operational practice? Have you encountered, or are you aware of any impediments to applying the findings from social and behavioral sciences to disaster planning, recovery and response activities? If so, do you have any suggestions as to how these impediments could be addressed?

A1. Although I am not a social scientist, I came to recognize the importance of social science in hurricane research through close communication with my social scientist colleagues who are experts on human behavior and response to natural disasters and through my own experience in several recent land-falling hurricane events.

Better understanding of three areas in social science is particularly important and of high priority: 1) how a diverse, complex user population gathers and interprets information (through media, Internet, or word-of-mouth) when responding to an approaching hurricane threat, 2) how experiences in the past, including both real events and false alarms, affect human reaction to forecasts of disastrous events, and 3) how to enhance the willingness of people to invest in protective measures that would lower the costs of low-probability, high-consequence hazards like hurricane hits.

The panic evacuation in Texas during Hurricane Rita in September 2005 and water and gas shortage in South Florida after Hurricane Wilma in October 2005 are vivid examples of failure to anticipate human behavioral responses to hurricane forecasts under different situations, which led to over- and under-preparedness. These were not only consequences of over-warning of Rita in Texas and many false alarms prior to Wilma in South Florida but also a lack of understanding of the psychology of human reactions to disasters.

There has been little implementation of research to operational practice, because social science to this point has only been able to offer broad principles and hypotheses rather than concrete guidance. The combination of the lack of invest-

ment in basic research in this area and the rarity of these high-impact events make it a particularly difficult problem (Meyer 2006[1]).

The impediments are both the lack of basic research on implementable solutions and the lack of training of emergency managers and public officials on the complexity of hurricane impacts on human psychology and organizational behavior. As I mentioned in my testimony, we need to have an integrated hurricane forecast and response system that offers accurate hurricane forecast, a seamless information flow from the forecast to risk assessment, emergency response and ultimately mitigation of hurricane damage. Improved forecasts will reduce false alarms and uncertainty in physical impacts of hurricanes and, therefore reduce over- or under-warnings. Successful implementation of such a system requires education of a new generation of physical and social scientists, technicians, forecasters, government managers, and a guaranteed smooth transition from research to operations.

Q2. In his testimony Dr. Prevatt stated that increased support for research on strengthening the existing built infrastructure and developing cost effective retrofit and mitigation measures would be the most effective way to reduce damage and economic losses from hurricanes. Would you comment on what priority you would assign to such research and development efforts within the context of a national hurricane research program?

A2. Research on strengthening the existing built infrastructure is an important part of the overall effort to reduce physical damages and economic losses from hurricanes. Meanwhile, we must realize that hurricane damage and economic losses are not limited to built infrastructures, but extend to the entire social and economic infrastructure that include information flow, communications, energy and food supplies, and emergency management. The cost for unnecessary evacuation from overwarning, for example, accounts for a major part of economic losses. Citizens who are better prepared by education and proper communication could reduce their losses. It is a highly complex problem that is far beyond built infrastructures alone. We need an integrated forecast, communication, and education system to improve response to hurricanes and mitigation to reduce hurricane damages and economic losses.

Although retrofitting existing built structures could be effective in reducing damage, it is not clear if the current data used in establishing the standards for "strengthening" the existing built structures is adequate. I would give it a high priority second to the research on understanding the impact of landfalling hurricanes in terms of extreme winds and flooding potential at a given area so we can determine the standards by which the existing built structures must be strengthened. A third priority worth mentioning, and one that would advance understanding of both mitigation and evacuation decisions, is the social science of how complex, multi-layered government and private organizations respond to hurricane risk.

Q3. How much of the potential improvement possible in the prediction of hurricane intensity will come from the availability of increasingly more powerful computers, which in turn will permit increasingly smaller computational grid spacing in the simulations you do? Will advances in computer power, which have been steady and continuous, solve the hurricane intensity prediction problem?

A3. Increased computer power is essential to improving hurricane intensity prediction, but must be accompanied by more advanced understanding and knowledge of how to best formulate and design numerical prediction models representing the physical reality of hurricanes. Reduced grid spacing allows us to resolve fine-scale features in hurricanes, e.g., the eye and eyewall, which are critical for hurricane intensity. However, it also presents new challenges because our current knowledge of how various physical processes work in extreme wind conditions, for example, the energy transfer at the air-sea interface with breaking waves, is still very limited. Furthermore, a lack of observations of the fine-scale structure in hurricanes, which hinders our ability to initialize the high-resolution models and validate model predictions, is another major challenge. Improvement in numerical models, high performance computers, innovative observations and data assimilation of the hurricane structure will have to be achieved in concert to guarantee substantive progress in predicting hurricane intensity change. Basic research and human resources are therefore more critical. We must educate and train the next generation of scientists, engineers, and forecasters at both undergraduate and graduate levels to ensure in-

[1] Meyer, Robert, "Why we Under Prepare for Hazards," in Ronald J. Daniels, Donald F. Kettl, and Howard Kunreuther (eds.), *On Risk and Disaster: Lessons from Hurricane Katrina,* University of Pennsylvania Press, pp. 153–174.

creased computer power will indeed yield societal benefit in prediction of hurricane intensity.

Questions submitted by Representative Mario Diaz-Balart

Q1. How much of the University of Miami's hurricane research is funded by NOAA? NSF? Are any of the grants jointly funded or is there other joint collaboration between the university and these federal agencies?

A1. The majority of the hurricane research funding at the University of Miami is from the NSF, ONR, and NASA. NOAA funds some research-to-operation projects, but relatively little basic research at universities in general. From my own experience of working on research related to better understanding and improving hurricane intensity forecasts at the University of Miami over the last 10 years, I have never received a direct research grant from NOAA.

Q2. As a representative of the Rosenstiel School, how would you characterize the level of cooperation between the different federal agencies currently engaged in hurricane research?

A2. The cooperation among federal agencies has been good at the program level. For example, NOAA has supported the hurricane research programs led by other agencies though its airborne observational capability, as in the Hurricane Rainband and Intensity Change Experiment (RAINEX) funded by NSF, the Coupled Boundary Layer Air-Sea Transfer (CBLAST)–Hurricane funded by ONR, and the Tropical Cloud System Processes (TCSP) funded by NASA.

Q2a. Do the proposed interagency and multi-disciplinary approaches in H.R. 2407 address all of your concerns?

A2a. I believe that H.R. 2407 will make the cooperation stronger by providing a coherent and integrated approach to hurricane research from the start.

Q2b. Do you have specific suggestions sitting on your side of the table that would improve your institution's interaction with the "interagency research efforts" as they currently exist?

A2b. Cooperation between agencies should not be limited to NSF and NOAA, but also others like ONR and NASA that are supporting hurricane research, as well as FEMA that can insure the improved hurricane forecast is effectively benefiting the emergency response and recovery efforts.

Q3. You mention the capabilities of European forecast models. How much collaboration is there between your institution and other countries? How much international cooperation do you see happening on the federal level on this type of research? Would you advocate for greater interactions with other country's research programs?

A3. Data sharing has certainly benefited all countries. This is particularly evident in both space- and Earth-based observing systems. I am absolutely supportive for more of the interactions among scientists from all countries. The collaboration has to be based on science. International scientific collaboration and coordination under federal support should be initiated by scientists. One area of immediate reward is the improvement in global model forecasts from other countries, e.g., the European Center, can affect the ensemble hurricane track forecasts. The real time ensemble forecasts from the European Center are not publicly available outside the European Union; users in the U.S. need to purchase these forecasts. Hence there are very few groups in the U.S. that are using the forecasts from the European Center model, which is unfortunate since these are arguably some of the best forecasts in the world.

Q4. The authorizations set forth in this bill are total amounts. So, how should the money be divided between NSF and NOAA to carry out the initiative? Are other "coordinating" federal agencies to receive part of the funding as well? Should they?

A4. NSF and NOAA should be co-lead agencies to address the hurricane problem from both basic research and transfer of research outcomes to operational practice. The funding should be divided 50/50 between the two agencies. The role of NSF should be to support the fundamental research (where a greater investment is needed), and the role of NOAA should be to support the transfer of research to operations. Other agencies can also contribute and play important roles based on their

traditional research interests (e.g., NASA in advancement of new remote sensing technology, ONR in air-sea coupling).

ANSWERS TO POST-HEARING QUESTIONS

Responses by David O. Prevatt, Assistant Professor, Department of Civil and Coastal Engineering, University of Florida, Gainesville

Questions submitted by Chairman Brian Baird

Q1. As you and many of the witnesses stated in their testimony, social science research plays a crucial role in better understanding and improving hurricane preparedness and response. What areas of social and behavioral science research do you consider to be highest priority areas?

A1. Social Science research plays a key role in getting homeowners to understand the technological options available and the financial impact of improving the hurricane resistance of their new or existing homes. I would put the need to educate the public on these options at the top of the list of needed research. We need to develop a much better understanding of the incentive mechanisms that stir homeowners to action. What is also needed is the social mechanisms to make homeowners aware of the risks imposed by such high impact, low frequency events like hurricanes. The risks must be conveyed not only from the individual homeowner's perspective but also as aggregated to the community risks—it is the price to pay for living in a region threatened by a known natural hazard.

The basis for this position is that despite dozens of new technologies that have been tested and shown to significantly improve the hurricane resistance of homes, these are not being readily implemented. Unfortunately, we are faced with educating the public about how homes are constructed and how/why buildings react the way they do to the high wind loads associated with a hurricane event. This is not necessarily an engineering lecture; rather, it is best presented as a logical or intuitive discussion of the performance of a building under high wind conditions.

The frequency of such discussion need to be addressed, and emphasis needs to be placed on educating the next generation of homeowners—our children who are more likely to embrace the technologies if they were exposed to knowledge of the risk from their childhood. (e.g., seat belt wearing in vehicles is almost 100 percent now, compared to the relatively small percentages of wearers when the legislation was originally introduced). People seem to accept the need to carry fire insurance, and some will even purchase fire extinguishers for their home. Few seem to understand their probability of sustaining damage from a flood or windstorm is, in many cases, greater than their risk of having a fire. Clearly, there's been some success in communicating fire risk and spurring individuals' actions that needs to be translated to natural hazards, like hurricanes, floods, and other windstorms.

Social science research is also needed to develop the most effective communication messages that persuade the majority of people to evacuate in advance of a hurricane. Conversely, social science research may be necessary to convince others not to evacuate when they are in no danger but their presence on the highways may add additional risks to themselves. The publicity encouraging evacuation should be aimed at those least likely to evacuate and in most danger—minorities, lower income, people without cars, for example—and designed by advertisers who know how to reach those groups. There is research underway about what to do about pets. It should be continued.

More social science research is needed to reduce post-hurricane psychological impacts. The use of psychological debriefing has been called into question by research findings showing that it may not change outcomes or may even worsen outcomes for some. However, there is still a need for further research on what are the most effective post-disaster interventions that would help mitigate the development of later problems such as post-traumatic stress disorder, depression, and other mental health problems.

Q2. How are the results of such research being translated into operational practice?

A2. Several states have programs in existence. Efforts are underway to educate and train design professionals architects and engineers and builders in hurricane-resistant construction. This key group works with homeowners during renovations and repairs and they can communicate the options and benefits of hurricane-resistant construction. FEMA identified and targeted this group for outreach and training over the last 10 years, providing its "Coastal Construction Manual" (FEMA 55) courses and other guidance materials.

However, very little training effort is aimed at new students who can be most influenced by this knowledge. The limited research support for faculty in our tertiary academic institutions has stifled research and removed incentives for faculty to pur-

sue these areas and so the education is not supported. In Florida, some tools that are available to assist in this process are:

- The computer-based **Home Structure Rating System (HSRS)** that was developed by the *University of Florida for the Florida Department of Financial Services* can provide an evaluation of the likelihood of a home in a given location being in the path of a hurricane. The HSRS analyzes the structural characteristics of the existing building, compares the structure to the expected wind loads, and provides the homeowner with a prioritized list of home improvements to be considered along with the cost range for the improvements and the reduction in wind damage insurance premium that can be expected.
- Four regional **Windstorm Damage Mitigation Training and Demonstration Centers (known as "Hurricane Houses")** designed and constructed by the University of Florida located in coastal areas across Florida. The Centers are located in Escambia, St. Johns, St. Lucie, and Broward Counties. These Centers are staffed by Florida Cooperative Extension Service faculty and form the statewide infrastructure that can reach the public with the necessary information and education programs. (Funding for the two remaining Centers to be located on Florida's Gulf Coast thus completing statewide coverage has not yet been provided.)
- The **My Safe Florida Home Program** operated by the **Florida Department of Financial Services** has provided free home inspections for thousands of homeowners in Florida—primarily in the coastal areas. These inspections are performed by certified inspectors that have been trained by the Florida Cooperative Extension Service faculty using the training-room facilities available at the Hurricane Houses. The data captured by the inspections results in a list of wind-resistant home improvements that the owner should consider, estimates of the cost of the improvements, and estimates of the reduction in wind insurance premium that may be expected.

Q3. Have you encountered, or are you aware of any impediments to applying the findings from social and behavioral sciences to disaster planning, recovery and response activities? If so, do you have any suggestions as to how these impediments could be addressed?

A3. **Incentive Mechanisms**

The Hurricane Houses in Florida are visited by thousands of people each year. We know these people come to the Centers for a variety of reasons and carry away with them added knowledge about the effect of wind on buildings and the alternatives available for retrofitting their homes to prevent or minimize wind damage. However, due to lack of adequate resources, the Centers are unable to conduct follow-up surveys or face-to-face interviews with the visitors about what did or did not motivate them to take action to harden their homes against wind damage. We know by the interest in the Hurricane Houses that the public wants the information; we do not currently know what has worked and what didn't work to stimulate the visitors to invest in wind resistant technology for their home.

Limited Technology Transfer Support

- The fact that there are currently only four out of six planned Hurricane Houses and that there is no central statewide outreach coordination function are testimony to the low priority that Florida has assigned to the social science research that will help us focus our message to the public about reducing potential property losses from Hurricane events.
- The situation in other states is in far worse shape than Florida. I am aware of only one hurricane demonstration building in Charleston, SC, run by the SC Sea Grant Consortium and which is no longer has a permanent staff. Another demonstration building in Baton Rouge Louisiana is also in operation run by faculty of the Louisiana State University.

Q4. In your testimony, you raise the importance of applying existing knowledge we have to design and retrofit structures to resist hurricane damage. What kind of research is being done to determine the most cost effective ways to retrofit?

A4. The academic engineering community is undertaking research on how to understand the physical effects of hurricane winds, rain and storm surge and to design structures and materials to be more wind and flood resistant. But there is little funding to support efforts to translate these results into codes and the construction/retrofit market. A key role for the Federal Government in this arena is to help bet-

ter identify and coordinate basic research, and provide mechanisms to get the results translated into action. The hurricane research initiative should focus primarily on basic research, but perhaps translation of results should not be an emphasis. That function could be performed by existing programs, such as the National Windstorm Impact Reduction Program (NWIRP), which Congress established in 2004 for the purpose of coordinating windstorm-related research and putting results into practice. The agencies involved in NWIRP have not received direct funding for the program, but with proper support, it could function well in coordinating research on retrofit methods developed through the hurricane initiative and translating results into the broader user community.

Although progress is being made on hurricane-resistant design, more support is needed to fund research to improve not only building codes, but other mitigation techniques and best practices. Building codes are a consensus document developed through participation of all parties in the construction industry. However, the building code sets out minimum legal limits of construction. The first challenge we face is that building codes today rely upon research that is over 30 to 40 years old, and very little new funding has been provided to develop new knowledge or upgrade existing ones. Second, every significant hurricane shows us that codes are not the only solution. Building a structure to meet code will help ensure the structure remains standing in a design-level event; it does not, however, guarantee that no significant damage will occur. Codes are primarily aimed minimizing loss of life; to minimize property damage, mitigation techniques that go beyond codes must be used.

So, while there is a need for research to improve codes, there are also other areas that must be researched and developed, including, risk-wise land use, comprehensive planning, code-plus techniques, inspector training and education, etc. These tools are needed alongside better codes to substantially reduce losses.

Q5. Are you aware of any social and behavioral science research being done relative to the issue of designing and retrofitting homes and other buildings?

A5. I am not familiar with this research but would recommend that resources of the National Hazards Center in Boulder, CO be used (Kathleen Tierney) Also, Ms. Leslie Chapman-Henderson of the Federal Alliance for Safe Homes—FLASH® would be a useful resource person as well.

Question submitted by Representative Vernon J. Ehlers

Q1. How could the hurricane initiative help encourage development and adoption of necessary building codes?

A1. Building codes are a start, but there is more to this that should be addressed. As was mentioned in response to Congressman Baird's last question, building codes are a consensus on minimum legal limits of construction. Building a structure to meet code will help ensure the structure remains standing in a design-level event; it does not, however, guarantee that no significant damage will occur. Codes are primarily aimed minimizing loss of life; to minimize property damage, mitigation techniques that go beyond codes must be used.

The hurricane research initiative can support both development of better codes through enhanced funding for basic hurricane research, as well as aid research into hazard mitigation techniques and mitigation planning. The latter could include support of social science researchers who examine community and individual decision-making with regard to hurricanes and related hazards. The science and engineering communities can develop a superior code, but it will be ineffective if communities fail to adopt it and invest their limited resources in implementing and enforcing it. The proposed hurricane research initiative includes support in this area.

Some examples of other subject areas that the initiative could address are:

- Effective mitigation of homes—Destructive testing of existing homes to compare as-built resistance vs. mitigated.
- Aging effects—long-term durability and performance issues, performance degradation of older homes and components.
- Emerging vulnerability issues—economic losses to newer homes due to water penetration.
- Full-scale testing of whole systems (both lab specimens and in-field real homes) subjected to controlled hurricane environments.
- Simulating real wind turbulence and rain conditions as measured in the field.

To be successful, the above research must fully engage all stakeholder groups (product manufacturers, home builders associations, certified test labs, codes and standards officials).

Questions submitted by Representative Mario Diaz-Balart

Q1. You mention in your testimony that "limited research and technology transfer support" focused on strengthening the existing built infrastructure are the reasons that mitigating damage and economic loss from hurricanes has been poor. Please expand on what you mean by technology transfer support and why this is a problem.

A1. Without technology transfer of methods to strengthen existing infrastructure we continue to accept that the majority of our structures will suffer severely in hurricanes. This need not be so. We need to ensure that the public and decision-makers understand that we do not have to suffer the current impacts from wind storms and associated water penetration problems. This could be accomplished through a dedicated research, training and information providing program. For example, limited work is currently going into wind uplift performance testing, which results in new technologies that are incorporated into the International Code Council's guidance for manufacturers and others. Researchers need to conduct additional work on testing methods to assist the industry in validating the concepts contained in the guidance.

With proper support from Congress and the Administration, the National Windstorm Impact Reduction Program (NWIRP) could help improve government coordination of research (including the hurricane research initiative) and subsequent technology transfer. In other words, the hurricane research initiative could focus more of its resources on fundamental research and research-to-operations (e.g., forecasts), while the NWIRP could focus on technology transfer and application of results by Federal, State, and local governments, code and standard development organizations, design professionals, and other stakeholders.

Q2. How much of the University of Florida's hurricane research is funded by NOAA? NSF? Are any of the grants jointly funded or is there other joint collaboration between the university and these federal agencies?

A2.

SPONSORING AGENCY	(1996 - 2008) RESEARCH	AVERAGE ANNUAL $
NSF	970,749	74,673
NOAA/DOC	1,662,732	127,902
FDOT	913,738	70,288
OTHER STATE	4,980,734	383,133
PRIVATE	1,184,128	91,087
FEMA	106,608	8,201
TOTAL	**9,818,689**	**755,284**

Research support to University of Florida from NOAA and the NSF has totaled approximately $2.6 million dollars over the 12-year period, 1996 through 2008. This figure represents 27 percent of the total external research support that the University of Florida received for hurricane-related research over that period. The average annual NSF support was $75,000 per year and support from the Department of Commerce/NOAA was $128,000 per year. About 60 percent of UF's external funds to support hurricane research have come from State agencies, such as Florida Department of Transportation (FDOT), the Department of Community Affairs, and the Department of Insurance.

Such limited research support is alarming, given that as the flagship university in the State of Florida, the University of Florida with its 50,000 student body arguably has been at the forefront of most significant hurricane related research for the

State of Florida. Despite this, only 35 researchers (Principal Investigator and Co-PIs) have received external funding to pursue hurricane research in the past 12 years. Further, the research expenditure is minimal compared to the costs of hurricane damage wrought by most recent storms (Hurricane Andrew -$30 billion, Charlie, Frances, Ivan, Jeanne, Dennis, Katrina, Rita and Wilma), it is not surprising therefore that current trends show increasing annual economic losses from hurricanes,

Q3. Speaking as a representative of the University of Florida, how would you characterize the level of cooperation between the different federal agencies currently engaged in hurricane research? Do the proposed interagency and multi-disciplinary approaches in H.R. 2407 address all of your concerns? So you have specific suggestions sitting on your side of the table that would improve your institution's interaction with the interagency research efforts as they currently exist?

A3. In some respects, federal agencies do cooperate well on hurricane-related activities, but research and loss reduction programs are areas where coordination could be improved. Agencies have varied existing authorities concerning hurricanes, and while some coordination occurs through the National Science and Technology Council's Subcommittee on Disaster Reduction, most agencies concentrate on activities that fulfill their specific missions. This limits the resources that can go into fundamental research and comprehensive, interagency efforts to reduce hurricane-related losses.

Programs dedicated solely to hazard loss reduction research and development (R&D) receive the smallest share of R&D funds from the Federal Government. The largest fraction goes to basic and applied research programs at the NSF, NOAA and NASA. The second largest category is operational support R&D, focused almost exclusively on weather-related hazards.

The largest fraction of R&D spending supports work on weather hazards and broadly related research on climatology, atmospheric science, and oceanography. The hurricane initiative proposed in H.R.2407 proposes to continue this trend. The second largest category of R&D funding—a distant second—is research on earthquakes. *While losses from weather-related hazards are estimated to be approximately twice as large as those from earthquakes, the allocation of R&D funds between these categories differs by more than a factor of 10 in favor of earthquake research.*

Closer examination of the funding for weather-related hazard R&D shows that most of the effort is focused on short-term prediction efforts, which have limited loss reduction potential within the full range of losses from natural hazards. Prediction can generally move individuals out of harm's way, but R&D focused on long-term loss reduction strategies could improve the resilience of communities and infrastructure, protecting lives and property in a far more substantial way.

While H.R. 2407 begins to address the disparity in funding for hurricane research, the legislation needs to better address coordination of efforts. For the hurricane research initiative to be successful in meeting its goals, there needs to be ongoing communication and coordination among the parties involved. There should be a mechanism for federal agencies to coordinate research and operational activities concerning hurricanes, track progress in meeting the initiative's goals, and ensure research results are being disseminated and used to reduce hurricane-related damages. Academic researchers, State and local officials, code groups, and other stakeholders should also have a mechanism to review the initiative's progress, identify gaps in current research, and bring forward new issues that must be addressed. One option Congress may consider is to give the hurricane research initiative a formal structure to accomplish all of this. The National Earthquake Hazards Reduction Program is an excellent model for organizing research and applied efforts across federal agencies, the academic community, and other non-federal sectors. Alternatively, there may be other existing programs, such as NWIRP, where these coordination functions can be incorporated, preserving maximum funding for research and related activities.

Q4. This bill would require the development of a National Infrastructure Database. Considering the national security implications of a single database that contains the location of every vulnerable building, road, utility, etc., in the country and the attendant requirements that would be established in order to access it, how could such a database be developed that would not compromise the safety and security of people living in these vulnerable structures?

A4. The Federal Government has several existing programs aimed at inventorying and characterizing the built environment. For example, in developing its loss estimation software, HAZUS, FEMA compiled initial building inventory data for the Nation, which is supplemented by more detailed data by State or local users. FEMA

recognized early on the great challenge in creating national data sets at the detail necessary to estimate hazard-related losses and develop meaningful mitigation actions. More recently, the U.S. Army Corps of Engineers has been tasked with developing a national levee database, which will include not only federal levees but structures built by State and local governments and private interests. Not surprisingly, it will take many years (and millions of dollars) for this database to be completed. Given the challenges inherent to developing a "National Infrastructure Database," it may be more advantageous to focus on developing a database or centralized clearinghouse of existing infrastructure information and ensure it is available to the researchers, agencies, and other groups engaged in the hurricane research initiative.

Q4a. The authorizations set forth in this bill are total amounts. So, how should the money be divided between NSF and NOAA to carry out the initiative? Are other "coordinating" federal agencies part of the funding as well? Should they?

A4a. Most should go to NSF, but agencies participating in the initiative (e.g., NOAA) need some support to fund intramural research and related activities. Further details of my proposals on allocation are included in my written testimony.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Stephen P. Leatherman, Chair Professor and Director, International Hurricane Research Center & Laboratory for Coastal Research, Florida International University

Questions submitted by Chairman Nick Lampson

Q1. What are the current major gaps in research to better forecast hurricanes? Does the proposed legislation H.R. 2407 and NOAA's Hurricane Forecasting Improvement Plan address these needs?

A1. A major problem in better forecasting hurricane intensity is understanding the vertical transport of energy through turbulence in the hurricane wind field. Turbulent eddies exist at a range of scales, which are smaller than a two kilometer grid—such a fine grid would require considerable more computer power than presently available and at phenomenal expense.

Questions submitted by Chairman Brian Baird

Q1. As you and many of the witnesses stated in their testimony, social science research plays a crucial role in better understanding and improving hurricane preparedness and response. What areas of social and behavioral science research do you consider to be highest priority areas? How are the results of such research being translated into operational practice? Have you encountered, or are you aware of any impediments to applying the findings from social and behavioral sciences to disaster planning, recovery and response activities? If so, do you have any suggestions as to how these impediments could be addressed?

A1. Two major areas to be addressed by social scientists are mitigation and evacuation. Recently an IHRC coastal resource economist developed the first quantitative evacuation model, which when fully developed, will provide considerable guidance regarding hurricane forecasts with respect to individual decision-making. The public has little knowledge of building safety in windstorms and people largely select houses based on the number of bedrooms, bathrooms, location and appearance. In addition it has been problematic to get the public to mitigate the windstorm hazard, largely because of the cost and lack of information of what can be done. The Wall of Wind research can demonstrate the value of new products and technologies to make your house hurricane resistant and those that are cost effective. The best way to transfer this information to the public is through the mass media of TV as backed up with detailed information on a web site, which is another goal of the IHRC.

Q2. In his testimony Dr. Prevatt stated that increased support for research on strengthening the existing built infrastructure and developing cost effective retrofit and mitigation measures would be the most effective way to reduce damage and economic losses from hurricanes. Would you comment on what priority you would assign to such research and development efforts within the context of a national hurricane research program?

A2. Approximately 99 percent of the problem is strengthening existing houses through retrofitting as only one percent of the building stock is new homes. More than 70 companies, including DuPont and 3M, have requested that we test their new products and technologies that could be used to mitigate hurricane damage in a cost effective manner.

Q3. How much of the potential improvement possible in the prediction of hurricane intensity will come from the availability of increasingly more powerful computers, which in turn will permit increasingly smaller computational grid spacing in the numerical simulations you do? Will advances in computer power, which have been steady and continuous, solve the hurricane intensity prediction problem?

A3. More powerful computers are necessary, but not sufficient, for improvements in the prediction of hurricane intensity; this is a much more difficult problem than the landfall area forecast, which is reaching the limits of predictability.

Question submitted by Representative Vernon J. Ehlers

Q1. How could the hurricane initiative help encourage development and adoption of necessary building codes?

A1. Better building codes will follow from research that focuses on how things break—the purpose of the full-scale, destructive testing by the Wall of Wind hurricane simulator. At present, we have only anecdotal evidence from post-storm inspections and empiricism (equations, not real data) for the establishment of building codes.

Questions submitted by Representative Mario Diaz-Balart

Q1. You discuss FIU's work with NOAA, but how much work does FIU do with NSF with regards to hurricane research? Do you see close collaboration between the two agencies? If so, how is this working? If not, do you think there should be collaboration?

A1. FIU has received some grants over the years from NSF; presently we have a $200k grant for wind engineering research (e.g., Wall of Wind) and about the same amount for atmospheric science research. In addition, we have recently been notified of a new award of $390k for socioeconomic research. NSF does not have an integrated hurricane research program; these grants come from difference divisions of NSF. Also, the level of funding from NSF is generally constrained.

Q2. Your testimony indicates that "understanding air-sea interactions" should be a medium priority versus a high priority. Likewise, you place "improved observations" as a high priority, as opposed to the National Science Board's recommendation that it be a medium priority. What is your rational for these differences in priority rankings?

A2. Air-sea interactions is very important with respect to hurricane intensification (deserves a high priority), but air-sea interaction research can also involve many other areas of far less importance. We gave a high priority rating to observations, especially for field measurements of storm surges so that the models can be calibrated and verified, which has not been done in the past. Also, direct measurements of storm surges are important in partitioning the damage from water vs. wind, which continues to be a major issue in insurance claims as evidenced by Hurricane Katrina.

Q3. Some of the research your institution conducts is Florida-oriented, but would seem to have national implications—specifically the work you are doing in materials, methodologies and techniques related to housing in hurricane prone areas. Considering that the work is partially funded by the private sector, how much of the results of your research can you disseminate for public use?

A3. All of the research that is being conducted by FIU will benefit the public. We are conducting some proprietary research of new hurricane mitigation products and technologies for private companies where there are patents pending. However, this research will benefit the public if these new products prove to be cost effective in strengthening houses and businesses.

Q4. In your written testimony, you list some of the areas in which FIU is currently conducting research. This includes an assessment of the social consequences and the human impacts of hurricanes, specifically how they affect perceptions and attitudes influencing critical issues such as evacuation.

a. Have you done any work on the complementary side, of government planning for effectively responding to hurricane-caused disasters?

b. How receptive are emergency managers at the local, State and national levels to suggestions, comments or criticisms? Do you see their perceptions and attitudes influencing not only their planning for emergency situations, but also their actually responding to them?

A4a,b. Professor Dario Moreno at FIU and the Metropolitan Center have conducted some research regarding government planning, especially involving evacuations. One case study involved the evacuation that occurred and costs incurred based on the forecast of Hurricane Charley in 2004 making landfall in the Tampa area.

Q5. The authorizations set forth in this bill are total amounts. So, how should the money be divided between NSF and NOAA to carry out the initiative? Are other "coordinating" federal agencies to receive part of the funding as well? Should they?

A5. FIU believes that NIST should be coordinating agency.