BRIDGE SAFETY: NEXT STEPS TO PROTECT THE NATION'S CRITICAL INFRASTRUCTURE

HEARING

BEFORE THE

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HOUSE OF REPRESENTATIVES

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BRIDGE SAFETY: NEXT STEPS TO PROTECT THE NATION'S CRITICAL INFRASTRUCTURE

WEDNESDAY, SEPTEMBER 19, 2007

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Committee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Bart Gordon [Chairman of the Committee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
RANKING MEMBER

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The Committee on Science and Technology

Hearing on:

Bridge Safety: Next Steps to Protect the Nation's Critical Infrastructure

2318 Rayburn House Office Building
Washington D.C.

September 19, 2007
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

WITNESS LIST

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Mr. Benjamin Tang
Principal Bridge Engineer
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Federal Highway Administration of the U.S. Department of Transportation

Mr. Harry Lee James
Deputy Executive Director and Chief Engineer
Mississippi Department of Transportation

Dr. Kevin Womack
Director , Utah Transportation Center
Professor of Civil and Environmental Engineering
Utah State University

Mr. Mark Bernhardt
Director, Facility Inspection
Burgess & Niple, Inc.

HEARING CHARTER

COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

Bridge Safety: Next Steps to Protect the Nation's Critical Infrastructure

WEDNESDAY, SEPTEMBER 19, 2007
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

I. Purpose

On Wednesday, September 19, 2007, the Committee on Science and Technology will hold a hearing entitled *"Bridge Safety: Next Steps to Protect the Nation's Critical Infrastructure"* to examine research and development activities to improve the safety of the Nation's bridges. The hearing will explore the current state of bridge-related research, including government and academic research into materials, design elements, and testing and inspection technologies. Witnesses will also discuss future research priorities for building improved bridge infrastructure and maintaining current bridges to avoid catastrophic failure.

II. Witnesses

Mr. Dennis Judycki is the Associate Administrator for Research, Development, and Technology at the Federal Highway Administration (FHWA) of the U.S. Department of Transportation (U.S. DOT) and Director of U.S. DOT's Turner-Fairbank Highway Research Center (TFHRC).

Mr. Benjamin Tang is a Principal Bridge Engineer for the Office of Bridge Technology at the Federal Highway Administration of the U.S. DOT.

Dr. Kevin Womack is the Director of the Utah Transportation Center and Professor of Civil and Environmental Engineering at Utah State University.

Mr. Harry Lee James is the Deputy Executive Director and Chief Engineer for the Mississippi Department of Transportation.

Mr. Mark Bernhardt is the Director of Facility Inspection for Burgess & Niple, an engineering firm.

III. Brief Overview

- Structural problems, both major and minor, plague a significant portion of bridges in the United States. According to the U.S. Department of Transportation's National Bridge Inventory, 73,764 bridges around the U.S. (12.4 percent of all bridges) were classified as "structurally deficient" in 2006, including the bridge that collapsed in Minnesota. The American Society of Civil Engineers (ASCE) in 2005 gave the Nation's bridge infrastructure a "C" grade in its *Report Card for America's Infrastructure* because of the large number of deficient bridges. However, the definition of structural deficiency is broad, and can cover everything from non-structural paving issues to serious flaws. State and local inspectors are responsible for determining which bridges need the most immediate attention.
- The challenge for policy-makers at the State, local, and federal level is to determine which bridges are the highest priority for repairs given limited funding. ASCE estimates that repairing every deficient bridge across the Nation would cost $9.4 billion per year for 20 years. Inspectors use a variety of methods to determine if a bridge has immediate need of repair, including visual inspection, sensors, and other non-destructive testing technologies. The existing methods are imperfect, however, and additional research is needed to develop methods that will provide better quality data on which bridges are in greatest need of immediate repair.

- The Federal Highway Administration, State highway administrations, and universities are sponsoring and carrying out research to improve bridge design, maintenance, and inspections. Current research covers a variety of fields, including materials, engineering design, technology development, and modeling. However, transferring successful technologies to end-users such as state highway administration officials is challenging because of cost concerns and training issues for advanced technology.
- Additional research is needed to better understand the current and future demands on bridges. Traffic loads are significantly higher than when many of the country's bridges were built, especially from truck traffic. FHWA is supporting research to design the "Bridge of the Future" with the goal of a century-long lifespan. This and similar projects should include projections for bridge usage throughout the intended lifespan to ensure that the bridge meets users' needs.

IV. Issues and Concerns

How are bridges currently tested for safety, and how effective are current testing methods and technologies? What technologies and techniques currently exist to improve bridges' structural integrity? States are currently responsible for all bridge inspections, which must be carried out biennially under the National Bridge Inspection Standards (NBIS), which are enforced by FHWA. If a bridge is deemed potentially problematic, inspectors can increase the frequency of evaluations. Approximately twelve percent of bridges are inspected annually. Inspectors examine the bridge deck (primary travel surface), superstructure (which supports the deck), and substructure (which supports the superstructure). Each component is given a rating based on its current condition, ranging from excellent to failed or out of service. If the bridge gets less than 50 points in its overall rating, it can be classified as structurally deficient. For reference, before it collapsed, the I–35W bridge in Minneapolis received a score of 50.

Some technology is currently in use to aid inspectors in their assessments of bridges, but generally bridge inspectors depend on visual observations to determine if a bridge is deficient in any category. Bridge inspectors are trained through university programs and also must complete required courses through FHWA's National Highway Institute (NHI). These courses are also used to deliver information about new technologies emerging from the U.S. DOT.

What future research is needed in the overall field of bridge safety, and how can engineers insure that new technologies are an improvement on the current state-of-the-art? Current bridge research covers three general fields: structural engineering, materials, and inspection technologies. Within these research areas, many different projects are carried out or funded by universities, State departments of transportation, and the Federal Government. Some private research, especially in the area of technology design and development, is also carried out by industry. Research priorities are generally guided by end-user needs, and the transportation research community has a strong, centralized structure for sharing both research results and technology needs. The Transportation Research Board (TRB), part of the National Research Council (NRC), hosts an annual meeting and other smaller events to facilitate collaboration among researchers and end users that is a primary source of information on research priorities. Following the bridge collapse in Minnesota, TRB put a greater focus on the specific field of bridge safety and announced that its 2008 annual meeting would highlight the issue of aging infrastructure. AASHTO also convenes a bridge committee comprised of State highway officials who are able to discuss needs specific to their states.

FHWA is also working on their Bridge of the Future project, which aims to use innovative designs and materials to build a bridge that will have a lifespan of at least a century (compared to current 25- to 50-year lifespans). However, the new designs, materials, and technologies that are developed through these research projects will only be useful if they are able to meet the long-term needs of users. Many current bridges—81,257 in 2007—are functionally obsolete because engineers were unable to accurately predict the types of traffic loads throughout the bridge's intended lifespan.

How can non-destructive testing of existing bridges and lessons from the Minnesota collapse be used to determine which bridges are the most susceptible to catastrophic failure? Currently, bridge inspectors rely primarily on visual inspections to determine whether bridges are in need of repair. While these inspectors go through rigorous training and take regular refresher courses to keep their skills up to date, there are obvious limits to inspections which cover only surface features of the bridges. New technologies are being introduced to help inspectors see into the structural elements of bridges so that they may better determine the overall strength and integrity. But there are barriers to adoption of these new technologies. Many are expensive and well outside the budget of state highway administrations. Others take highly technical training to operate effectively and are too difficult for busy bridge inspectors to learn to use. Some technologies also require near continuous monitoring or modeling to identify potential problems. Additional research is needed to develop technologies for non-destructive testing of bridges that are effective and efficient for bridge inspectors so that catastrophic failures can be predicted before they happen.

What technology transfer programs exist at FHWA and university transportation research centers, and how effective are those programs? In transportation fields, technology transfer is a special challenge because no solution works well for everyone. Differences in traffic loads, climate, size and shape, and other bridge characteristics mean that new engineering designs, materials, and technologies may work well for a bridge engineer in California but not in New York or Florida. Thus, technology transfer efforts must include both determining the customer's unique needs and transferring the appropriate technology. For the former, FHWA and the University Transportation Centers depend on organizations of end-users, including TRB and AASHTO, to facilitate discussions of technology needs. The strong participation in these groups means that end-users are making their needs known to the appropriate people, but technology adoption remains slow. FHWA programs to encourage the adoption of new technology include seminars and discussions at TRB events and courses offered at the National Highway Institute (NHI) to train engineers and inspectors in the use of new technology.

V. Background

The collapse of the I–35W bridge in Minnesota was, unfortunately, not the first of its kind. In 1967, a bridge from West Virginia to Ohio collapsed, killing dozens of people and spurring the Federal Highway Administration to standardize inspections of bridges to avoid future tragedies. The National Bridge Inspection System now uses a point system to help state inspectors and the Federal Government determine which bridges are in greatest need of repair. On a 100 point scale, bridges that score less than 50 points are described as "structurally deficient." Some bridges are also classified as "functionally obsolete" meaning that they are unable to perform to the current necessary traffic capacity. These bridges limit the size of vehicles allowed to cross. Neither designation means that the bridge is in imminent danger of collapse. Points are awarded based on the condition of the substructure, superstructure, and surface; thus, a low scoring bridge may merely need repaving to bring it back from structural deficiency.

The sheer number of structurally deficient bridges around the country is cause for concern, though, because many do have underlying structural problems. In 2006, FHWA found that 73,764 bridges were structurally deficient, including the one that collapsed in Minnesota. There is not a centralized system that the Federal Government uses to further classify structurally deficient bridges as suffering from dangerous structural (as opposed to cosmetic or less urgent) conditions. This makes it far more difficult to determine the true vulnerability of the bridges in the United States. The American Society of Civil Engineers (ASCE) has carried out their own assessment of the Nation's bridges, and found that the Nation's urban bridges, which carry much larger than average numbers of vehicles daily, are classified as structurally deficient at a much higher percentage than rural bridges, making the situation more dangerous than the number suggest on their own. ASCE has called for stronger investment in repairing infrastructure and long-term research efforts. Repairs, however, are an enormous financial challenge. ASCE anticipates a total cost of $188 billion to repair all current structurally deficient bridges around the country.

While the issue of bridge structural problems is not new, changing patterns in the U.S. transportation sector have made fixing deficient bridges much more pressing. The Bureau of Transportation Statistics (BTS) found that the number of vehicles on roads and bridges has increased from 156 million to 235 million since 1980, and economic growth has spurred the long haul trucking industry to put more and heavier trucks on the road. These traffic loads are far higher than those originally anticipated by bridges' engineers, and may accelerate deterioration of already crumbling infrastructure.

Because it is financially and logistically unfeasible to repair all problematic bridges around the country in the short-term, State highway administrations, bridge inspectors, and the public rely on the results of research and technology development to avoid catastrophic and deadly collapses. The research community has recognized bridges as a priority, and is putting available resources into both short- and long-term research to improve safety. However, funding for this research is extremely limited. FHWA has only approximately $22 million available for bridge related research, and must leverage research carried out by universities, states, and private industry to move forward.

Chairman GORDON. I want to welcome everyone to today's hearing on *Bridge Safety: Next Steps to Protect the Nation's Critical Infrastructure.* We were all horrified by the images of I–35W bridge collapse in Minneapolis last month, and the Congress has begun moving to address the serious problem of deteriorating bridges.

Infrastructure in the United States, and in my own home State of Tennessee, 37 bridges were found to be deficient by Road Improvement Survey in 2005, and I am sure that my colleagues on the Committee could all share similar statistics. Clearly the disaster that struck Minnesota could have happened anywhere. This is a wakeup call that we need to be doing more to strengthen and secure our bridges now and for the long-term. And while funding bridges is important and necessary, we cannot keep on with business as usual if we are to maintain a safe, national inventory of nearly 600,000 bridges. In the American Society of Civil Engineers' 2005 Infrastructure Report card, they reported that it would cost upwards to $188 billion just to fix the Nation's current structurally deficient bridges. There has to be a better, more efficient way. I am hoping our witnesses today can shed some light on what that better way is.

The witnesses here today represent the Federal Government, State government, academia, and industry. Each of these groups is working hard on the innovative research and development that will hopefully help us to prevent these types of tragedies in the future. They are developing new materials for stronger decks, new engineering techniques for more resilient bridges, new technologies to help inspectors more accurately assess the conditions of a bridge, and of course, new technologies are only useful insofar as they are adopted by builders and inspectors. So, I hope to hear more about technological transfer programs and what we can do to make innovative technology more accessible to hardworking engineers and to inspectors that need them.

Investing our resources wisely is the first step to ensuring the American public crosses the Nation's bridges confidently.

Before I recognize my friend and colleague, Ranking Member, Mr. Hall, let me say that we are going to allow both—have two additional opening statements by our Chairman and Ranking Member of the Subcommittee on Technology Innovation which covers this area, I am going to have to briefly step across the hall. I have a bill concerning 9–1–1 that is important for all of us, and so I am going to turn to Mr. Wu and recognize Mr. Hall for his opening statement.

[The prepared statement of Chairman Gordon follows:]

PREPARED STATEMENT OF CHAIRMAN BART GORDON

I want to welcome everyone to today's hearing on *Bridge Safety: Next Steps to Protect the Nation's Critical Infrastructure.* We were all horrified by the images of the I–35W bridge collapse in Minneapolis last month, and Congress has begun moving to address the serious problems of deteriorating bridge infrastructure in the United States. In my home State of Tennessee, 37 bridges were found to be deficient by a Road Improvement Survey in 2005. My colleagues on the Committee could all share similar statistics. Clearly, the disaster that struck Minnesota could have happened anywhere. This is a wakeup call that we need to be doing more to strengthen and secure our bridges now and for the long-term.

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Investing our resources wisely is the first step to ensuring that the American public crosses the Nation's bridges confidently.

I'd now like to recognize my colleague, the Ranking Member from Texas, Mr. Hall, for an opening statement. We'll then allow two additional opening statements from the Chairman and Ranking Member of the Subcommittee on Technology and Innovation, which covers surface transportation R&D for the Committee.

Mr. HALL. I thank you, Mr. Chairman, and I say good morning to you gentlemen. Thank you for the time you are giving us today, the time you have given us in preparation and your trip home. We appreciate you being here because your input is what we really look to in order to write our legislation because you know more about what we are talking about than we do, and you are very kind and gracious to give us your time.

We are a nation of infrastructure. It is kind of funny. I have had a lot of advice from a lot of people about these bridges and everything. Every time I get up on one when I look way down there and see little people in small cars I have some kind of an eerie feeling, you know, thinking that some day that the thing is going to fall if we don't do something about it and don't keep checking it. One guy suggested to me that—my district goes several hundred miles from Dallas County to the end of Texarkana, Bowie County, over to the Arkansas border, about 300 miles. He said, if you can stay on them farm-to-market roads, you will be a lot safer. I don't know if that is true or not, but maybe you folks are going to be able to help us.

More than any other country in the world, we do rely on a massive, interconnected web of power lines and power plants, telecommunications facilities, train tracks, roadways, and bridges to, you know, go about our everyday lives; and that is why tragedies like the I–35 bridge collapse in Minneapolis strike each of us so personally. During our own, everyday lives since August the 1st we have all thought of the 185 people on the I–35 bridge when it collapsed and the 13 who perished. Perhaps as we drive across bridges in our hometowns on the way to work or to the school or to the shopping center down the road we think about it, and it causes concern. Clearly the loss of life is unacceptable, and then what to do about it, what we can do about it, and how practical it is to do what we ought to do about it and whether or not we will do what we ought to do is something that we just have to work out together. And we have to listen to you and try to adapt our ability to respond to what your recommendations are.

Ensuring the safety of our basic infrastructure has to be the top priority of Federal, State, and local governments. This is a core principle of public policy and the reason the Committee is meeting here today. Sadly, this is not the first time that a major bridge has failed. In 1967, 46 people died from the collapse of the Silver Bridge in Point Pleasant, West Virginia. The following year, the Federal Government began a nationwide bridge inspection program. Today the National Bridge Inventory including almost 600,000 bridges, almost 25 percent of these are over 50 years old. Of the 49,518 bridges on the inventory in my home State of Texas, 2,219 or five percent are considered structurally deficient. I live in the smallest county in Texas. There are 254 counties. Mine is the smallest geographically. I have bridges that I am very fearful of, bridges that I have pictures of my wife and me standing, leaning up against the banister the day they were poured; and that is 50 or 60 years ago. Those bridges are probably very dangerous. This designation of structurally deficient doesn't mean that these bridges are in immediate danger of collapse; it does, however, mean that signs of fatigue and stress are beginning to show and that the bridge requires close monitoring. The I–35 bridge was one such structurally deficient bridge, however, and was inspected a year prior to the collapse.

So today we have a panel before us who can tell us what we are doing as a nation to improve the monitoring and inspection of bridges. What are the technologies and the skills that will allow us to better assess and monitor the health of these critical pieces of infrastructure? What can be done in the next five or 10 years to improve the data we have on bridges and our ability to correct interpret that data? And can we do this while also attending to the other challenges facing transportation officials such as growing congestion and deteriorating roadways?

I don't know. We would like to hear that from you all. I wrote a bill about the drought that we have and how to address it later and how to have quicker response for the ranchers and farmers before it is too late; and of course, you know what the first question was when I was back in my district, telling them about how I had offered the drought bill. And one old farmer said, well, Congressman, can you make it rain? And I had just admitted that I couldn't and we would do something about that at a later time. And sure enough we had too damn much rain about three weeks ago and Texoma Lake overran and drowned out the rice farmers down below. Now if I go back to that same place and make that speech, he will say, Congressman, can you make it stop raining? So we can only do what you guys and ladies and gentlemen point out to us and help us give your best judgment on it. We appreciate your being here.

Mr. Chairman, I yield back.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Good morning Mr. Chairman.

We are a nation of infrastructure. More than any other country in the world we rely on a massive, interconnected web of power lines and power plants, telecommunications facilities, and train tracks, roadways, and bridges to go about our everyday lives.

This is why tragedies like the I–35 bridge collapse in Minneapolis strike each of us so personally. During our own everyday lives since August 1st we have all thought of the 185 people on the I–35 bridge when it collapsed and the thirteen who perished, perhaps as we drove across bridges in our home towns on the way to work, or to school, or to the shopping center down the road.

Clearly this loss of life is unacceptable.

Ensuring the safety of our basic infrastructure must be the top priority of our Federal, State, and local governments. This is a core principle of public service and the reason this committee is meeting today.

Sadly, this is not the first time that a major bridge has failed. In 1967, forty-six people died from the collapse of the Silver Bridge in Point Pleasant, West Virginia. The following year the Federal Government began a nationwide bridge inspection program. Today, the National Bridge Inventory, includes almost 600,000 bridges. Almost twenty-five percent of those are over fifty years old. Of the 49,518 bridges on the inventory in my home State of Texas, 2,219 or five percent are considered "structurally deficient."

This designation, "structurally deficient," does not mean these bridges are in immediate danger of collapsing. It does, however, mean that signs of fatigue and stress are beginning to show and that the bridge requires close monitoring. The I–35 bridge was one such "structurally deficient" bridge, however, and was inspected a year prior to the collapse.

So, today, we have a panel before us who can tell us what we're doing as a nation to improve the monitoring and inspections of bridges. What are the technologies and skills that will allow us to better assess and monitor the health of these critical pieces of infrastructure? What can be done in the next five or ten years to improve the data we have on bridges and our ability to correctly interpret that data? And can we do this while also attending to the other challenges facing transportation officials such as growing congestion and deteriorating roadways?

I look forward to hearing your answers and thank you for testifying today.

I yield back.

Mr. WU. [Presiding] Thank you very much, Mr. Hall. As Chairman Gordon referred, on the 1st of August, the whole country was shocked by the collapse of the I–35 bridge across Mississippi at Minneapolis, and our condolences and prayers to all those who were directly affected by that bridge collapse. But for everybody else around the country, I think that one thought that must be on folks' minds is, "What about the bridges that I drive over? What about my commute to work or from work?" These appropriate concerns highlight how much we have taken our national infrastructure system for granted. Of the 116,000 or so bridges in the National Highway System, over 6,000 are rated structurally deficient, 80 of these are in my home State of Oregon, and eight are in my congressional district. After the I–35 bridge collapse, Congress moved quickly to offer federal help, and we are now left with a long-term need to better address how to constantly and consistently evaluate and repair our national infrastructure. Investing in research to develop new building materials, new engineering techniques, and a sufficient technologic toolbox for bridge inspectors will be critical to our ability to accurately assess the structural condition of our nation's bridges and to develop bridge infrastructure that will last for decades and perhaps even a century with minimal repairs.

The Federal Highway Administration, State highway administrations, and universities have long been engaged in surface transportation research in a wide variety of applications from bridge design to construction to inspection. However, the transfer of these technologies to end-users has faced barriers such as the cost of technologies, engineering, and modeling.

I hope that our witnesses can address these issues.

Also, I hope that our witnesses will discuss the research and the design capabilities the Federal Government can provide for State inspectors to accurately rank repair needs. While inspectors use a variety of methods to determine if a bridge has an immediate need of repair, the existing methods are imperfect, and additional research is needed to develop methods that will provide better quality data on which bridges require immediate attention.

I look forward to the testimony of our witnesses and their expertise to help guide this committee in addressing the research needs to protect our aging infrastructure and what the Federal Government can do to make sure our citizens do not question whether or not their daily commute is safe.

[The prepared statement of Chairman Wu follows:]

PREPARED STATEMENT OF CHAIRMAN DAVID WU

Thank you Mr. Chairman.

Mr. Chairman, on August 1, the country was astonished by the collapse of the I–35 bridge in Minneapolis, and what was more certain than the thoughts and prayers on the American people to those affected was the thought "What about the bridges I drive over? What about my commute?"

These are penetrating questions, and these questions highlight that we take our national infrastructure system for granted.

Of the 116,172 bridges on the National Highway System, 6,175 bridges are rated as structurally deficient. There are 80 of these bridges in my home state of Oregon are rated as structurally deficient, and eight are in my district.

In the aftermath of the I–35 bridge collapse Congress moved immediately with federal dollars. We are now left with the immediate need to evaluate and repair our national infrastructure. The overwhelming number of bridges in need of repair, and the associated cost requires the prioritization of federal and State resources.

Investing in research to develop new building materials, new engineering techniques and a sufficient toolbox for bridge inspectors will be critical in our ability to accurately assess the structural condition of our nation's bridges.

I look forward to the testimony of our witnesses and their expertise to help guide this committee address the needs of our aging infrastructure and what the Federal Government can provide to make sure our citizens do not need to question whether or not their daily commute is safe.

Mr. WU. And now I would like to recognize the Ranking Member of our subcommittee, Dr. Gingrey for his opening statement.

Mr. GINGREY. Thank you, Chairman Wu, and Ranking Member Hall. I have some prepared remarks. I can't resist the urge like most Members to ad lib a little bit here.

I will start out by saying I am certainly proud to be here with the Rainmaker. I didn't realize that movie was based on the legislative life of Ralph Hall. That was a very interesting little bit of information.

Again, Mr. Chairman, I do thank you, and I would like to start by reiterating as we all have the deep felt sorrow and concern that we all have for the family members and the loved ones of those who died in the collapse of the Interstate 35 West bridge in Minneapolis. I believe it was on August 1st of this year. Our thoughts and prayers continue to go out to the families of those who lost their lives.

Bridge safety is a growing problem across the country and includes not just the National Highway System but of course the many more bridges and the state and local roadways. In my State of Georgia, as an example, there are 14,500 bridge, 14,500 just in the State of Georgia, population about 9.4 million people. One thousand one hundred of these bridges, that is about eight percent of the total, are "structurally deficient;" and nationally, 12 percent of bridges have received that rating and in some states it goes up as high as 25 percent structurally deficient.

Structurally deficient bridges can be found in every part of the country in the midst of sprawling cities but also out in the remote areas as Ranking Member Hall indicated and stated in his remarks. Repairing them will take an enormous effort that will need the aid of science and technology; and hopefully we can build advanced structures that are more robust, that are more reliable, and that will have the ability to detect potential problems and warn officials electronically.

On the ad lib part, let me just say that 42 years ago, I was working as a co-op student. I was attending Georgia Tech as a chemistry major, and I was working at a nuclear plant in South Carolina. And my job, one quarter, was to run a probe through a heat exchanger, and I think there were 25 different channels in that heat exchanger. And you could literally take these heat exchangers off of the reactor and inspect with this probe any deterioration or corrosion of the metal, and that was 42 years ago I was doing that. You think about today and walk in any bathroom almost anywhere, in any city, in any country, and electronically the commode flushes and the water turns on and off. So you know, I think it probably is the time, as I continue with my prepared remarks, that we will be able to do that in regard to the safety of these bridges and not have to rely just on physical inspection on a periodic basis. I know reaching the goal will not be easy. Replacing aging bridges with new technology, advanced designs, is going to require time and money that the federal and the State transportation departments, they don't have it. They don't have it readily at hand today. We have a strong need for research and development of low-cost approaches to inspect or rehabilitate bridges.

I am particularly concerned about our current visual inspection techniques and what can be done to improve this system in the near future. In the near future. I would like to draw the panel's attention to this issue. I look forward to hearing your thoughts. Technology such as embedded sensors clearly offers dramatically more precise and accurate data. However, we are a long way from a widespread use of such systems and will continue to rely on properly trained personnel to make those final safety determinations, even though as Chairman Wu indicated or someone at the dais, a year ago, a year before this tragic accident as I understand it, there was this physical inspection. And maybe the panelists will be able to tell us about the recent construction on that bridge to maybe determine if that had any effect, either.

But we need to have inspection processes and training that are validated as effective and regularly improved. I am pleased that we will hear today from Mark Bernhardt, a bridge inspector. His company has contracts in over 10 states, and he can give us a sense of what a well-trained individual can do, but for that matter, what a well-, best-trained individual just physically can't do.

So I thank the panel for coming before us today, and I look forward to an enlightening discussion on research and development in this area.

Thank you, Mr. Chairman. I yield back.

[The prepared statement of Mr. Gingrey follows:]

PREPARED STATEMENT OF REPRESENTATIVE PHIL GINGREY

Thank you Mr. Chairman. I'd like to start by reiterating the deep-felt sorrow and concern that we all have for the family members and loved-ones of those who died in the collapse of the Interstate 35 West Bridge in Minneapolis on August 1st of this year. Our thoughts and prayers are with them.

Bridge safety is a growing problem across the country and includes not just the National Highway System, but State and local roadways as well. In my State of Georgia, for example, there are 14,523 bridges. 1,113 of these bridges, or about eight percent, are "structurally deficient." Nationally, 12 percent of bridges have received this rating and some states have as high as 25 percent of their bridges listed as "structurally deficient."

Structurally deficient bridges can be found in every part of the country, in the middle of sprawling cities and in remote wildlands. Repairing them will take an enormous effort that will need the aid of science and technology. Hopefully, we can build advanced structures that are more robust, more reliable and that will have the ability to detect potential problems and warn officials electronically. Reaching this goal will not be easy, however. Replacing aging bridges with new, technologically enhanced designs will require time and money that federal and State transportation departments DO NOT have readily at hand. We have a STRONG need for research and development of low-cost approaches to inspect or rehabilitate bridges.

I am particularly CONCERNED about our current visual inspection techniques and what can be done to improve this system in the near future. I'd like draw the panel's attention to this issue and look forward to hearing your thoughts. Technology such as embedded sensors clearly offers dramatically more PRECISE and ACCURATE data. However, we are a long way from widespread use of such systems and will continue to rely on properly trained personnel to make final safety determinations. We need to have inspection processes and training that are validated as effective and regularly improved. I'm pleased that we'll hear today from Mark Bernhardt, a bridge inspector whose company has contracts in over 10 states and who can give us a sense of what a well-trained individual can do and for that matter, what a trained individual cannot do.

I thank the entire panel for coming before us today, and look forward to an enlightening discussion on Research & Development in this area. Thank you and I yield back.

Mr. WU. Thank you, Dr. Gingrey. If there are Members who wish to submit additional opening statements, your statement will be added to the record at this point.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Thank you, Mr. Chairman. I am pleased to be here today as we examine research and development measures to address structurally deficient bridges in the United States. I would like to welcome today's witnesses.

The tragic bridge collapse that occurred on August 1, 2007, in Minneapolis, MN, serves as a wake up call that we must properly invest in maintaining our infrastructure, which includes the tools needed to evaluate and monitor its condition.

While we have a first-class transportation system, it is in many instances nearing the end of its life expectancy, and we have neglected to upgrade and modernize our infrastructure over the years.

For example, our Interstate Highway System is almost 50 years old. Thirty-two percent of our major roads are in poor or mediocre condition; one of every eight bridges is structurally deficient; and 36 percent of the Nation's urban rail vehicles and maintenance facilities are in substandard or poor condition.

While the need for construction upgrades and renovations are apparent, we must also recognize the vital need for technological advancements in tools and methods to safely, accurately, and economically evaluate these structures.

We should not build our infrastructure and then walk away without maintaining, evaluating, and modernizing it as it becomes unsafe. I supported a $375 billion highway bill that was advocated by a 2002 Department of Transportation report because I strongly believe that our infrastructure must be a top priority. We were able to pass a $286.4 billion bill; however, that is not enough to meet our needs. According to DOT, more than $65 billion could be invested immediately by all levels of government, to replace or otherwise address existing bridge deficiencies.

While we have programs and money specifically established in the highway bill for bridge improvements and repairs, money is allowed to be transferred and rescinded to other accounts. That inhibits completion of important projects, including making sure our bridges are structurally sound.

We must find a way to make the necessary improvements to our roads and bridges to make sure the highest level of safety is maintained and that the U.S. economy remains strong. As we have not kept up with the maintenance and upkeep of our bridges, it is even more vital to develop advanced technologies to evaluate and monitor current bridge structures. I am interested in hearing the thoughts and ideas of our witnesses on these topics.

I look forward to today's hearing as we examine these important issues.

[The prepared statement of Mr. Carnahan follows:]

PREPARED STATEMENT OF REPRESENTATIVE RUSS CARNAHAN

Mr. Chairman, thank you for hosting this hearing to examine research and development activities to improve bridge safety through enhanced structural engineering and inspection technologies.

As increasing traffic loads take their toll on America's transportation infrastructure, the Nation's bridges are plagued by growing structural deficiencies that range from paving issues to serious, life-threatening flaws. Numerous analysts over the past few years have concluded that more than twelve percent of the country's bridges will require urgent repairs over the next several years, at a cost of nearly $200 billion. The challenge facing policy-makers and inspectors is to determine how to allocate limited funding to the bridges in greatest need of repair.

The tragic collapse of Interstate 35W in Minnesota brought our attention to a widespread problem that affects every community. In my home State of Missouri, nearly 8,000 bridges have been identified as structurally deficient or functionally obsolete, including 125 Interstate Highway bridges. The total average daily traffic over structurally deficient interstate bridges in Missouri is 3,280,648 vehicles.

Moreover, the Federal Highway Administration has listed eight bridges on the National Highway System in my district (MO–3) to be structurally deficient. These bridges include: I–55 North at Hillsboro Road in Jefferson County, I–64 East at Laclede Station Road in St. Louis County, I–64 East at Clayton Terrace in St. Louis County, I–64 East at McCausland Ave in St. Louis City, I–44 West at Kingshighway Blvd. in St. Louis City, I–55 North at 2nd Street in St. Louis City, I–64 West at I–55 in St. Louis City and I–64 East at I–55 in St. Louis City.

Improving bridge safety is imperative. While I believe we must direct more resources towards our nation's infrastructure, it is also crucial that we direct our attention to the subject of today's hearing, improving technology for bridge design, maintenance, and inspection, and reviewing current methods of collaboration and technology transfer between the research community and State highway administrations. I am eager to hear our witnesses' assessments of bridge-related innovation and research priorities. Your first-hand experiences are vital to maintaining our nation's infrastructure.

To all the witnesses—thank you for taking time out of your busy schedules to appear before us today. I look forward to hearing your testimony.

[The prepared statement of Mr. Melancon follows:]

PREPARED STATEMENT OF REPRESENTATIVE CHARLIE MELANCON

Thank you Chairman Gordon and Ranking Member Hall for holding this important hearing on bridge safety. Since the collapse of the I–35 bridge in Minnesota, many Americans have questioned the safety of the bridges they cross every day, but this is only one part of a much larger issue. The tragedy in Minnesota emphasizes the importance of not just bridge safety, but the safety of our entire public infrastructure system.

Americans depend on public infrastructure every day and they deserve to be confidant that their tax dollars are being used to make them safe during their commutes and in their communities. As their elected representatives in government, it is our job to promote this security by ensuring that all elements of public infrastructure—bridges, roads, dams, and levees—are up to code.

These are needs—not wants. The United States cannot prosper and grow without safe, reliable public infrastructure. We only have to look to our recent past for proof. As we saw after Hurricane Katrina, the manmade disaster caused by the levee failures was more disastrous to New Orleans and south Louisiana than the damage inflicted by the hurricane. It was the levee failures that made Katrina the most costly, and one of the most deadly, disasters in U.S. history.

I applaud this committee for its work to ensure that our bridges are safe. However, I hope that the work does not end there. Let us take this opportunity to begin studying the safety of all the elements of our public infrastructure system—bridges, roads, dams and, not least of all, levees. We owe it to the American public to make sure they have reason to feel safe again.

Thank you and I yield back my time.

[The prepared statement of Mr. Mitchell follows:]

PREPARED STATEMENT OF REPRESENTATIVE HARRY E. MITCHELL

Mr. Chairman,

Thank you for convening this morning's hearing.

All of us extend our deepest sympathies to the Minneapolis community and to the loved ones who died or were injured in the I–35 West Bridge collapse.

This is the second hearing in which I have participated investigating this tragic accident. The Transportation and Infrastructure Committee, on which I also serve, held a hearing on the causes of the accident two weeks ago.

I am pleased that Chairman Gordon has called us here today to look at the issue from a different perspective. . .that of the current state of bridge safety-related research.

Of the 600,000 bridges in the U.S., 73,764, or more than 12 percent, of them are considered to be deficient. One of those bridges included the I–35 West Bridge in Minneapolis. The American Society of Civil Engineers rates the Nation's bridge infrastructure by the letter grade of "C." I am glad to report that ASCE gave Arizona an "Aminus" for highway bridge safety.

Arizona is a growing state and a good deal of our infrastructure is new. It is an arid state, and as a result, our bridges are subject to fewer corrosive factors such as moisture.

Of the 7,248 bridges in Arizona, 161 are considered deficient. Arizona residents want assurances that the bridges they travel across are safe and sturdy structures. Last month, I accompanied representatives of Arizona's State Department of Transportation. We toured the Loop 202 bridge over 56th Street, and they walked me through the inspection process. I came away from that tour with a better appreciation of the inspection process. The inspection protocols are both time consuming and expensive.

We need to explore ways and techniques by which we can detect structural deficiencies earlier, more accurately and within reasonable costs. For the most part, the inspection process provides engineers with only a "snapshot" of bridge conditions. We look to research projects and technological developments that will enable us to assess bridge conditions over a longer span of the infrastructure's life cycle.

Today's hearing will provide us with some ideas on the appropriate methods to conduct relevant research and development into infrastructure research and innovation.

Thank you, Mr. Chairman.

Mr. WU. I am deeply pleased to have such an expert group of witnesses before the Committee today to discuss this very important topic. Mr. Dennis Judycki is the Associate Administrator for Research, Development, and Technology at the Federal Highway Administration and Director of the U.S. DOT's Turner-Fairbank Highway Research Center. With him is Mr. Benjamin Tang, Principal Bridge Engineer for the Office of Bridge Technology at the FHA. Mr. Harry Lee James is the Deputy Executive Director and Chief Engineer for the Mississippi Department of Transportation. Dr. Kevin Womack is a Director of the Utah Transportation Center and Professor of Civil and Environmental Engineering at Utah State University. Finally, we have Mr. Mark Bernhardt, Director of Facility Inspection for Burgess & Niple, an engineering firm in Ohio. Thank you all for being here.

As our witnesses already know, spoken testimony is to be limited to five minutes each. Your written statements will be entered into the record, and after this period, Members of the Committee will have five minutes each to ask questions. And we will begin with Mr. Judycki. Please proceed.

STATEMENT OF MR. DENNIS C. JUDYCKI, ASSOCIATE ADMINISTRATOR, RESEARCH, DEVELOPMENT, AND TECHNOLOGY, FEDERAL HIGHWAY ADMINISTRATION, U.S. DEPARTMENT OF TRANSPORTATION; ACCOMPANIED BY MR. BENJAMIN TANG, PRINCIPAL BRIDGE ENGINEER/TEAM LEADER, OFFICE OF BRIDGE TECHNOLOGY, FEDERAL HIGHWAY ADMINISTRATION, U.S. DEPARTMENT OF TRANSPORTATION

Mr. JUDYCKI. Thank you, Mr. Chairman. Members, it is a pleasure to be here. I am pleased to report today on Federal Highway's research, development, and technology activities that enhance our highway bridges. And as you mentioned, Mr. Chairman, joining me today is Benjamin Tang, the Principal Bridge Engineer with the Federal Highway Administration.

As you have mentioned, America was stunned by the collapse of the I–35 bridge in Minneapolis. The cause of the failure is still unknown, and Federal Highways is assisting the National Transportation Safety Board in their investigation of the collapse.

Several Turner-Fairbank Highway Research Center experts are, as we speak, on site helping with the forensic work. Others are developing a computer model to evaluate the behavior of the bridge. Although examination of the physical members of the bridge being recovered from the site provides the best evidence of why the bridge collapsed, the computer allows simulation and evaluation of multiple failure scenarios, which can be evaluated against the actual bridge failure and physical forensic evidence.

We are committed to helping the NTSB complete its work as quickly as possible, but certainly, as you can appreciate, must take the time to fully understand what happened so that we can be sure that this tragedy will not happen again.

Federal, State, and local transportation agencies consider the inspection of the Nation's nearly 600,000 bridges to be of vital importance and invest significant funds in bridge inspection technologies and techniques for which have been evolving for the last 30 years since the establishment of the National Bridge Inspection Standards. Commonly used methods for evaluating concrete members during "routine" inspections include mechanical sounding to identify areas of delamination and degradation. Similarly for steel members, routine methods include cleaning and scraping, and the use of various tests to identify cracking and areas of significant corrosion. More state-of-the art methods utilized during in-depth inspections for concrete and steel bridges include impact echo, infrared thermology, ground-penetrating radar, and ultrasonic methods.

There are numerous other technologies under development that have the potential to substantially advance the practice of bridge inspection. Unfortunately, there is no one-size-fits-all approach for use of non-destructive evaluation testing. Each technology is designed for a specific purpose and for a specific function. Federal highways, state DOTs, university transportation centers, and industries continue to investigate and improve the practicality in advancing these technologies.

There are also a number of monitoring systems that can be used to provide real-time data and alert bridge owners to such things as threshold stresses in load-carrying members, excessive movement, crack growth, or scour around a bridge pier. However, monitoring systems don't eliminate the need for regular visual inspections, nor do they ensure that failure of a bridge component will not occur.

Federal Highways is actively coordinating a National Bridge Research Program with our partners and stakeholders, and our research and development efforts include not only promising advanced non-destructive evaluation technologies for inspection, but also long-term bridge performance and high performance structures and innovative materials.

The current Federal Highway Bridge Research Program is focused on effective stewardship and management of bridge infrastructure, assuring of a high level of safety and security for highway bridges, and thirdly, developing the "Bridge of the Future."

FHWA's responsibility for research and technology encompasses not only managing and conducting research and sharing the result but certainly supporting and facilitating technology and innovation deployment. This includes working with University Transportation Centers, others in academia, the State DOTs, industry, and the Transportation Research Board.

FHWA also utilizes its Local Technical Assistance Program as a mechanism for transferring technologies to State and local agencies, and education and training programs provided through our National Highway Institute help introduce new technologies and raise the state of the practice. Ultimately, though, a key measure of success for any highway technology innovation depends on the acceptance and adoption by stakeholders.

It is Federal Highway's ongoing responsibility to continue to advance the state-of-the-art through research and development and to work with our partners to raise the state-of-the-practice in bridge engineering.

I would like to thank you again for the opportunity to testify and will be pleased to answer any questions that you may have.

[The prepared statement of Mr. Judycki and Mr. Tang follows:]

PREPARED STATEMENT OF DENNIS JUDYCKI AND BENJAMIN TANG

Mr. Chairman and Members, we are pleased to appear before you today to report on the Department of Transportation's research, development, testing, and evaluation activities, as administered by the Federal Highway Administration (FHWA), to ensure the safety of the Nation's highway bridges. This is a very important hearing topic in the wake of the tragic collapse of the Interstate 35 West (I–35W) bridge over the Mississippi River in Minneapolis, Minnesota. On behalf of the Department, we extend our deepest sympathy to the loved ones of those who died and to the injured.

Minnesota Bridge Collapse

America was stunned by the collapse of the I–35W bridge at approximately 6:00 PM, Central Daylight Time, on Wednesday, August 1, 2007. Numerous vehicles were on the bridge at the time and there were 13 fatalities and 123 people injured. The I–35W bridge originally opened in November 1967 and became one of the critical facilities in a vital commercial and commuting corridor. The bridge was an eight-lane, steel deck truss structure that rose 64 feet above the Mississippi River. The main span extended to 456 feet in length to avoid putting piers in the water which would have impeded river navigation. As of the 2004 count, an estimated 141,000 vehicles traveled per day on the bridge.

We do not yet know why the I–35W bridge failed, and the Department is working closely with the National Transportation Safety Board (NTSB) as it continues its investigation to determine the cause or causes. In the interim, we are taking every step to reassure the public that America's infrastructure is safe. The Secretary of Transportation has issued two advisories to States in response to what has been learned so far, asking that States re-inspect their steel deck truss bridges and that they be mindful of the added weight construction projects may bring to bear on bridges.

The Federal Highway Administration is assisting the NTSB in a thorough investigation, which includes a structural analysis of the bridge. Within days of the collapse, development of a computer model based upon the original design drawings for the bridge began at FHWA's Turner-Fairbank Highway Research Center in McLean, Virginia. This model can perform simulations to determine the effect on the bridge of removing or weakening certain elements to recreate, virtually, the actual condition of the bridge just prior to and during the bridge's collapse.

By finding elements that, if weakened or removed, result in a bridge failure similar to the actual bridge failure, the investigators' work is considerably shortened. While examination of the physical members of the bridge being recovered from the site provides the best evidence of why the bridge collapsed, the analytical model allows the evaluation of multiple scenarios which can then be validated against the physical forensic evidence. We are committed to accomplishing this work as quickly as possible, but it is expected to take several months. Our experts will continue to be there, on the ground in Minneapolis, to provide assistance. We need to fully understand what happened so we can take every possible step to ensure that such a tragedy does not happen again. Data collected at the accident scene, with the help of the Federal Bureau of Investigation's 3–D laser scanning technology, is being used to assist in the investigation.

Federal, State, and local transportation agencies consider the inspection of our nearly 600,000 bridges to be of vital importance and invest significant funds in bridge inspection activities each year. We strive to ensure that the quality of our bridge inspection program is maintained at the highest level and that our funds are utilized as effectively as possible. On August 2, the day after the collapse, Secretary of Transportation Mary E. Peters requested the Department of Transportation's Inspector General to conduct a rigorous assessment of the federal-aid bridge program and the National Bridge Inspection Standards (NBIS).

National Bridge Inspection Program

The National Bridge Inspection Program was created in response to the collapse, in 1967, of the Silver Bridge over the Ohio River between West Virginia and Ohio, which killed 46 people. At the time of that collapse, the exact number of highway bridges in the United States was unknown, and there was no systematic bridge inspection program to monitor the condition of existing bridges. In the *Federal-aid Highway Act of 1968,* Congress directed the Secretary of Transportation in cooperation with State highway officials to establish: (1) NBIS for the proper safety inspection of bridges, and (2) a program to train employees involved in bridge inspection to carry out the program. As a result, the NBIS regulation was developed, a bridge inspector's training manual was prepared, and a comprehensive training course, based on the manual, was developed to provide specialized training. To address varying needs and circumstances, State and local standards are often even more restrictive than the national standards.

The NBIS require safety inspections at least once every 24 months for highway bridges that exceed 20 feet in total length located on public roads. Many bridges are inspected more frequently. However, with the express approval by FHWA of State-specific policies and criteria, some bridges can be inspected at intervals greater than 24 months. New or newly reconstructed bridges, for example, may qualify for less frequent inspections. Approximately 83 percent of bridges are inspected once every 24 months, 12 percent are inspected annually, and five percent are inspected on a 48-month cycle.

The State transportation department (State DOT) must inspect, or cause to be inspected, all highway bridges on public roads that are fully or partially located within the State's boundaries, except for bridges owned by federal agencies. States may use their Highway Bridge Program funds for bridge inspection activities. Privately owned bridges, including commercial railroad bridges and some international crossings, are not legally mandated to adhere to the NBIS requirements; however, many privately owned bridges on public roads are being inspected in accordance with the NBIS.

For bridges subject to NBIS requirements, information is collected on bridge composition and conditions and reported to FHWA, where the data is maintained in the

National Bridge Inventory (NBI) database. The NBI is essentially a database of bridge information that is "frozen" at a given point in time. This information forms the basis of, and provides the mechanism for, the determination of the formula factor used to apportion Highway Bridge Program funds to the states. A sufficiency rating (SR) is calculated based on the NBI data items on structural condition, functional obsolescence, and essentiality for public use. The SR is then used programmatically to determine eligibility for rehabilitation or replacement using Highway Bridge Program funds.

Bridge inspection techniques and technologies have been continuously evolving since the NBIS were established over 30 years ago and the NBIS regulation has been updated several times as Congress has revised the inspection program and its companion program, the Highway Bridge Program (formerly Highway Bridge Replacement and Rehabilitation Program). The most recent NBIS revision took effect in January 2005. The bridge inspector's reference manual has been updated as well, and we have developed, through our National Highway Institute (NHI), an array of bridge inspection training courses.

There are five basic types of bridge inspections—initial, routine, in-depth, damage, and special. The first inspection to be completed on a bridge is the "initial" inspection. The purpose of this inspection is to provide all the structure inventory and appraisal data, to establish baseline structural conditions, and to identify and list any existing problems or any locations in the structure that may have potential problems. The "routine" inspection is the most common type of inspection performed and is generally required every two years. The purpose of "routine" inspections is to determine the physical and functional condition of a bridge on a regularly scheduled basis. An "in-depth" inspection is a close-up, hands-on inspection of one or more members above or below the water level to identify potential deficiencies not readily detectable using routine inspection procedures. A "damage" inspection is an emergency inspection conducted to assess structural damage immediately following an accident or resulting from unanticipated environmental factors or human actions. Finally, a "special" inspection is used to monitor, on a regular basis, a known or suspected deficiency.

Safety is enhanced through these inspections and by "rating" bridge components, such as the deck, superstructure, and substructure, and by the use of non-destructive evaluation (NDE) methods and other advanced technologies. Visual inspection is the primary method used to perform routine bridge inspections, and tools for cleaning, probing, sounding, and measuring, and visual aids are typically used. On occasion, destructive tests are conducted to evaluate specific areas or materials of concern, or to help identify appropriate rehabilitative work. Type, location, accessibility, and condition of a bridge, as well as type of inspection, are some of the factors that determine what methods of inspection practices are used. When problems are detected, or during the inspection of critical areas, more advanced methods are employed.

Commonly used methods for evaluating concrete elements during "routine" inspections include mechanical sounding to identify areas of delamination (the separation of a layer of concrete from the reinforcing steel in the concrete member) and other forms of concrete degradation. Similarly, for the "routine" inspection of steel members, methods include cleaning and scraping, and the use of dye penetrant and magnetic particle testing to identify cracking and areas of significant corrosion.

State-of-the-art methods utilized during "in-depth," "damage," and "special" inspections include impact echo, infrared thermography, ground penetrating radar, and strain gauges for concrete structures and elements, and ultrasonic, eddy current, radiography, acoustic emissions, strain gauges, and x-ray technology for steel structures and elements.

There are numerous other technologies under development that have the potential to substantially advance the practices used for bridge inspection. Some of these technologies are also being developed or are in limited use by other industries, such as the aerospace and nuclear industries. There is no one-size-fits-all approach in the use of non-destructive evaluations and testing; each technology is designed for a specific purpose and function. Although these developing technologies have the potential to augment and advance bridge inspection practice, the challenge is to find a way to make them efficient, effective, and practical for field use. FHWA, industry, academia, the Transportation Research Board (TRB), and State DOTs continue to investigate and improve the practicality of many of these technologies. As a result of these efforts, a number of systems have recently become available that can assist an inspector in the identification and quantification of such things as reinforced concrete deterioration, steel tendon distress, and the displacement or rotation of critical members in a bridge.

There are also a number of monitoring systems that can be used to provide real time data and alert the bridge owner to such things as failure of load carrying members, excessive rotation or displacement of an element, overload in a member, growth of a crack, or scour around a bridge pier. The type of information provided by these systems is either very specific and provides detailed information on isolated areas or members of the bridge, or rather generic and provides general bridge behavior information. The most practical of these systems are being used by owners following an "in-depth" or "special" inspection, to monitor the performance of the element or the bridge, when some specific concern has been raised but the concern is not considered to be a short-term safety hazard. However, the effectiveness and costs associated with monitoring systems must be weighed against the benefits gained. Like any emerging technology, changes and updates in monitoring systems can become a big challenge to maintain economically over the long haul. Today, bridges are being built to last 75 to 100 years and installing any new monitoring systems and expecting them to be durable and serviceable for such a long period has never been done before. Monitoring systems that are available today require routine maintenance and repair, and continuous assessment to ensure that they are working correctly. In addition, they do not eliminate the need for regular visual inspections. In many circumstances, it is more effective to increase the inspection frequency, repair or retrofit areas of concern, or replace the structure.

Since 1994, the percentage of the Nation's bridges that are classified as "structurally deficient" has declined from 18.7 percent to 12.1 percent. The term "structurally deficient" is a technical engineering term used to classify bridges according to serviceability, safety, and essentiality for public use. Bridges are considered "structurally deficient" if significant load-carrying elements are found to be in poor or worse condition due to deterioration or damage, or the adequacy of the waterway opening provided by the bridge is determined to be extremely insufficient to the point of causing intolerable traffic interruptions. The fact that a bridge is classified as "structurally deficient" does not mean that it is unsafe for use by the public.

These infrastructure quality numbers for bridges should, and can, be improved, but it is inaccurate to conclude that the Nation's transportation infrastructure is unsafe. We have quality control systems that provide surveillance over the design and construction of bridges. We have quality control systems that oversee the operations and use of our bridges. And we have quality control over inspections of bridges to keep track of the attention that a bridge will require to stay in safe operation. These systems have been developed over the course of many decades and are the products of the best professional judgment of many experts. We will ensure that any findings and lessons that come out of the investigation into the I–35W bridge collapse are quickly learned and appropriate corrective actions are institutionalized to prevent any future occurrence.

Bridge Research and Technology Programs

The current FHWA bridge research program is focused on three areas: (1) the "Bridge of the Future," (2) effective stewardship and management of the existing bridge infrastructure in the United States, and (3) assuring a high level of safety, security, and reliability for both new and existing highway bridges and other highway structures.

The "Bridge of the Future" is intended to be a bridge that can last for 100 years or more, and require minimal maintenance and repair—while being adaptable to changing conditions, such as increasing loads or traffic volumes. FHWA's bridge research and technology (R&T) programs are focusing on improving the long-term performance of our nation's highway infrastructure in an effective yet economical way.

In the *Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users* (SAFETEA–LU), Congress authorized and funded research in five program areas: long-term bridge performance, innovative bridge delivery, high performance and innovative materials, nondestructive inspection technology, and seismic research. The specific programs authorized by SAFETEA–LU are summarized in the following:

Long-Term Bridge Performance

Long-Term Bridge Performance Program (LTBPP)—The LTBPP has been designed as a 20-year effort that will include detailed inspections and periodic evaluations and testing on a representative sample of bridges throughout the United States in order to monitor and measure their performance over an extended period of time. The program will collect actual performance data on deterioration, corrosion, or other types of degradation; structural impacts from overloads; and the effectiveness of various maintenance and improvement strategies typically used to repair or rehabilitate bridges. The resulting LTBPP database will provide high quality, quantitative performance data for highway bridges that will support improved designs, improved predictive models, and better bridge management systems.

Innovative Bridge Delivery

Innovative Bridge Research and Deployment (IBRD) Program—The IBRD program encourages highway agencies to more rapidly accept the use of new and innovative materials and technologies or practices in highway structure construction by promoting, demonstrating, evaluating, and documenting the application of innovative designs, materials, and construction methods in the construction, repair, and rehabilitation of bridges and other structures. This will increase safety and durability and reduce construction time, traffic congestion, maintenance costs, and life-cycle costs of bridges.

High-Performance and Innovative Materials

High-Performance Concrete (HPC) Research and Deployment Program— The HPC program is a subset of the IBRD program. It continues the advancement of HPC applications through targeted research that addresses needed improvements in design, fabrication, erection, and long-term performance in order to achieve the Bridge Program strategic outcomes. HPC research focuses on material and casting issues, including improved performance criteria, lightweight concrete, curing, and test methods; structural performance concerns, including compression, shear, and fatigue behavior for both seismic and non-seismic applications; and concepts related to accelerated construction and bridge system design and performance.

High-Performing Steel (HPS) Research and Technology Program—The HPS research and technology transfer program is focused on resolving a number of issues and concerns with the design, fabrication, erection, and long-term performance of both conventional and High Performance steels. The program focuses research and technology transfer and education in the areas of materials and joining (for example, optimized welding processes and procedures); long-term performance (including advanced knowledge on performance limitations of weathering steels and the potential development of a 100-year shop-applied permanent steel coating system); innovative design (including testing and deployment of modular steel bridge super- and substructure systems); and fabrication and erection tools and processes.

Ultra-High-Performance Concrete (UHPC) Research and Technology— UHPC is a unique material which is reinforced with short steel fibers, but requires no conventional steel reinforcing. Prior FHWA research on UHPC focused on basic material characterization, and the development of optimized structural systems using this very high performance, but costly, material. Under the UHPC program, additional work will be conducted to further understand the unique structural properties of this material and assess its corrosion-resistance properties, while addressing its use in other structural components including pre-cast bridge deck panels and pre-stressed I- and bulb-tee girders.

Wood Composite Research—The University of Maine is conducting a research program focused in the development and application of wood/fiber reinforced polymer (FRP) composite materials for potential use as primary structural members in highway bridges.

Non-destructive Inspection Technology

Steel Bridge Testing Program—This program is focused on the further development and deployment of advanced NDE tools that can be used to detect and quantify growing cracks in steel bridge members and welds. As described in SAFETEA–LU, the NDE technology should ultimately be able to detect both surface and sub-surface cracks, in a field environment, for flaws as small as 0.010 inches in length or depth.

Seismic Research

Seismic Research Program—The University of Nevada, Reno, and the State University of New York at Buffalo are conducting a seismic research program intended to increase the resilience of bridges and reduce earthquake-induced losses due to highway damage.

FHWA is also conducting and managing a number of other important bridge research projects in conjunction with various partners and stakeholder groups, all focused on improving the performance and durability of our Nation's highway bridges—both those exposed to normal everyday traffic and use, and those exposed to the damaging effects of extreme natural and man-made hazards.

In addition to FHWA, there are a number of other organizations that sponsor bridge research, and a much larger group of agencies that conduct bridge R&T. These include State DOTs, industry, other federal agencies, and academia. Other transportation modes also conduct limited bridge research, including the railroad industry.

FHWA actively coordinates the National research program with our partners and stakeholders for agenda-setting, and in the conduct of research and delivery of new innovations. Our staff participates in numerous national and international organizations and serves on committees focused on bridge research, development, and technology transfer. We organize formal technical advisory groups and technical working groups, comprised of federal, State, and local transportation officials; bridge engineering consultants and industry groups; and academia to assist in the design, conduct, and delivery of the program.

An important R&T partner for FHWA is the University Transportation Centers (UTC) Program, managed by the Research and Innovative Technology Administration (RITA). FHWA works with the UTCs to identify opportunities for collaboration that will increase knowledge and skills among State and local highway agencies. FHWA holds periodic workshops that bring together researchers and practitioners from FHWA, State DOTs, TRB, and UTCs to learn about each others' interests and capabilities, new research opportunities, and technologies under development. FHWA held an infrastructure workshop for UTCs and State DOTs at Turner-Fairbank Highway Research Center in March 2007. FHWA is working with a number of UTCs on transportation research, including the University of Tennessee, the University of Minnesota, Utah State University, Rutgers, and the University of Missouri-Rolla. RITA also consolidates bridge technology information from all the Department's modal administrations to assist us in having the best available technologies.

State and local highway agencies learn of new technologies developed by UTCs through a variety of events sponsored by FHWA. These include annual workshops show-casing the results of UTC research on particular topics, and numerous conferences, seminars and workshops co-sponsored with specific UTCs (for example, the "Self Consolidating Concrete Workshop" at South Dakota State University). FHWA also utilizes its highly successful Local Technical Assistance Program (LTAP) as a mechanism for transferring technologies developed through the UTC program to State and local highway agencies, and tribal governments.

FHWA is also an active participant with the American Association of State Highway and Transportation Officials (AASHTO) in technology transfer such as the AASHTO Technology Implementation Group and the Joint AASHTO/FHWA/National Cooperative Highway Research Program International Technology Exchange Program, more commonly known as the International Scanning Program. Recent scans have included a scan on bridge management, and a follow-on scan in 2007 on Bridge Evaluation Quality Assurance. The 2007 scan identified and explored bridge inspection processes in use in European countries.

Ultimately, a key measure of success of any highway technology depends on its acceptance by stakeholders on a national scale. FHWA's responsibilities for R&T include not only managing and conducting research, but also sharing the results of completed research projects, and supporting and facilitating technology and innovation deployment. FHWA's Resource Center is a central location for obtaining highway technology deployment assistance. (The multiple services offered by the Resource Center are listed at *www.fhwa.dot.gov/resourcecenter/*.) Education and training programs are provided through the FHWA NHI (*www.nhi.fhwa.dot.gov*).

There are a number of barriers to technology deployment that may explain the relatively slow adoption of highway technologies that appear cost effective. Lack of information about new technologies is one barrier that may be overcome with information and outreach programs. Long-standing familiarity with existing technologies gained through education or experience also may hamper the adoption of newer technologies. Education and training programs provided through the NHI often help to transcend these types of barriers.

It also may be difficult for stakeholders to envision the long-range benefits of a new technology relative to initial investment costs, especially if the payback (break-even) period is long. Even if stakeholders are aware of eventual cost savings from a more efficient or effective highway technology, they may have confidence in traditional ways of, for example, assessing pavement performance. Demonstration projects that provide hard quantitative data can help tip the scales so that stakeholders are more willing to try and eventually regularly use innovative technologies.

Despite these efforts, technology deployment is also slowed by residual uncertainties about performance, reliability, installation, and maintenance costs; availability of the next generation of the technology; and the need for the necessary technical and physical infrastructure to support the technology in question. These persistent barriers can be addressed with outreach programs and collaborative efforts with stakeholders—ranging from the TRB to researchers within State DOTs—as well as other incentives to enhance the cost effectiveness of new technologies. Taken together, these initiatives often encourage earlier and broader adoption of highway technologies by increasing stakeholder familiarity with new technologies.

One such program is FHWA's Highways For LIFE. (*http://www.fhwa.dot.gov/hfl/hflfact.cfm*). The purpose of Highways for LIFE is to advance long lasting highways using innovative technologies and practices to accomplish fast construction of efficient and safe pavements and bridges, with the overall goal of improving the driving experience for America. The program includes demonstration construction projects, stakeholder input and involvement, technology transfer, technology partnerships, information dissemination, and monitoring and evaluation. The innovative technologies that the Highways for LIFE program promotes include prefabricated bridge elements and systems, road safety audits, and tools and techniques for "Making Work Zones Work Better."

Perhaps the main barrier to technology deployment is the general lack of incentive mechanisms to encourage the deployment of new technologies. We need to develop better incentive mechanisms in the way the program is designed, the way we procure, and the extent to which we rely on the private sector.

The Missouri Safe and Sound Bridge Improvement Project provides an example of a potentially innovative way to improve incentives and encourage innovation and private sector participation.

On May 25, 2007 the Department of Transportation approved a $600 million allocation of Private Activity Bonds to the Missouri DOT for the Missouri Safe and Sound Bridge Improvement Project. The allocation will be made available to two short-listed bidders who are competing for a contract to bring 802 of Missouri's lowest rated bridges up to satisfactory condition by December 2012 and keep them in that condition for at least 25 years. The contract will be awarded largely on the basis of the lowest level of "availability payments" that the bidder will accept to improve and maintain the 802 bridges. Missouri DOT will use federal formula funds to pay the availability payments.

SATETEA–LU authorized $15 billion in Private Activity Bonds. These bonds provide tax-exempt financing for private firms to carry out highway and surface freight transfer projects. This innovative financing approach will allow Missouri to complete these much needed bridge improvements more quickly and, it is hoped, at a lower cost. Other States, including Pennsylvania and North Carolina, are also interested in this innovative approach.

Through these and other mechanisms, FHWA supports the development and implementation of innovative technology deployment practices and processes throughout the highway community.

Conclusion

The I–35W bridge collapse was both a tragedy and wake-up call to the country. The Department's Inspector General will be monitoring all of the investigations into the collapse and reviewing our inspection and funding programs to decide and advise us what short- and long-term actions we may need to take to improve the program. Though we will have to wait for the NTSB's report before we really know the cause of the collapse, a top-to-bottom review is underway to make sure that everything is being done to keep this kind of tragedy from occurring again. The public deserves to know and trust that our Nation's highways are safe.

We look forward to continuing to work with Congress to give the people of this Nation the safe, efficient, and effective transportation system that they expect and deserve.

Thank you again for this opportunity to testify. We will be pleased to answer any questions you may have.

BIOGRAPHY FOR DENNIS C. JUDYCKI

Dennis Judycki is the Associate Administrator for Research, Development & Technology (RD&T), a position held since January 1999. In this position, he is Director of FHWA's Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia, and is responsible for leadership in the development and coordination of national research and technology partnerships, corporate facilitation and coordination of the delivery of technology and innovation, and the formulation, conduct and evaluation of research and development. Pending the appointment of an Executive Director, Mr. Judycki served as the FHWA Deputy Executive Director for two months at the end of 2001.

Prior to his RD&T appointment, Mr. Judycki held the position of Associate Administrator for Safety & System Applications (SSA), responsible for the FHWA programs in technology and innovation application, highway safety, traffic management and intelligent transportation system (ITS), and training through the National Highway Institute.

Mr. Judycki earned a B.S. in Civil Engineering from New England College in Henniker, New Hampshire and a M.S.C.E. with a specialty in Urban Transportation Planning and Traffic Operations from West Virginia University. After college in 1968, he joined the FHWA's 18-month Professional Development Program in Urban Planning. His first permanent assignment with the FHWA was as the Urban Transportation Planning Specialist in the California Division Office. In 1994, Mr. Judycki was selected for the Office of the Secretary of Transportation (OST) position of Senior Staff Assistant to the Region 5 DOT Secretarial Representative in Chicago, Illinois. Mr. Judycki's first position in Washington, D.C., was as the Special Assistant to the FHWA Executive Director, a position held for five years. He was appointed to the Senior Executive Service (SES) in 1981 as the Chief of the Urban Planning & Transportation Management Division. In 1985 he become the Director of the Office of Traffic Operations before becoming Associate Administrator for SSA in 1990.

Mr. Judycki is a member of several professional organizations, including the Institute of Transportation Engineers and the American Public Works Association. He is the USDOT delegate to the Board of Directors of the ITS World Congress and the Organization for Economic Co-operation and Development (DECD)/European Council of Ministers of Transport (ECMT) Joint Transport Research Bureau and Committee.

Mr. Judycki has been recognized with numerous Senior Executive Service Annual Performance Awards, the Secretary's Award for Meritorious Achievement, two team National Partnership for Reinventing Government (Hammer) Awards, the Lester P. Lamm Memorial Award, the Secretary of Transportation's Team Award, and the Presidential Meritorious Senior Executive Rank Award. In 1998, Mr. Judycki received the Presidential Distinguished Senior Executive Rank Award, the top honor within the career civil service.

BIOGRAPHY FOR BENJAMIN TANG

Mr. Tang is the Principal Bridge Engineer and Team Leader for the U.S. DOT, Federal Highway Administration (FHWA) at the Office of Bridge Technology, Washington, D.C. He leads the long span major bridges and tunnels group. He has served with great distinction as a structural engineer and program manager in several offices within the FHWA for the past 30 years.

He is a graduate of University of Maryland (B.S.C.E.) and University of Illinois (M.S.C.E.). He is a licensed professional engineer in Maryland and serves on several technical committees on the Transportation Research Board, AASHTO, State Transportation Agencies and private industry.

Benjamin is the technical expert and review authority for all bridge and structural matters for the federal-aid bridge program. He is responsible for drafting federal polices and regulations. He is also responsible for developing the bridge technology program under the SAFETEA–LU. He is championing the use of innovative bridge technologies, such as accelerated bridge construction, high-performance materials and load resistance factor design.

Mr. Tang received numerous distinguished service awards and recognition throughout his federal career. He shared the American Society of Civil Engineers, 2007 Pankow Award for Innovation in collaboration with the developer of a cradle system for cable-stayed bridges.

Mr. LIPINSKI. [Presiding] Thank you, Mr. Judycki, right there on time. Next we have Mr. Harry Lee James. Mr. James?

STATEMENT OF MR. HARRY LEE JAMES, DEPUTY EXECUTIVE DIRECTOR AND CHIEF ENGINEER, MISSISSIPPI DEPARTMENT OF TRANSPORTATION; MEMBER, STANDING COMMITTEE ON HIGHWAYS, AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS

Mr. JAMES. Thank you, Mr. Chairman, for allowing me to be here today. Again, I am Harry Lee James. I am the Chief Engineer for the Mississippi DOT. I am also the former State Bridge Engineer for the Mississippi Department of Transportation. On behalf of AASHTO, I would like to thank you for the focus of this committee on transportation infrastructure needs and particularly bridges, bridge safety, and preservation; and hopefully I can provide you with some information and answers to the questions that you have previously provided to us.

As far as bridge inspection, the techniques that are used by the states today range from simple to complex; simple being the inspector going out, looking at the structure, touching it, feeling it, listening to it, and to the complex inspections that require ultrasound, magnetic particle testing, monitoring devices that have been imbedded in a bridge during its construction as well. Many times though the basic is the best. Keep it simple so that we can minimize the inconvenience to the public, because many times you have to close a bridge or, at least, some lanes of traffic when you are performing an inspection, and also for the safety of the bridge inspector as well. Many times he is precariously dangling hundreds of feet in the air trying to manage for his own safety as well as a multitude of equipment that he might have to carry with him to perform his tasks. Again, basic is best in most cases.

As far as research, there is always a greater need. We need to continue our efforts to look for the next best thing. We continue to use proven technologies in our design and our construction. However, we can't give up the fight for looking for new technologies out there to help us looking at this aging infrastructure that we have.

How do we prioritize our bridge repair and replacement needs at the statewide level? There is no single approach, there is no magic bullet. We just have to go out there and do what we can with the resources that we have. It takes much diligence and stewardship on the part of the DOTs and Federal Highway to maintain the systems that we have. We are very fortunate that bridge management systems have been helped in development by Federal Highway, and many states have adopted these in their use to look at prioritizing these repair and replacement programs that we have to do.

As far as consequences of what could happen short-term, what may happen long-term, the bridges that were designed and built back in the '30s and up to the '50s, '60s, and even into the '70s, and we have bridges of many ages on our system of some 16,000 in the State of Mississippi, those bridges, the ones particular on the interstates, were designed back in the '60s are not designed for the loads that they carry today. Consequently, they deteriorate at a faster level than what was originally anticipated. As far as long-term, things are not going to get any better. We can build something today a lot cheaper than we could build it five years ago with the current increases of cost of construction and other issues that we have to deal with as a State highway agency. More is always needed to assist us.

One thing that could help us is getting projects entered into our work program at a faster rate. It is unfortunate that we have to wait until a tragedy such as what happened in Minnesota. And also in Mississippi, we lost two major bridges on our coast from Katrina; it takes something like that for us to basically suspend the rules and be able to act fast to get something back in service in a timely manner.

It is very challenging, my job, to look at a state-wide program and maintain it. We have the traveling public that we have to see to, we have our construction workers, as well as our contractors, and safety is a big issue.

I really appreciate the opportunity to come before you today to offer some information to you, and I will be glad to take any questions that you might have. Thank you.

[The prepared statement of Mr. James follows:]

PREPARED STATEMENT OF HARRY LEE JAMES

Introduction

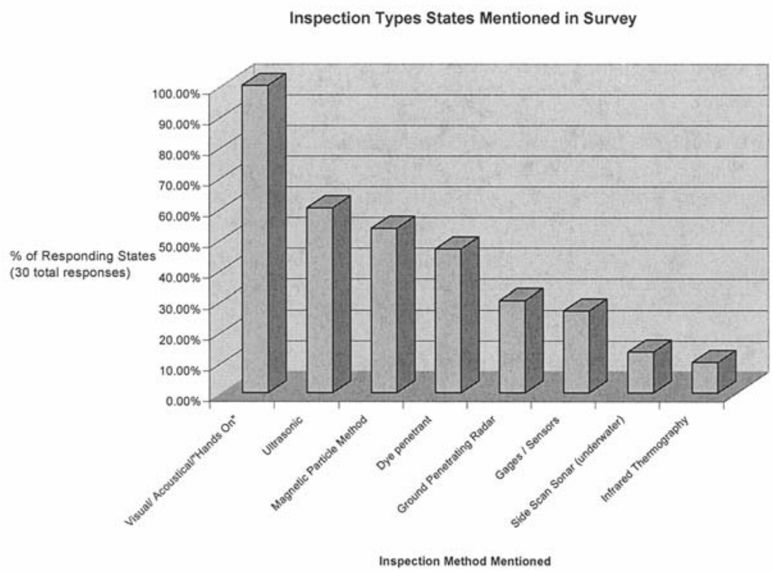
Mr. Chairman, my name is Harry Lee James. I am the Deputy Executive Director and Chief Engineer for the Mississippi Department of Transportation. I am a member of the Standing Committee on Highways of the American Association of State Highway and Transportation Officials (AASHTO), and I am a registered Professional Engineer in the State of Mississippi.

On behalf of AASHTO, I want to express my appreciation for your focus on infrastructure needs in America. The State Departments of Transportation (State DOTs) consider bridge safety and bridge preservation to be one of our highest priorities, and we take this responsibility to preserve the safety and mobility of the traveling public very seriously.

I am here to provide you and the public with the answers to some critical questions that have been posed by the House Committee on Science and Technology since the tragic collapse of the Interstate 35W bridge in Minneapolis.

Question 1

A) What technologies and techniques do state departments of transportation currently use to inspect bridges? What are the benefits and disadvantages?



Every state conducts a thorough and continual bridge inspection and rehabilitation program. America's bridges are inspected every two years by trained and certified bridge inspectors, conditions are carefully monitored, and, where deterioration is observed, corrective actions are taken.

The most common and widely used method of inspection is by far the visual inspections by teams led by Professional Engineers. These can be described as using Sight, Sound and Touch for General Inspections. Sight is the normal visual inspection technique used by all states, Sound refers to the sounding technique (use of hammer sounding and chain drag) on concrete to integrity of the concrete (does it crumble), and Touch refers to the 100 percent hands on Fracture Critical Member inspection included in every General Inspection. If needed, these inspections are supplemented by other non-destructive testing methods.

The benefit of visual inspections is that we can collect a large volume of data on the condition of the components of every bridge. The disadvantage is that inspections are costly and time consuming. In addition to qualitatively documenting visible damage, degradation, and distress in structural elements, visual inspection can include quantitative measurements such as loss of steel due to corrosion or the size of cracks in concrete.

Some other common Non-Destructive testing (NDT) techniques are Magnetic Particle method for detection of cracks in suspected areas, ground penetrating radar to evaluate bridge decks with overlays, infrared thermography and ultrasonic testing to identify cracks that are either too small to be seen, or are beneath the surface of the metal and dye-penetrant tests which also detect cracks that are not visible to the naked eye. Dye-penetrant tests are inexpensive and very simple to perform. Mag-particle is fairly easy to perform. The disadvantages are that dye-penetrant only identifies cracks that have broken the surface of the steel. Mag-particle testing requires relatively flat and smooth surfaces. Almost all the common technologies are applicable to steel, not concrete or timber. All the techniques require specialized training and often times expensive equipment.

Some other innovative techniques include special "health monitoring" of bridges using special gauges and sensors. Some of these include strain gauges, inclinometers, load cells, weather stations, corrosion sensors, humidity sensors, and accelerometers.

Oregon is out front when it comes to using advanced technology to assess the condition of bridges. Currently they have instruments on seven bridges and have installed a device that uses air pressure to measure scour at bridge foundations on one other bridge.

Equipment or Technique	Material Tested			Desired Information, Measured Defect or Material Property
	Concrete	Steel	Timber	
Visual Inspection	X	X	X	Overall external material deterioration.
Audible Inspection	X	X	X	Concrete delamination, steel bolt and rivet looseness, timber integrity.
Infrared Thermography	X			Concrete deck delamination
Ground Penetrating Radar	X			Concrete deck voids, overlay thickness, and reinforcing steel location; soil/foundation engineering and underwater profiling/scour location.
Acoustic Emission	X	X	X	Crack, corrosion, weld defects and member embrittlement.
Ultrasonic Testing	X	X	X	Non-homogenous investigation, delamination, surface crack and weld discontinuity detection.
Dye Penetrant		X		Crack or flaw detection in non-porous metals.
Magnetic Particle		X		Crack or flaw detection in ferrous metals.
Monitoring Systems	X	X	X	Measurement of strains to calculate stresses in members.
Video Camera	X	X	X	Devices, such as Aqua-Vu, can be used for visual inspection of underwater as well as hard to reach components.

B) What research is needed to improve inspections?

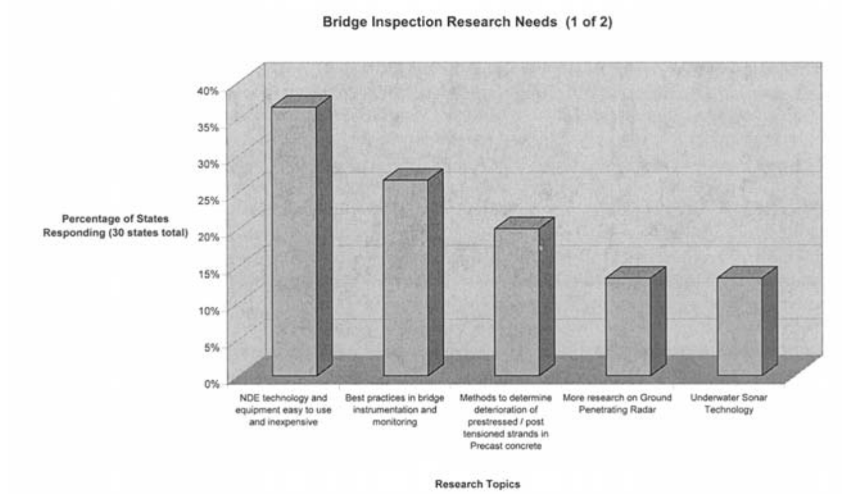
The National Bridge Inspection Standards are periodically reviewed and updated to reflect the latest knowledge. The last update was implemented in January 2005. The program was changed significantly in several areas:

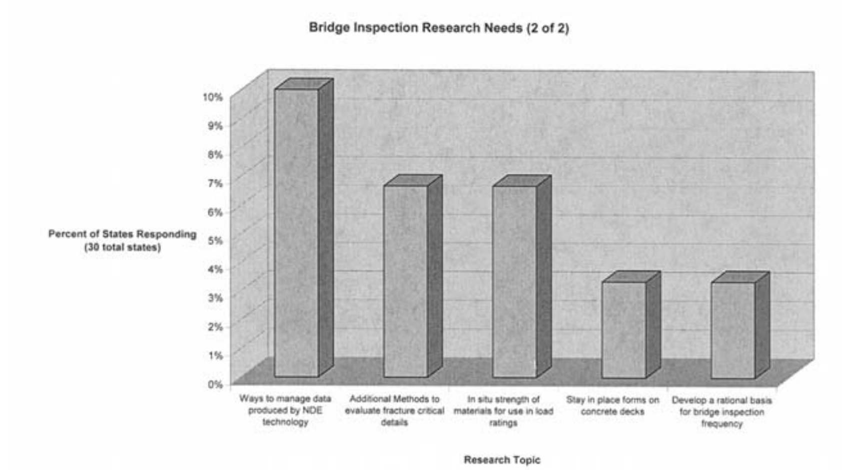
- The fracture-critical inspection interval was shortened (not to exceed 24 months) and the qualifications for underwater inspectors were increased (80 hours of training are now required).
- The qualification requirements for Program Managers and Team Leaders were increased. For example, non-licensed engineers must take a 10-day class and have five years experience, with most of that experience taking place directly in field inspection, to become a Team Leader.
- States must have a quality control and assurance program in place for their bridge inspection program. The program should include periodic field review of inspection teams, periodic bridge inspection refresher training for program managers and team leaders, and independent review of inspection reports and computations.

These recent updates to the National Bridge Inspection Standards demonstrate that the Federal Highway Administration is diligent in updating and advancing inspection standards based on input from the states. In addition, states frequently supplement federal inspection requirements with more detailed data collection and analysis. For example, 40 states currently employ an element-level inspection process that focuses on individual components of a structure.

In an informal AASHTO survey conducted on Sept. 1st to which 27 states and the USDA Forest Service replied, several areas of research were determined to be high priority. The one most often mentioned was the need for non-destructive testing technology/equipment that is inexpensive and easy to operate for a "typical" inspector. Also needed are ways to effectively manage and interpret the immense amount of data that is produced by bridge monitoring systems. In addition, with all of the pre-stressed and post-tensioned structures currently being built, it will be necessary to inspect the strands in these structures to determine the operating structural capacity of these bridges after they have been in service and exposed to the environment for some time. An effective way to inspect this and deterioration of pretensioned, pre-stressed strands in pre-cast beams and boxes is needed. Loss of pre-stress concrete capacity can occur rapidly and lead to collapse such as the I–70 bridge in Pennsylvania.

Additional research in is also needed in ways of yielding cost-effective, efficient methodologies for the identification and monitoring of fatigue cracks in steel members. Lastly, many states would like to see the reinstatement of the HERMES ground penetrating radar research now tabled at Turner-Fairbank.





C) How is FHWA helping to meet these research needs?

The Federal Highway Administration (FHWA) has been a strong supporter of bridge research and bridge inspection and evaluation standards. Due to small staff and limited resources, many local governments do not have the expertise to use the technologies or review the research that is generated.

FHWA works cooperatively with the American Association of State Highway and Transportation Officials (AASHTO) to fund bridge related research projects through the Transportation Research Board TRB and National Cooperative Highway Research Projects (NCHRP). They also fund bridge research projects through SHRP2.

FHWA funds have been used by the states and by AASHTO for software development projects to perform structural evaluation of existing bridges and to develop bridge management tools. Most notably, FHWA funded a pilot project with Caltrans in the early 1990's to develop bridge management software that contains advanced asset-management decision-making capabilities. This software is now funded by AASHTO and is known as PONTIS. It is used nationally and internationally.

FHWA owns and operates the Turner-Fairbank Highway Research Center, which provides research and development related to new highway technologies. Current bridge inspection technologies being developed include ground penetrating radar (Hermes II), acoustic emission monitoring. Bridge technology programs operated under this research center include Non-Destructive Evaluation (NDE) Validation Center, the Long-Term Bridge Performance Program and Paint and Corrosion Laboratories.

The NDE Validation Center is designed to act as a resource for state transportation agencies, industry, and academia concerned with the development and testing of innovative nondestructive evaluation (NDE) technologies.

The Long-Term Bridge Performance Program (LTBP) was launched earlier this year. It is 20-year research effort that is strategic in nature with specific short- and long-term goals. The program will include detailed inspection, periodic evaluation and testing, continuous monitoring, and forensic investigation of representative samples of bridges throughout the United States to capture and document their performance. We feel this is an important program because it has the potential to provide a better understanding of bridge deterioration and to provide better deterioration models than are now used in Pontis.

FHWA sponsors studies to develop inspection techniques and remedies for common problems found in the Nation's inventory of bridges such as arresting fatigue cracks, detecting and preventing protecting bridge with chlorides in concrete, detecting and preventing development of reactive aggregate.

Recently, the Federal Highway Administration's Transportation System Preservation program, an initiative of the Asset Management division, has added Bridge Preservation to the program. Several workshops have been held in 2007 and these workshops have helped to identify needed research in the area of bridge preventative maintenance.

Also, the International Activities office of FHWA has sponsored several international scan tours in the area of Bridge inspection and quality control. Most recently, a European Scan was undertaken in June 2007 in the area of Bridge Quality Control and Quality Assurance. Additionally, FHWA works to help sponsor Transportation Pooled Funds which support specific research projects Federal Highways also provides training through the National Highway Institute and helps to disseminate information through many publications, reports, memos and announcements.

While substantial funding has been devoted to bridge research, since the passage of SAFETEA–LU research funding has been constrained. Two factors give rise to that constraint. First, overall research funding was less than recommended by AASHTO and second, earmarks exceeded the total dollars made available for FHWA research and thus constrained overall discretionary research.

The pending SAFETEA–LU Technical Corrections bill that passed the House and is pending in the Senate would free up additional funds for the FHWA research program with no need to increase the overall cost of SAFETEA–LU. AASHTO has urged passage of this important legislation.

Bridge Research Under SHRP 2

Recent events have again demonstrated that America's highways, once the envy of the world, are deteriorating, sometimes disastrously so. Through age and overuse their capacity to safely serve America's transportation needs is being compromised. The Renewal focus area of the Second Strategic Highway Research Program (SHRP 2) seeks to develop the tools needed to systematically "renew" our highway infrastructure to serve the 21st century in ways that are rapid, minimally disruptive to users, communities, and the environment and that yield much longer-lived bridges and roadways.

Highway infrastructure largely comprises three basic elements: bridges, pavements and earthworks. All three elements are showing the deterioration of age and over-use and all three are addressed in the SHRP 2 research plans. While all three elements are vulnerable to deterioration that might compromise the physical safety of highway users, bridges are, by far, the most vulnerable. This fact was not lost on the committees of experts that guided the formulation of the SHRP 2 research, and renewal of America's highway bridges remains a key element of the SHRP 2 research, despite the dramatic reduction in funds actually authorized in the SAFETEA–LU legislation. Unfortunately, some of the originally planned research—directly applicable to safety assessment and the maintenance and repair of existing structures—proved unaffordable.

Bridge Research Currently Included in SHRP 2

Three current projects, with total funding of $5 million, directly address bridge renewal, including "Durable Bridges for Service Life beyond 100 Years: Innovative Systems, Subsystems, and Components."

Two other projects, valued at $8 million, address bridge renewal in part, including one project related to "A Plan for Developing High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection."

Table 1: Projects Directly Addressing Bridges

Project No.	Renewal Bridge Research Projects	Total budget (x1,000)	Estimated duration (months)
R04	Innovative Bridge Designs for Rapid Renewal	$2,000	48
R19-A	Durable Bridges for Service Life beyond 100 Years: Innovative Systems, Subsystems, and Components	$2,000	48
R19-B	Durable Bridges for Service Life beyond 100 Years: Service Limit State Design	$1,000	30

Table 2: Projects Partly Addressing Bridges

Project No.	Renewal Research Projects	Total budget (x1,000)	Estimated duration (months)
R06	A Plan for Developing High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection	$5,000	60 (Estimated)
R07	Performance Specifications for Rapid Highway Renewal	$3,000	60

Bridge Research Included in the Original SHRP 2 Research Plans

TEA–21 called for the Transportation Research Board (TRB) to conduct a study to determine the goals, purposes, research agenda and projects, administrative structure, and fiscal needs for a new strategic highway research program or a similar effort. Among the recommendations of the committee as detailed in *TRB Special Report 260,* was that "Highway Renewal" be included as one of the four focus areas of SHRP 2. A subsequent detailed analysis of highway renewal research needs alone indicated a funding need of approximately $95 million.

However, the passage of SAFETEA–LU provided only $150 million for the entire SHRP 2 research effort; thus serious cutbacks were made in all four research focus areas. Funding available for highway renewal research was reduced to $30 million. Efforts to optimize the research plans and combine projects were undertaken. Nonetheless, five important bridge research projects were dropped from the SHRP 2 program, including such topics as "Bridge Repair/Strengthening Systems," "Techniques for Retrofitting Bridges with Non-Redundant Structural Members," and "Monitoring and Design of Structures For Improved Maintenance and Security."

Table 4: Bridge Research Projects Dropped from SHRP 2 due to Lack of Funding

Project No.	Renewal Research Projects	Total budget (x1,000)	Estimated duration (months)
R20	Design for Desired Bridge Performance	$2,000	36
R24	Development of Rapid Renewal Inputs to Bridge Management and Inspection Systems	$2,000	72
R25	Monitoring And Design Of Structures For Improved Maintenance And Security	$1,500	72
R27	Bridge Repair/Strengthening Systems	$500	24
R28	Techniques for Retrofitting Bridges with Non-Redundant Structural Members	$1,000	36
	Total Budget	**$7,000**	

These projects would be as valuable to the safety assessment, maintenance management, and repair of existing bridges as they would be to a program of systematic renewal. Statements of work have already been developed for these research projects. The cost estimates shown are bare minimums and may require some upward adjustment.

TRB is ready to coordinate the SHRP 2 research with any program pursuing this research. The research remains significant to the achievement of the overall SHRP 2 goals.

Question 2

A) For those bridges deemed structurally deficient, how do state and local governments prioritize repairs and replacements?

The states use a number of different methods to prioritize their bridge needs.

While there is no "single approach" to prioritizing bridge program candidates, all approaches consider safety, then preservation and serviceability. Many states use a priority type of formula or a ranking system. These formulas and rankings taking into effect a combination variables of many different types. Some of the common considerations, in addition to the structurally condition ratings, are load ratings, field conditions, available funding, importance (criticality) of the bridge, average daily traffic, and alternate or detour route length. In addition to asset management programs and rankings, projects are scrutinized and approved through the normal STIP process that includes approvals from State and local transportation leaders and the transportation commissions where applicable.

One example is Oregon's project selection method. It integrates inspection data from PONTIS with other bridge condition data, specifically non-deterioration based needs, including, as examples; seismic, scour, and functional deficiencies. ODOT links various data collections to identify projects in twelve categories. Data primarily from Pontis is used to select problem bridges in the substructure, superstructure, and deck condition categories. Data outside of Pontis is used to select problem bridges in the seismic, scour, bridge rail, deck width, load capacity, vertical clearance, paint, coastal bridge (cathodic protection), and movable bridge categories.

Many states are moving away from a strictly "worst first" project selection process. Increases in the costs of traffic mobility and project staging have also influenced the move toward targeting route segments for repair and replacement projects.

However, several states are also still using a "worst first" selection method, sometimes with consideration for traffic load, social effects and politics. Overall, there is no "norm" in the area of prioritization.

Michigan's Well Developed Bridge Management System

Michigan DOT has a well developed asset management program that preserves Michigan's bridge through a balanced approach of doing capital preventive maintenance, rehabilitation, and replacement. They use a forecasting tool called Bridge Condition Forecast System to determine the best implementable strategy of the three types of work. Today the mix of fixes is 18 percent Preventive Maintenance, 30 percent rehabilitation, and 48 percent replacement.

The department also uses AASHTO CoRe elements and Pontis smart flags to make project level decisions, track deterioration rate of bridge elements (transition probabilities). Progress is monitored each year towards defined condition state goals, and strategy is modified as needed. By slowing the deterioration rate of fair bridges (keeping them from becoming structurally deficient (SD)) and concentrating on rehabilitating (first option) and replacement of SD bridges, the state has been able to make good progress at eliminating Structurally deficient bridges. Local agencies have reengineered their program (once called critical bridge program, but today called local agency bridge program), following the lead of the state trunkline program, and they are now managing their network of local agency structures.

While doing this the state has found the federal regulations regarding the Highway Bridge Program (HBP) are still too restrictive (although improving). This has resulted in several states transferring money out of the HBP program into other less restrictive programs. This gives a false impression that bridge money is not needed, which is very misleading. The HBP program is becoming more flexible with the allowance to use HBP funds for painting bridges and preventive maintenance, however, it is still built upon the framework of the 30 year old sufficiency rating formula that assigns a rating based upon structural deficiency and functional obsolescence.

In the latest federal highway legislation, SAFETEA–LU, the name of the portion of the act providing funding for bridge improvement and preservation was changed from "Highway Bridge Rehabilitation and Replacement Program" (HBRRP) to "Highway Bridge Program" (HBP). Along with the name change, came increased flexibility for states, counties, and cities to fund a broader assortment of bridge preservation projects. For example, "systematic preventive maintenance" now qualifies for HBP funds. With this change, it now appears that the three broad categories of bridge preservation are covered; i.e., replacement, rehabilitation and preventive maintenance. However, there remains at least one important exception that prevents the HBP program from becoming what it can and should be. As it currently stands, HBP funds still cannot be used for rehabilitation or replacement of bridge decks when only the deck is in poor condition. The reason for this is explained below.

Bridges qualify for rehabilitation and replacement based upon the "Sufficiency Rating Formula, as explained in Appendix B of the FHWA's "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges." The sufficiency rating formula is a 100-point scale. A bridge in new condition, having no deficiencies, has 100 points, and each deficiency on a bridge reduces the structure's sufficiency rating by a predetermined value. When a bridge's sufficiency rating falls below 80 points, the bridge qualifies for rehabilitation, and when the sufficiency rating falls below 50 points, the bridge qualifies for replacement.

The problem, as it relates to bridge decks, is the formula gives very little weight to the condition of a bridge deck. The formula only lowers a bridge's sufficiency rating three points when the deck condition (NBI Item #58) is four (poor). It only lowers the sufficiency rating five points when the deck condition is three (serious) or below. In comparison, the formula lowers a Bridge's sufficiency rating 25 points when, either, the superstructure (NBI Item #59) or the substructure (NBI Item #60) conditions are four (poor). The formula lowers a bridge's sufficiency rating 40 points, and 55 points, when the condition of the superstructure or substructure is three (serious) or two (critical), respectively. As a result, if only a bridge deck is rated poor, the bridge does not qualify for HBP funds.

To qualify preventive maintenance activities for HBP funds, states must work with their FHWA division office to demonstrate they have a "systematic plan" for maintaining their bridges. Once a "systematic plan" is demonstrated, a list of HBP eligible preventive maintenance activities can be developed. In Michigan, preventive maintenance activities relating to bridge decks include deck patching, expansion joint replacement, epoxy overlays, and hot mix asphalt overlays. Rigid overlays (i.e. * concrete, latex modified concrete, or micro-silica concrete) are classified as rehabilitation projects, therefore a bridge must meet the more stringent sufficiency ratings as discussed above.

Rigid overlays are a well-proven cost effective preservation activity for bridge decks, especially those that receive large traffic volumes. Likewise, it is easily shown that it is cost effective to rehabilitate or replace structurally deficient bridge decks before more extensive damage is done to the superstructure and substructure. It simply does not make sense to exclude rehabilitation and replacement of bridges decks from HBP funds when the rest of the structure is in fair to good condition. This is like saying you should not replace or repair the shingles on your home's roof until moisture has been allowed to penetrate and destroy the drywall or crack the foundation.

By definition, a bridge is "structurally deficient" if any one of the three major elements is rated four (poor) or below. Consequently, if only the bridge deck is rated four (poor) or below, the bridge is structurally deficient. This is an important point to be aware of because Section 1114 of SAFETEA–LU "declares that it is in the vital interest of the United States that a highway bridge program be carried out to enable States to improve the condition of their highway bridges over waterways, other topographical barriers, other highways, and railroads through replacement and rehabilitation of bridges that the States and the Secretary determine are structurally deficient or functionally obsolete and through systematic preventative maintenance of bridges". Therefore, allowing rehabilitation or replacement of structurally deficient bridge decks is consistent and directly supported by SAFETEA–LU.

It is also important that to remember and convey that bridges do not exist in a vacuum. Bridges are always tied to the roads they connect. Many of the structurally deficient bridges we have are located on major freeways that are tied up in long-term corridor improvement studies, or there simply is not enough money to do the needed improvement to the corridor or interchange. The bridge may need replacement, but that must go along with a freeway widening (adding lanes), or redesign of an interchange. In many cases, we can not just simply fix the bridges without doing major road improvements also.

Bridge Management Software

Currently, 43 states plus Puerto Rico and the District of Columbia, along with several local agencies (including Los Angeles and Phoenix) and six international agencies, use an AASHTO BRIDGE*Ware*® software program called *Pontis*®. This is a computer-based bridge management system developed to assist in the challenging task of managing an agency's structures. Pontis can store bridge inventory and inspection data, formulate network-wide preservation and improvement policies for use in evaluating the needs of each bridge in a network, and make recommendations for what projects to include in an agency's capital plan for deriving the maximum benefit from limited funds.

Once inspection data have been entered, Pontis can be used for maintenance tracking and federal reporting. Pontis integrates the objectives of public safety and risk reduction, user convenience, and preservation of investment to produce budgetary, maintenance, and program policies. Additionally, it provides a systematic procedure for the allocation of resources to the preservation and improvement of the bridges in a network. Pontis accomplishes this by considering both the costs and benefits of maintenance policies versus investments in improvements or replacements.

Responses from an informal August 2007 AASHTO survey[1]1 found that 17 of 37 states use an in-house computerized bridge management system that allows for prioritization and monitoring of elements in conjunction with either Pontis data collection or an in-house database. In some cases, Pontis is used by the states as a data collection system only, but many states are also using the management capabilities of Pontis, which allow them to predict bridge element deterioration levels and prioritize spending.

As noted, most states have some form of computerized bridge management system in place; however, the complexity and abilities vary. The goal of this effort may be to better define the abilities a state should have within its bridge management system and allow for flexibility within each state to accomplish these goals in the most efficient manner possible.

B) What are the possible short- and long-term consequences of maintaining the current level of bridge repair and replacement efforts (if no changes are made to the current systems)?

Most states responding to the AASHTO informal survey cite that their systems will not be affected greatly in the short-term if there are no changes made. However, most stated that long-term effects of an unchanging system would be significant. One example can be seen in Utah, where approximately five percent of the State system is Structurally Deficient. UDOT has developed and maintains strategic goals and performance measures for the overall health of its bridge system, as do many other states. Historically, funding from the Federal Bridge Programs (HPRR) is not adequate to address all of the needs. Therefore Utah's program is supplemented with State funds for both bridge replacement and preventive programs. Even with the supplemental State funds, resources are not adequate to address all of the Structurally Deficient bridges.

The consequence of inadequate funding includes increased risk. Typically states manage the risk of structurally deficient bridges with a variety of processes including; more frequent inspections, and consideration for load restrictions, shoring, and possible closure of a bridge. There are a large number of bridges that were built during the "Interstate Era." Many of these bridges are already functionally obsolete, and many more will become functionally obsolete as traffic volumes increase. More importantly, the volume of freight is expected to double in the next 20 years, and the long-term trend in the industry has been for increased vehicle weight and axle loads. Improvements in tire technology will allow even greater axle loads, and the expanded use of drop axles has resulted in vehicles with concentrated loading that far exceeds the standard vehicles used for load rating.

There has been insufficient funding to replace bridges at a sustainable rate. If the funding is maintained at current levels, this trend will continue and the average bridge age will continue to increase, while the conditions continue to decrease. Bridges will deteriorate faster than they can be repaired and/or replaced. This will require load limiting (posting) of bridges and/or the closing of bridges. Thus limiting the use of the existing transportation system—significantly impacting the Nation's economy.

A funding program is needed that will allow states to "sustain" an efficient transportation system for the distant future. Since bridges have a 50 to 100 year lifespan, the results of a non-sustainable funding program are not immediately apparent, but will nonetheless result in significant impacts to the economy if not dealt with at a level that will "sustain" the efficiency needed for economic growth.

Some states report that, in the short-term, failure to maintain SD bridges will necessitate costly "emergency" repairs to allow routes to remain open at required functional levels. These emergency repairs reduce funds available for more permanent and cost effective rehabilitations

Is Current Bridge Investment Adequate?

It should be noted that currently states are spending dramatically more money on bridges than is provided under the federal Bridge Program. For example, in 2004 the federal Highway Bridge Program provided $5.1 billion to the states. That year, states actually spent $6.6 billion in federal aid for bridge rehabilitation. State and local funding added another $3.9 billion for bridge repairs. FHWA reports that in 2004 a total of $10.5 billion was invested in bridge improvements by all levels of government.

Oregon's 10-year state bonding program is providing $1.3 billion of state funding for the rehabilitation of hundreds of deficient bridges. This is twice the amount received in federal bridge funding.

According to U.S. DOT's *2006 Conditions and Performance Report,* the backlog of needed repairs on National Highway System bridges alone total over $32 billion, which includes over $19 billion needed on Interstate Highway System bridges. Structurally deficient bridges on the National Highway System only represent one-tenth of the total number of structurally deficient bridges on the U.S. road network. As wear and tear on our nation's infrastructure continues, it will only continue to increase the needs in coming years.

The *Conditions and Performance* report also states that maintaining the current investment level of $10.5 billion annually would reduce the backlog of bridge needs by half over the next 20 years. An increase in that investment level to $12.4 billion per year for bridge system rehabilitation would eliminate the backlog by 2024, excluding any kind of necessary spending on expansion or enhancements.

In addition to providing needed additional funding, we recommend investigating what can be done to streamline processes that delay the implementation of needed repairs on our nation's highway system, including reducing environmental red tape and allowing the use of proprietary engineering-related products that could spur innovation in long-term solutions.

During the last reauthorization of the federal transportation bill, SAFETEA–LU gradually increased annual funding levels for the Highway Bridge Program by six percent over the life of the bill (from FY 2005 to FY 2009). However, far outpacing that increased funding have been dramatic increases in materials costs for steel, concrete, fuel, asphalt. States report that prices jumped 46 percent over the years from 2003–2006. In addition, the *Conditions and Performance* report attributes increases in the "cost to maintain highways" to the rising cost of construction in large urbanized areas due to environmental mitigation and construction strategies (such as night work) intended to reduce the impacts of work zones on users.

Aside from the well-documented dramatic increases in construction costs, there have been equally dramatic increases in traffic, especially heavy trucks, on the Nation's major highways. Today, the average mile of Interstate highway carries 10,500 trucks per day. By 2035, that number is expected to more than double to 22,700 trucks per day.

The truck issue also extends to overweight vehicles. As an example, in Iowa, the DOT's Bridge Office issues an average of 50 permits per day for trucks weighing over 156,000 pounds, or approximately 7,500 permits per year. These trucks are roughly twice the standard "legal" weight limit, causing significant wear and tear on the system, but are necessary for the economic health of our country. And these numbers are only anticipated to increase.

Thus, we are left with a system that has challenges to meet, and a program that does not have enough funding to overcome the current backlog.

Question 3

A) How do State and local governments use the results of research and technology development by the Federal Government?

Many states work closely with the FHWA, AASHTO, and other groups to share technology with local government agencies and consultants. In addition, training programs such as the National Highway Institute, Library sessions, and Webinar's, are used to exchange information. Similar to any field, advances in highway infrastructure typically are the result of cumulative improvements over time from many sources instead of major breakthroughs. The Departments of Defense, Energy, Commerce, and Transportation all contributed to the state-of-the-art in structural steels, corrosion-resistant materials, Portland cement concrete, and asphaltic concrete that are now routinely used for highways. In addition to the materials, designs, and practice that are currently in use, reports and research papers stemming from Federal Government programs are routinely referenced by practitioners and researchers at State and local DOTs to make decisions on using a new technology or pursuing further research into a new technology.

There are many excellent reports that are produced through the National Cooperative Highway Research Program, under the direction of the Transportation Research Board of the National Academies. These reports let states know what the leaders in certain areas are doing. Taking the time to read reports and learn about what others have done enables individual states to avoid the expense and time of learning the lessons that have already been learned by others. For example, the NCHRP *"Manual for Bridge Rating Through Load Testing"* has excellent guidance for bridge owners to test older bridges that have low calculated load capacity yet are not deteriorated and seem to be performing well.

The results of many federal research projects are used to implement changes to design philosophies and inspection techniques. Recent examples include the migration of our design philosophy to LRFD, the addition of new SU type rating vehicles to the current federal rating vehicles (Type 3, 3S2, 3–3), etc. States use the results of research from sources such as NCHRP for the inspection, testing and analysis of bridges, when the results of the projects are directly implemented into the AASHTO bridge design, maintenance and analysis codes or when the results of the research is published.

In addition, most states enroll DOT staff in National Highway Institute (NHI) courses for technical training. NHI courses are developed with the help of Federal Government and participate in federally sponsored conference and workshops to seek information on new technologies.

B) How do federal technology transfer programs for bridge-related research and technology development help the states?

Technology transfer programs, such as organizing conferences and NHI courses, assist states in being aware of the current state-of-the-practice. Peer exchange programs help peers to meet and discuss best practices and issues they face every day. The states encourage FHWA to develop periodic bridge inspection/management peer exchange programs and program peer reviews to facilitate more discussions and improvements.

The Technology Transfer (T2) program, National Highway Institute, and other program are extremely helpful in sharing information. The T2 program is very beneficial in that it has a dedicated staff to administer the program, reducing workload for DOT and FHWA personnel. More information on T2 can be found at: *http://www.federallabs.org/*. The Federal Laboratory Consortium for Technology Transfer (FLC) is the nationwide network of federal laboratories that provides the forum to develop strategies and opportunities for linking laboratory mission technologies and expertise with the marketplace. The FLC was organized in 1974 and formally chartered by the Federal Technology Transfer Act of 1986 to promote and strengthen technology transfer nationwide. Today, more than 250 federal laboratories and centers and their parent departments and agencies are FLC members.

In many federally sponsored technology transfer events, individuals with many years of experience are able to share what technology had worked for them, and what technology had fallen short. This was an excellent forum to learn about the research being done on a recently developed paint that holds promise for a significantly longer service life. Without technology transfer programs, individual states would not benefit from the lessons of others and would have to rely exclusively on vendor information. One example of these types of events were two Bridge Preservation Workshops held earlier this year. These workshops enabled engineers from all states to gather together and discuss issues related to bridge management and maintenance.

In addition, technology transfer and programs such as the Innovative Bridge Research and Deployment Program (IBRD) provide a means to disseminate information, experience and "lessons learned" that allow states to use new materials such as high strength steel and high performance concrete more efficiently. More information on IBRD can be found at: *http://www.fhwa.dot.gov/bridge/ibrd/*

C) What technical assistance have state and local governments received from the U.S. DOT for steel truss bridge inspections following the bridge collapse in Minneapolis? Was this technical assistance helpful?

Since August 1, in compliance with federal requests, every state has reviewed or is in the process of re-inspecting its steel deck truss bridges.

Most states noted that although their FHWA division office let them know they were available to assist, no assistance from them was needed or solicited. However, several states noted and appreciated the numerous forms of technical assistance provided by FHWA ranging from Technical Advisories, copies of reports, updates on emergency efforts, national teleconferences, and meetings with the local FHWA office. A few states also noted that the technical advisories did provide a basis for a uniform national response in light of the I–35 collapse in Minnesota.

In Georgia, it was noted that the FHWA Division participated in the inspections of GDOT's two steel deck truss bridge structures and GDOT appreciated their participation in the inspections.

Conclusion

We continue to make progress in addressing bridge replacement and rehabilitation needs, but there just isn't enough money to close the gap. Each year, as bridges continue to age and deteriorate, it is an uphill battle to keep up with the demands.

AASHTO and the State DOTs stand ready to help Congress address the needs for transportation infrastructure in America. The tragic Minneapolis bridge collapse rightly raises concerns about the condition and needs of the Nation's bridges. AASHTO and the State DOTs continue to work with NTSB and others as they investigate the cause of this tragic event, and when a cause has been identified we are committed to working jointly with Congress to address the issue head-on and to correct the situation in the most expedient way possible. Until that time, it is important to avoid premature speculations, and diligently obtain all relevant data to arrive at the appropriate solution.

BIOGRAPHY FOR HARRY LEE JAMES

After having earned a Bachelor of Science Degree in Civil Engineering (with honors) from Mississippi State University (MSU) in 1976, Harry Lee James worked in the private construction industry and later for a consulting engineering firm before joining the MDOT team as a bridge designer in 1982. Mr. James was appointed State Bridge Engineer in 1999, and in February 2003 he was appointed to the position of Deputy Executive Director/Chief Engineer. Because of his focus on bridges throughout his career, this appointment has given Mr. James the unique opportunity and obligation to promote better and safer bridges.

Mr. James is a licensed Professional Engineer and a licensed Professional Land Surveyor in Mississippi. He serves on the American Association of State Highway Officials' (AASHTO) Standing Committee on Highways, he is a member of the National Cooperative Highway Research Program (NCHRP) 12–62 Panel, and he was formerly on the AASHTO Subcommittee on Bridges and Structures. Mr. James serves as vice chair of the AASHTO Standing Committee on TRAC and is the committee's newest member. Mr. James believes that top-down support of TRAC, or any program is key to its success, and he plans to bring that message to the states within his southeast U.S. AASHTO district.

Mr. James is a native of Canton, Mississippi. He is the father of two young children, both girls. Together with his wife, who is also an engineer, they hope to inspire their children to careers in transportation.

Mr. LIPINSKI. Thank you, Mr. James. I feel right at home here with all the engineers on the panel. Dr. Womack?

STATEMENT OF DR. KEVIN C. WOMACK, DIRECTOR, UTAH TRANSPORTATION CENTER; PROFESSOR OF CIVIL AND ENVIRONMENTAL ENGINEERING, UTAH STATE UNIVERSITY

Dr. WOMACK. Thank you. I am here as the Chair of the Transportation Policy Committee of the American Society of Civil Engineers, but I am also a structural engineer by training and have been involved in the area of bridge research for the past 15 years. I am pleased to lend ASCE's expertise to the problem of the Nation's crumbling infrastructure that was highlighted by the collapse of the I–35 West bridge in Minneapolis.

Like all bridges, all man-made structures deteriorate. Deferred maintenance allows deterioration and causes bridges to be more susceptible to failure. As with other critical infrastructure, a significant increase in investment is essential to maintain the benefits and to assure the safety that society demands. Research is a critical effort that can reduce the existing investment gap between the funding available and the funding needed to improve the condition and performance of our highway infrastructure.

The Highway Trust Fund has been an essential source of funding for surface transportation research and technology and SAFETEA–LU, the Surface Transportation Research, Deployment and Development and the University Transportation Research sections were both completely programmed or earmarked and over-authorized creating a difficult environment within which FHWA and RITA must allocate funds. An added result to this fact is that FHWA now has no discretionary funds to maintain certain core research programs, which means that its Turner-Fairbank Highway Research Laboratories are underutilized, its contract research program is limited, and such critical efforts such as the biennial Conditions and Performance Report may be in jeopardy. The practice of extreme programming and earmarking of the research title needs to be eliminated in future transportation authorization bills.

When looking at research in bridges, the current university and FHWA research activities do look at materials and process. Newer, more efficient designs can now be made due to computer analyses, which have been researched extensively. Design methods, the newest of which is the Load and Resistance Factor Design, have been researched and must continue to be researched to determine the performance of these lighter structures that use materials more efficiently.

There is a need to study long-term bridge life to develop a better understanding of how bridges age and deteriorate. This will allow us to better predict and model bridge behavior and could lead to improved maintenance practices and better bridge management. The FHWA's Long-Term Bridge Performance Program, a planned 20-year research program, should lead the way in this effort.

Obviously, to maintain bridges, more funds are needed, and more of those funds need to go into the maintenance of the structure, not just the deck. It is our hope that the Long-Term Bridge Performance Program will help to provide answers as to how to properly channel our nation's bridge maintenance funds.

Once a bridge is safely and optimally designed, it is of most use to the public if it can be built quickly and with the least disruption to traffic. Accelerated bridge construction can help to accomplish this goal. Prefabrication of bridge elements and new construction techniques are being championed by states and the Federal Highway Administration. However, performance questions remain, particularly in the area of seismic performance of these types of structures. Research into these types of questions is essential.

In terms of safety, inspection is the crux of this issue. A more clearly defined inspection protocol should be developed through research that goes beyond visual inspections to testing and monitoring that includes instrumentation. This new protocol must be as objective as possible with no doubt as to what steps are to be taken and when. One way to make visual inspection less subjective is to have it done by licensed, professional engineers and not by technicians. This, however, will lead to an exacerbation of the workforce issue and the current shortage of civil engineers, particularly in the transportation area.

The objective of research is to develop beneficial new technologies that will be better performing and more durable. Though the initial cost of these new technologies may be higher, their efficiencies and durability will, in the long run, reduce maintenance, repair, and rehabilitation costs in addition to creating longer service lives. This is how research can assist in closing the current investment gap that is so well-defined in the Conditions and Performance Report. The Federal Government should do more to encourage states to use new technologies without requiring the states to assume all the risk. There is an FHWA program, the Innovative Bridge Research and Deployment Program, that is designed to provide money to states for the use of innovating materials or technologies. This program needs to be expanded and monitored to ensure that these funds actually go toward proving new technologies. However, at the end of the day, procurement and procedures must be changed to count for life cycle costs, innovation, and contractor qualifications, or there will be no motivation to use new technologies. Successfully and efficiently addressing the Nation's infrastructure issue, bridges and highways included, will require long-term, comprehensive, nationwide strategy, one that includes research. For the safety and security of our families, we as a nation can no longer afford to ignore this growing program. We must demand leadership from our elected officials because without action, aging infrastructure represents a growing threat to public health, safety, and welfare, as well as to the economic well-being of our nation.

Thank you, Mr. Chairman, that concludes my statement. I will be glad to answer any questions the Committee would have.

[The prepared statement of Dr. Womack follows:]

PREPARED STATEMENT OF KEVIN C. WOMACK

Chairman Gordon, Congressman Hall and Members of the Committee:

Good morning. I am Kevin Womack, Chair of the Transportation Policy Committee of the American Society of Civil Engineers (ASCE).[1] I am a Professor of Civil and Environmental Engineering at Utah State University and Director of the Utah Transportation Center, a federally funded University Transportation Center. I serve on the National Academies' Research and Technology Coordinating Committee, an

[1] ASCE, founded in 1852, is the country's oldest national civil engineering organization. It represents more than 140,000 civil engineers in private practice, government, industry, and academia who are dedicated to the advancement of the science and profession of civil engineering. ASCE is a 501(c) (3) non-profit educational and professional society.

advisory committee to the Federal Highway Administration. I am a structural engineer by training and have been involved in the area of bridge research for the past 15 years.

Thank you for holding this hearing. As someone who has worked in this field for many years, I can say that there are few infrastructure issues of greater importance to Americans today than bridge safety.

I am pleased to appear today to lend ASCE's expertise to the problem of the Nation's crumbling infrastructure that was highlighted by the tragic events of August 1, 2007, when the I–35W Bridge in Minneapolis collapsed into the Mississippi River.

I. Bridge Conditions

More than four million vehicles cross bridges in the United States every day and, like all man-made structures, bridges deteriorate. Deferred maintenance accelerates deterioration, which may make bridges more susceptible to failure. As with other critical infrastructure, a significant investment is essential to maintain the benefits and to assure the safety that society demands.

In 2005, ASCE issued the latest in a series of assessments of the Nation's infrastructure. Our *2005 Report Card for America's Infrastructure* found that as of 2003, 27.1 percent or 160,570 of the Nation's 590,753 bridges were structurally deficient or functionally obsolete, an improvement from 28.5 percent in 2000. In fact, over the past 12 years, the number of deficient bridges, both structurally deficient and functionally obsolete categories, has steadily declined from 34.6 percent in 1992 to 25.8 percent in 2006.

However, this improvement is contrasted with the fact that one in three urban bridges (31.2 percent or 43,189) were classified as structurally deficient or functionally obsolete, much higher than the national average.

In 2005, the FHWA estimated that it would cost $9.4 billion a year for 20 years to eliminate all bridge deficiencies. In 2007, FHWA estimated that $65 billion could be invested immediately in a cost beneficial manner to address existing bridge deficiencies.

The 10-year improvement rate from 1994 to 2004 was a 5.8 percent (32.5 percent - 26.7 percent) reduction in the number of deficient bridges. Projecting this rate forward from 2004 would require 46 years to remove all deficient bridges. Unfortunately, bridges are now deteriorating at a rate faster than we can maintain them, so this 46 year projection has grown to 57 years to eliminate all deficient bridges. This shows that progress has been made in the past in removing deficient bridges, but our progress is now slipping or leveling off.

There is clearly a demonstrated need to invest additional resources in our nation's bridges. However, deficient bridges are not the sole problem with our nation's infrastructure. The U.S. has significant infrastructure needs throughout the transportation sector including roads, public transportation, airports, ports, and waterways. As a nation, we must begin to address the larger issues surrounding our infrastructure so that public safety and the economy will not suffer.

II. Bridge Inspection Program

The National Bridge Inspection Standards (NBIS), in place since the early 1970s, require biennial safety inspections for bridges in excess of 20 feet in total length located on public roads. These inspections are to be performed by qualified inspectors. Structures with advanced deterioration or other conditions warranting closer monitoring are to be inspected more frequently. Certain types of structures in very good condition may receive an exemption from the two-year inspection cycle. These structures may be inspected once every four years. Qualification for this extended inspection cycle is reevaluated depending on the conditions of the bridge. Approximately 83 percent of bridges are inspected once every two years, 12 percent are inspected annually, and five percent are inspected on a four-year cycle.

Information is collected documenting the conditions and composition of the structures. Baseline composition information is collected describing the functional characteristics, descriptions and location information, geometric data, ownership and maintenance responsibilities, and other information. This information permits characterization of the system of bridges on a national level and permits classification of the bridges. Safety, the primary purpose of the program, is ensured through periodic hands-on inspections and ratings of the primary components of the bridge, such as the deck, superstructure, and substructure. This classification and condition information is warehoused in the National Bridge Inventory (NBI) database maintained by FHWA. This database represents the most comprehensive source of information on bridges throughout the United States.

It is important to note, however, that the value of the NBI is limited, although it is certainly a useful tool to evaluate the condition of public bridges. Among its limitations, a user cannot tell the condition of a specific element of the bridge, i.e., a girder or diaphragm or bearing. The overall rating encompasses the superstructure, the substructure, and the deck which all have unique elements. Therefore, the NBI cannot offer the kind of information that may be required for in-depth analysis.

Two documents, the American Association of State Highway and Transportation Officials' (AASHTO) *Manual for Condition Evaluation of Bridges* and the FHWA's *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges,* provide guidelines for rating and documenting the condition and general attributes of bridges and define the scope of bridge inspections. Standard condition evaluations are documented for individual bridge components as well as ratings for the functional aspects of the bridge. These ratings are weighted and combined into an overall Sufficiency Rating for the bridge on a 0–100 scale. These ratings can be used to make general observations on the condition of a bridge or an inventory of bridges.

The factors considered in determining a sufficiency rating are: S1—Structural Adequacy and Safety (55 percent maximum), S2—Serviceability and Functional Obsolescence (30 percent maximum), S3—Essentiality for Public Use (15 percent maximum), and S4—Special Reductions (detour length, traffic safety features, and structure type—13 percent maximum).

In addition to the sufficiency rating, these documents provide the following criteria to define a bridge as structurally deficient or functionally obsolete, which triggers the need for remedial action. The structural capacity of a bridge is also determined and is used to decide if a bridge should be restricted to trucks of lower weights.

Structurally Deficient—A structurally deficient bridge may be restricted to light vehicles because of its deteriorated structural components. While not necessarily unsafe, these bridges usually have limits for speed and weight, and are approaching the condition where replacement or rehabilitation will be necessary. A bridge is structurally deficient if its deck, superstructure, or substructure is rated less than or equal to 4 (poor) or if the overall structure evaluation for load capacity or waterway adequacy is less than or equal to 2 (critical). This is on a condition scale with ratings between 9 (excellent) and 0 (representing a failed condition). In a worse case scenario, a structurally deficient bridge may be closed to all traffic.

Functionally Obsolete—A bridge that is functionally obsolete is safe to carry traffic but has less than the desirable geometric conditions required by current standards. A bridge is functionally obsolete if the deck geometry, under-clearances, approach roadway alignment, overall structural evaluation for load capacity, or waterway adequacy is rated less than or equal to 3 (serious). A functionally obsolete bridge has older design features and may not safely accommodate current traffic volumes and vehicle sizes. These restrictions not only contribute to traffic congestion, but also pose such major inconveniences as lengthy detours for school buses or emergency vehicles.

Structural Capacity—Components of bridges are structurally load-rated at inventory and operating levels of capacity. The inventory rating level generally corresponds to the design level loads but reflects the present bridge and material conditions with regard to deterioration and loss of section. Load ratings based on the inventory level allow comparisons with the capacities for new structures. The inventory level results in a live load which can safely utilize an existing structure for an indefinite period of time. The operating rating level generally describes the maximum permissible live load to which the bridge may be subjected. This is intended to tie into permits for infrequent passage of overweight vehicles. Allowing unlimited numbers of vehicles to use a bridge at the operating level may shorten the life of the bridge.

Bridge Engineers and Bridge Inspectors:

Bridge inspection services should not be considered a commodity. Currently, NBIS regulations do not require bridge inspectors to be Professional Engineers, but do require individuals responsible for load rating the bridges to be Professional Engineers. ASCE believes that non-licensed bridge inspectors and technicians may be used for routine inspection procedures and records, but the pre-inspection evaluation, the actual inspection, ratings, and condition evaluations should be performed by licensed Professional Engineers experienced in bridge design and inspection. They should know the load paths, critical members, fatigue prone details, and past potential areas of distress in the particular type of structure being inspected. They must evaluate not only the condition of individual bridge components, but how the components fit into and affect the load paths of the entire structure. The bridge engineer may have to make immediate decisions to close a lane, close an entire bridge, or take trucks off a bridge to protect the public safety.

A new inspection protocol must be developed. This will involve visual inspection, load testing, and monitoring through instrumentation of bridges. The new protocol must be as objective as possible, with no doubt as to what steps are to be taken and when. One way to make the visual inspection less subjective is to have them all done by licensed professional engineers and not by technicians. This, however, will lead to an exacerbation of the workforce issue and the current shortage of civil engineers, particularly in the transportation arena, that is only going to get worse.

III. Bridge Design and Research

The Highway Trust Fund has been an essential source of funding for surface transportation research and technology (R&T) for decades. Research results have led to many benefits including: materials that improve the performance and durability of pavements and structures; design methods that reduce scour (and the consequent threat of collapse) of bridges; intelligent transportation systems technologies that improve safety and reduce travel delay; methods and materials that radically improve our ability to keep roads safely open in severe winter weather; innovative management approaches that save time and money; and analytical and design approaches that reduce environmental impacts, support sustainable development and improve the aesthetic and cultural aspects of transportation facilities.

These benefits are provided through several major transportation research programs. In the highway area these programs include the FHWA program, the National Cooperative Highway Research Program (NCHRP), and State department of transportation programs largely funded through State Planning and Research (SPR) funds. In the transit area the main programs are that of the Federal Transit Administration (FTA) and the Transit Cooperative Research Program (TCRP). The University Transportation Centers (UTC) program supports various transportation modes.

In SAFETEA–LU, the Surface Transportation Research, Deployment and Development and the University Transportation Research sections were both completely programmed or earmarked and over-authorized, creating a difficult environment within which FHWA and the Research and Innovative Technology Administration (RITA) must allocate funds. An added result to this practice is that FHWA now has no discretionary funds to maintain certain core research programs, which means that its Turner-Fairbank Highway Research Center laboratories are underutilized. The Research Center's contract research program is limited, as is its provision of expert technical support for states when they encounter bridge and tunnel problems. States are now made to prove they can pay for any FHWA technical support. Finally, such critical efforts as the biennial Conditions and Performance Report may be in jeopardy. The practice of extreme programming and earmarking of the research title needs to be eliminated in future surface transportation authorization bills. Competition and selection on qualifications, not special interest group influence is essential for an effective research program. And the FHWA must be left with sufficient discretionary funds to maintain certain core programs.

When looking at research on bridges, the current university and FHWA research agenda does look at materials and process. While materials and process are areas for improvement, the design of bridges is a well-developed discipline. In fact, one reason the bridges in this country have lasted so long is that those 30-, 40-, and 50-year-old, or even older bridges were typically designed very conservatively with appropriate redundancy. Newer more efficient designs can now be made due to computer analyses (finite elements), improved materials, and construction advances, which have been researched extensively. Design methods, the newest of which is the Load and Resistance Factor Design (LRFD) have been researched and must continue to be researched to determine the performance of these lighter structures that use materials more efficiently.

Better performing concretes can be made with increased durability and, if needed, increased strength. Evaluation of this concrete with new, high strength reinforcing bars is needed, as well as research into the engineering properties and feasibility of using lightweight high performance concrete for bridges.

Research is ongoing at NCHRP to evaluate the remaining fatigue life of existing older steel bridges in America. This is an important study. However we also need to continue the research, development, and deployment of high performance steel for bridges, with its increased toughness and improved weldability.

Fiber-reinforced polymer (FRP) composites continue to hold promise for the future for bridges. Research to develop guidelines for using FRP in bridge decks, as well as using FRP externally-bonded sheets as a strengthening repair system for concrete girders and piers, is important.

Bridge and tunnel security is an area that demands our attention. Research into blast resistant design for bridges and tunnels and development of specifications and training materials for bridge engineers is important to our nation's security.

Hurricane Katrina is most known to engineers for the damage that it did to New Orleans and the levees. What isn't as well known is the damage that it did to bridges in Louisiana, Mississippi, and Alabama due to wave action, storm surge, and debris. Research being done through a joint AASHTO–FHWA–TRB transportation pooled-fund study to develop Guide Specification and a Handbook of Retrofit Options for Bridges Vulnerable to Coastal Storms is critical work for the safety and operability of our nation's bridges during extreme events.

There is also a need to study long-term bridge life to develop a better understanding of how bridges age and deteriorate. This will allow us to better predict and model bridge behavior and could lead to improved maintenance practices and better bridge management. The FHWA's Long-Term Bridge Performance Program, a planned 20-year research program, should lead the way in this effort. At present, this program is significantly under-funded.

As for maintenance, it is based on the funding available and which bridge is most in need of repair. That usually means deck repair, not the structure of the bridge. When the public notices problems, such as potholes and the like, these get attention. The public rarely notices severe structural problems unless concrete is falling from the bottom of an overpass bridge.

Obviously, to properly maintain bridges, more funds are needed, and more of those funds need to go into the maintenance of the structure, not just the deck. It is our hope that the Long-Term Bridge Performance Program will help to provide answers as to how to properly channel our nation's bridge maintenance funds.

Once the bridge is safely and optimally designed, it is of most use to the public if it can be built quickly and with the least disruption to traffic. Accelerated bridge construction can help to accomplish this goal. Prefabrication of bridge elements and new construction techniques are being championed by states and the Federal Highway Administration. However, some questions remain concerning performance in earthquake regions. Research into these questions is needed.

In short, how bridges are designed, withstand extreme events, age, and how construction techniques and materials for bridges can improve should continue to be researched to look for more efficient practices.

In terms of safety, inspection is the crux of this issue. I firmly believe that a more rigorous inspection and testing protocol should be developed and this should be a significant research topic. This is where an issue arises with the I–35W bridge. It was inspected appropriately, issues were discovered, and then there were no strict guidelines as to what to do next. It was decided to more closely monitor and inspect the bridge, but that was all done visually. If a better defined protocol were developed, the next step should have been instrumentation that could have been permanently placed on the bridge to monitor its condition constantly. The chances that instrumentation would have picked up something critical in Minneapolis would have been much greater than further visual inspections alone. Whether or not this would have picked up the impending failure is something we cannot know, but chances would have definitely been better.

A more clearly defined inspection protocol should be developed, through research, which goes beyond visual inspections to include testing and monitoring with instrumentation.

Few states or their bridge contractors take advantage of new technologies due to the current practice of selecting low-cost bids. There usually is no incentive for the contractors to use new technology; it is often more expensive and may have increased risk. Until life cycle costs, along with the consideration of innovative materials or construction practices, are considered in awarding bids, then nothing is going to happen. States are very wary of using new materials and technologies, because if the technology does not work, the state becomes legally liable.

The Federal Government should do more to allow states to use new technologies, without requiring the states to assume all the risk. There is an FHWA program—the Innovative Bridge Research and Deployment program, with a funding level of $13.1 million available—that is designed to provide money to states for the use of innovative material or technologies. However, I do not believe the funds are being used by all the states in a manner that would result in proof of new technologies.

Again, until procurement procedures are changed to account for life cycle costs, innovation, and contractor qualifications, there is little motivation or financial incentive to be innovative.

IV. Addressing the Current Bridge Deficiencies

We need to adopt a risk-management approach to determine our priorities for the maintenance, rehabilitation and replacement of bridges. We must define the greatest risk, looking at the likelihood of bridge failure and the cost in lives and money of such a failure. We must then determine where the funds should go to ensure the greatest return in terms of public safety. This means that the bridges in the worst shape do not necessarily get the money for repairs if they have a low potential loss of life and economic impact. With limited funds, this is the most fiscally most responsible way to go.

The short-term consequences are what we have seen occur-periodic bridge failures that result in loss of life and economic loss. The long-term consequences of doing nothing more than we do now will be potentially disastrous. As the classic bridges (unique designs that span major rivers) become older and the Interstate bridges reach the end of their design life, bridge collapses may become more frequent with time, as will the resulting loss of life, and the economic consequences of tying up the country's major shipping lanes.

V. ASCE's Policies Regarding Bridges

In 1988, the National Council on Public Works Improvement estimated that a doubling of the annual expenditure on infrastructure is needed to meet national needs. Doubling of spending, even through the use of innovative financing techniques, is unlikely. To increase productivity and reduce costs through the development of innovative design, materials, construction methodologies, rehabilitation technologies, maintenance procedures, and operation techniques are essential, to reducing the correct investment gap that exists in caring for our surface transportation infrastructure.

Currently, there are a number of obstacles which discourage innovation on a widespread scale. Civil engineers, for example, are under increasing pressure to eschew innovation and to be conservative in their judgment because of lawsuits, rules, regulations, legislation, standards, budget expectations and restrictions, and a desire for financial predictability.

Fragmentation of the design and construction industry limits the support of long-term research efforts that could result in technological gains and innovation. Appropriate technical innovation and support groups can contribute to improved disaster resilience, cost effectiveness and improved productivity and quality throughout the infrastructure industry.

The public demands that the operation, maintenance, expansion, rehabilitation and new construction of the Nation's infrastructure be performed to enhance economic vitality, disaster resilience and public safety, but with minimal impact on their lives. The public requirement calls for innovative solutions to minimize costs of delays, environmental costs and project costs. Establishing these innovative solutions requires coordination and sustained research and development.

INFRASTRUCTURE RESEARCH AND INNOVATION

ASCE supports efforts to foster research and development related to infrastructure facilities. The goal is to enhance support of economic vitality while assuring public safety and disaster resilience through increased innovation, productivity and security in design, materials, construction, rehabilitation, maintenance and operations as applied to America's infrastructure facilities.

ASCE believes appropriate methods to implement infrastructure research, innovation and security include:

- Supporting legislation and policies that encourage development of new technology and processes;
- Supporting and encouraging, through appropriate incentives, research to accelerate the development of existing technology and develop new technology in the fields of design, materials, construction, maintenance, rehabilitation, and operation of the infrastructure with understanding of the need for disaster resilience;
- Supporting appropriate funding for infrastructure research at the federal level in conjunction with State/local agencies, universities and private enterprise;
- Supporting efforts to identify and disseminate information on Federal, State, and local governments, academia and private sector infrastructure research and development activities;
- Supporting efforts to limit the risk and liability that would discourage innovative infrastructure technology;

- Focusing national attention on infrastructure needs through cooperative efforts;
- Providing opportunities for academia and practicing engineers to conduct research and development activities; and
- Supporting efforts that develop and implement new strategies and technologies to mitigate the impact of disasters on the Nation's infrastructure in a consistent manner.

The Role of the Federal Government in Civil Engineering Research and Development

Federal R&D funding currently provides a substantial percent of the total U.S. civilian R&D investment. Federal leadership is essential to civil engineering research. With inadequate federal funding, the ability to maximize the leveraging of R&D funds through government-university-industry partnerships would not be possible.

ASCE supports a focused federal civil engineering research and development (R&D) program consistent with national goals. Programs should promote new U.S. capabilities, improve efficiencies and advance the practice of civil engineering to improve the quality of life.

ASCE encourages coordinated and integrated basic and applied civil engineering research that leverages federal R&D funds through government-university-industry partnerships. Programs fostering basic research should focus on maintaining a steady flow of talent and technology to U.S. industry and agencies. Programs focusing on higher risk research with the potential for high payoff should meet national needs and improve the quality of life by:

- Enhancing public health and safety;
- Enhancing environmental quality;
- Supporting the goals of sustainable development;
- Improving public works infrastructure;
- Improving global competitiveness in U.S. civil engineering products and processes; and
- Enhancing national security.

SURFACE TRANSPORTATION RESEARCH FUNDING

ASCE supports the following general principles in the reauthorization of research and technology programs in the Nation's surface transportation legislation:

- Improvements resulting from research and technology (R&T) are critical to achieving national transportation goals in safety, quality of life, economic health, environmental impacts, sustainability, and security.
- Adequate funding should be dedicated to R&T activities.
- Research programs should be conducted according to the highest scientific and engineering standards, from priority-setting to award of contracts and grants to review and evaluation of research results for implementation.
- Research programs should be carried out with appropriate involvement from stakeholders in the public, private, and academic sectors.
- Technology transfer activities are critical to successful implementation of research results and should be supported with R&T funds.
- Public-private partnerships should be fostered by identifying appropriate roles for each partner and providing incentives for private investment.

Within the context of the general principles set out above, ASCE supports the following actions regarding specific surface transportation R&T programs.

- The research and technology portion of the State Planning and Research (SPR) program should be maintained to help support state-specific activities while continuing to encourage the states to pool these resources to address matters of more general concern.
- University research should continue to be supported through the University Transportation Centers (UTC) program using a competitive selection process that guarantees quality participants and fairness in the allocation of funds. The Federal Highway Administration's (FHWA) program should be strengthened by giving it sufficient funding and flexibility to implement the recommendations of TRB Special Report 261, *The Federal Role in Highway Research and Technology*: to focus on fundamental, long-term research; to perform research on emerging national issues and on areas not addressed by oth-

ers; to engage stakeholders more consistently in their program; and to employ open competition, merit review, and systematic evaluation of outcomes.

- A continuation of the Strategic Highway Research Program SHRP II beyond the life of SAFETEA–LU, ensuring that critical research will be continued in key areas of surface transportation.
- The Federal Transit Administration's (FTA) research program should be given sufficient funding and flexibility to work with its stakeholders to develop and pursue national transit research priorities.
- The new Research and Innovative Technology Administration (RITA) should have a well-defined scope and responsibility and appropriate funding, in addition to currently authorized research funding, so that it may supplement and support the R&T programs of the modal administrations.

VI. Conclusion

Successfully and efficiently addressing the Nation's infrastructure issues, bridges and highways included, will require a long-term, comprehensive nationwide strategy—one that includes research and identifying potential financing methods and investment requirements. For the safety and security of our families, we, as a nation, can no longer afford to ignore this growing problem. We must demand leadership from our elected officials, because without action, aging infrastructure represents a growing threat to public health, safety, and welfare, as well as to the economic well-being of our nation.

Thank you, Mr. Chairman. That concludes my statement. I would be pleased to answer any questions that you may have.

BIOGRAPHY FOR KEVIN C. WOMACK

Dr. Womack is currently Professor of Civil and Environmental Engineering at Utah State University, and Director of the Utah Transportation Center, a Federally funded University Transportation Center.

Dr. Womack received his Doctorate degree in Civil Engineering from Oregon State University in 1989, his Masters of Science degree from the University of Pennsylvania in 1985 and his Bachelors of Science degree from Oregon State University in 1980. He has been a member of the American Society of Civil Engineers for over 20 years and currently chairs their National Transportation Policy Committee. He has also served as a past Chair of the Technical Committee on Structural Identification and Health Monitoring of Constructed Facilities; and as a member of the Technical Committee on the Performance of Structures During Construction.

Currently Dr. Womack is also serving on the National Academy's Research and Technology Coordinating Committee, an advisory committee to the Federal Highway Administration.

In 2001–02 Dr. Womack worked as an AAAS/ASCE Congressional Fellow for the Senate Committee on the Environment and Public Works, under then Chairman Senator James Jeffords. He was responsible for writing much of the research title contained in the Senate version of SAFETEA.

Dr. Womack is a registered professional engineer in the States of Oregon and Utah, and has worked as a consulting engineer with the firm of Kramer, Chin and Mayo, Inc. of Seattle, Washington. He is a structural engineer by training and has been involved in the area of bridge research for the past 15 years.

Mr. LIPINSKI. Thank you, Dr. Womack. I can tell you are all engineers because you are all almost sticking within the five-minute limit which we don't always see.

Mr. Bernhardt.

STATEMENT OF MR. MARK E. BERNHARDT, DIRECTOR, FACILITY INSPECTION, BURGESS & NIPLE, INC.

Mr. BERNHARDT. Thank you. Mr. Chairman, honorable Members of the Science and Technology Committee, good morning.

Again, my name is Mark Bernhardt, and I am the Director of Facility Inspection for Burgess & Niple in Columbus, Ohio. I have been working in the bridge inspection field for over 10 years, and in that time I have managed, reviewed, or performed more than 3,000 bridge inspections.

Burgess & Niple is also a member of ACEC, the American Council of Engineering Companies. ACEC is the business association of America's engineering industry representing over 5,500 member firms from across the country. On behalf of ACEC and the industry, we appreciate the opportunity to testify before you today to discuss the research and technology that contributes to bridge safety.

In order for transportation agencies to make sound decisions regarding bridge maintenance and rehabilitation, they require comprehensive information on bridge conditions. Many factors control the validity of the data being supplied to the decision-makers. These factors are as varied as inspector training and experience, effective of bridge management systems, inspection methods, and available funding. All of these factors play a role in ensuring bridge safety.

Bridge inspections in the U.S. are generally visual, thus qualitative in nature. A comprehensive study of the reliability of visual inspection was performed by the FHWA's Non-Destructive Evaluation Center in 2001. This study suggested that visual-only inspections provide data that is often highly variable and influenced by many factors such as the inspector's comfort level with working at height, structure accessibility, and duration of inspection. It is the general consensus within the engineering community that visual inspection practices must be supported by rigorous training, certification, and quality assurance programs and frequently supplemented with testing techniques to ensure reliable results.

The primary non-destructive evaluation techniques utilized during the inspection of steel bridges include magnetic particle, dye penetrant, and ultrasonics. These tests are relatively low cost, and proven protocols have been developed for their use and the interpretation of results. For concrete bridge decks, very simple procedures such as dragging a chain across the bridge deck can be a very good indication of hidden deficiencies. Its modern counterpart, ground penetrating radar, can do the same thing only more objectively and with repeatability. The Bridge Inspector's Reference Manual which forms the basis of bridge inspector training programs nationwide details these test methods as well as dozens of other effective methods.

What these tests and visual inspection all have in common is that they record conditions only at a single point in time. They are a mere snapshot of bridge conditions. While this is generally adequate for relatively low-risk structures, structurally deficient or complex structures that pose a greater risk to the traveling public require more. The emerging field of structure health monitoring holds much promise for real-time evaluation of structures and objective evaluation of bridge conditions. Structure health monitoring involves the installation of sensors under bridge components that allow for remote collection and observation of data at any time. These can include strain gauges, weigh-in motion systems, fiber optics, cameras, corrosion sensors, and acoustic emission equipment, all tied to data servers and digitally accessible in real time.

Funding for research and pilot projects in this area should continue to be a priority. Bridge engineers can be most effective by providing the decision-makers in transportation agencies with objective, data-driven recommendations. This data, combined with operational risk-based factors, can be used to determine optimum prioritization of bridge repairs.

Underlying all of this, however, is the fact that simply collecting more data and providing more frequent inspections will not improve overall bridge safety. Additional funding for bridge repair and replacement is required to adequately keep pace with bridge program needs.

Professional engineers benefit greatly from the results of research and technology programs funded by the Federal Government. The traveling public is the greatest beneficiary, however. Lessons learned and the conclusions reached during NCHRP and FHWA research projects are effectively disseminated to practicing bridge engineers. They are immediately incorporated into improved design, evaluation, and analysis methods.

In the weeks following the Minnesota I–35 bridge collapse, Burgess & Niple was asked by a number of State transportation agencies to assist with the inspection of steel deck truss bridges. This work was performed in response to an FHWA Technical Advisory. In general, the inspections were carried out in the same manner as those completed prior to the I–35 collapse. Investigation into the I–35 bridge collapse is still ongoing. It will likely be some time before the investigating engineers reach a definitive conclusion as to the precise cause of the collapse. Even if the cause of the collapse is found to be unrelated to bridge inspection practices, it is my hope that the dialog that has resulted from this tragic event will lead to improvements in the field of bridge inspection and result in a safer infrastructure system. A better understanding of bridge conditions through the expanded use of testing and structure health monitoring can help to improve both the allocation of bridge repair funds and bridge safety.

Thank you, Mr. Chairman, and I am happy to answer any questions you or the Committee Members may have.

[The prepared statement of Mr. Bernhardt follows:]

PREPARED STATEMENT OF MARK E. BERNHARDT

Mr. Chairman, honorable Members of the Science and Technology Committee, good morning.

My name is Mark Bernhardt and I am the Director of Facility Inspection for Burgess & Niple, Inc. in Columbus, Ohio. I have been working in the bridge inspection field for over 10 years and in that time I have managed, reviewed, or performed more than 3,000 bridge inspections and 160 load ratings.

Burgess & Niple is also a member of ACEC, the American Council of Engineering Companies, the business association of America's engineering industry representing over 5,500 member firms across the country. On behalf of ACEC and the industry, we appreciate the opportunity to testify before you today to discuss the research and technology that contributes to bridge safety.

Bridge deterioration is a significant problem facing transportation agencies nationwide. This is evidenced by the more than 73,000 structurally deficient bridges currently listed in the National Bridge Inventory (NBI). In order for federal, State, and local agencies to make sound decisions regarding bridge maintenance, rehabilitation, and replacement programs, they require comprehensive information on bridge conditions. Many factors control the validity of the data being supplied to the decision-makers in transportation agencies. These factors are as varied as inspector training and experience; effectiveness of bridge management systems; inspection methods; and available funding. All of these factors play a role in ensuring bridge safety. In today's testimony, I will focus my comments on just one of these areas—inspection methods. Specifically, I will outline some common techniques and technologies employed during bridge inspection operations, the emerging field of Structure Health Monitoring, and the effectiveness of technology transfer programs.

BRIDGE INSPECTION TECHNIQUES

Bridge inspections in the U.S. are generally visual, thus qualitative in nature, and follow the requirements outlined in the National Bridge Inspection Standards. Bridge inspections are performed to determine if any immediate hazards exist that would warrant reducing allowable loads on a structure or closing it entirely; to ascertain the extent of deficiencies or structural damage resulting from deterioration or other causes; and to enable bridge maintenance, repair, or replacement to be programmed effectively through early detection of deficiencies.

The primary tool employed by bridge inspectors today is the eyes. A comprehensive study of the reliability of visual inspection was performed by the FHWA's Non-Destructive Evaluation Center in 2001. This study suggested that visual-only inspections provide data that is often highly variable and influenced by many factors such as the inspector's comfort level with working at height, structure accessibility, and duration of inspection. With regard to localized defects in superstructure members, the study found that less than 8% of the inspectors successfully located weld cracks and other implanted defects in test bridges. It is the general consensus within the engineering community that visual inspection practices must be supported by rigorous training, certification and quality assurance programs, and supplemented with testing techniques to ensure reliable results.

Many common and proven non-destructive and destructive testing techniques are available to the inspector to supplement visual observations and provide more useful quantitative data. Additionally, the emerging field of Structure Health Monitoring holds much promise for real-time evaluation of structures and objective evaluation of bridge conditions. Providing more quantitative data to bridge program managers enables them to more effectively allocate bridge rehabilitation dollars. One current challenge with these tests, however, is how to best integrate the results into existing Bridge Management Systems.

The primary nondestructive evaluation techniques utilized during the inspection of steel bridges include magnetic particle, dye penetrant, and ultrasonics. These tests are relatively low cost, and proven protocols have been developed for their use and the interpretation of results. For concrete bridge decks, very simple procedures such as dragging a chain across a bridge deck can be a very good indication of hidden deficiencies. Its modern counterpart, Ground Penetrating Radar, can do the same thing, only much more objectively and with repeatability. Electrical potential can be measured to assess corrosion of embedded reinforcing steel, samples of concrete can be extracted for laboratory testing, and Impact Echo tests can be used to locate voids in post-tensioning ducts. The Bridge Inspector's Reference Manual, which forms the basis of bridge inspector training programs nationwide, details these test methods as well as dozens of other effective methods.

LIMITATIONS OF CURRENT PRACTICES

What these tests all have in common, as well as the federally mandated NBI inspections, is that they are often used to record conditions only at a single point in time. They are a mere a snapshot of bridge conditions. While this is generally adequate for relatively low risk structures, structurally deficient or complex structures that pose a greater risk to the traveling public require more. This is where Structure Health Monitoring holds the most promise. Structure Health Monitoring involves the installation of various sensors and monitors onto bridge components that allow for remote collection and observation of data at anytime. These can include strain gages, weigh-in-motion systems, fiber optics, cameras, corrosion sensors, and acoustic emission equipment, all tied to data servers and digitally accessible in real time. While a number of successful structure monitoring programs have been implemented, the technology is still emerging. Funding for research and "pilot projects" in this area should continue to be a priority. Bridge engineers can be most effective by providing the decision-makers in transportation agencies with objective, data driven recommendations. The structural condition data, combined with operational "risk-based" factors such as traffic counts, can be used to determine optimum prioritization of bridge repairs.

Underlying all of this, however, is the fact that simply collecting more data and providing more frequent inspections will not improve overall bridge safety. The engineering and scientific community can help to improve the relevance of the data by further researching advanced testing techniques. Additional funding for bridge repair and replacement is required to adequately keep pace with bridge program needs.

FHWA LONG-TERM BRIDGE PERFORMANCE PROGRAM

Presently, the FHWA is in the process of rolling out its Long-Term Bridge Performance Program. This proposed 20-year program will provide the funding and opportunity to develop standard protocols for the myriad of nondestructive testing methods, sensors, and monitoring systems available. The engineering community requires more knowledge in the areas of life cycle costs, deterioration models and mechanisms, and validation of the effectiveness of repair and rehabilitation strategies to improve the practice of bridge management. Another goal of this long-term program is to provide such data. I would encourage the Members of Congress to continue funding this essential program when its budget comes up for renewal.

FEDERAL TECHNOLOGY TRANSFER

Professional Engineers benefit greatly from the results of research and technology programs funded by the Federal Government. The traveling public is the greatest beneficiary, however. Lessons learned and conclusions reached during NCHRP and FHWA research projects are effectively disseminated to practicing bridge engineers. They are immediately incorporated into improved design, evaluation and analysis methods.

In the weeks following the Minnesota I–35 bridge collapse, Burgess & Niple was asked by a number of State transportation agencies to assist with the inspection of steel deck truss bridges. This work was performed in response to FHWA Technical Advisory 5140.27—Immediate Inspection of Deck Truss Bridges Containing Fracture Critical Members. In general, the inspections were carried out in the same manner as those completed prior to the I–35 collapse. Some additional focus was placed on the gusset plate connections between members due to speculation that this was an area of concern on the I–35 bridge.

The investigation into the I–35 bridge collapse is still ongoing. It will likely be some time before the investigating engineers reach a definitive conclusion as to the precise cause of the collapse. Even if the cause of the collapse is found to be unrelated to bridge inspection practices, it is my hope that the dialogue that has resulted from this tragic event will lead to improvements in the field of bridge inspection and result in a safer and improved infrastructure system. A better understanding of bridge conditions through expanded use of testing and Structure Health Monitoring can help to improve both the allocation of bridge repair funds and bridge safety.

Thank you Mr. Chairman and I am happy to answer any questions you or the Committee Members may have.

BIOGRAPHY FOR MARK E. BERNHARDT

Education

Purdue University—BS, Civil Engineering, 1991

Registration

Professional Engineer—Alaska, Arizona, Colorado, Louisiana, Montana, New York, Ohio, Texas, Utah, Virginia

Summary

Mr. Bernhardt joined Burgess & Niple in 1997 and is Director of the Facility Inspection Section. In his present position he manages a staff of engineers who perform structural condition assessments of bridges, towers, dams, and buildings. Before joining B&N, Mr. Bernhardt gained experience performing forensic structural inspections of various facilities nationwide. His professional work experience includes the following:

- Project management of large structural inspection projects
- Bridge inspection and load rating analysis
- Quality control/quality assurance reviews
- Performance of condition assessments of existing structures
- Structural evaluations in the wake of natural disasters such as fires, rock slides, hurricanes, and earthquakes
- Use of high-angle rope access techniques to inspect large buildings, dams, towers, and bridges
- Determination of the cause of structural failure
- Design of repairs for distressed and deteriorated structures

He has managed, reviewed, or performed more than 3,000 bridge inspections and 160 load ratings and climbed more than 100 bridges. Many of these inspections have utilized both destructive and non-destructive testing techniques to evaluate conditions. Mr. Bernhardt has authored a number of papers on bridge inspection and is a qualified NBI Team Leader experienced with AASHTO and FHWA inspection manuals, PONTIS, and the use of computer equipment and software for inspection and load rating. He is also a member of Ohio's FEMA Urban Search and Rescue Team in the position of Structural Specialist. Mr. Bernhardt holds a Bachelor of Science degree in Civil Engineering from Purdue University and is a Registered Professional Engineer in 10 states.

Relevant Background

Bridge Inspection—Project Manager, QA/QC Manager, NBI Team Leader, or team member on various bridge inspection projects, including a variety of bridge superstructure types such as arch, girder, suspension, and truss and involving various materials including steel, concrete, and timber. Mr. Bernhardt has accessed more than 100 large bridges by utilizing adapted rock climbing techniques. Representative bridge inspection projects include:

- **FHWA Eastern Federal Lands Highway Division Federal Lands and National Parks Bridge Inspections, Nationwide—**Project Manager for task orders that included NBI inspections of more than 600 bridges located in Yellowstone National Park, the Blue Ridge Parkway, the Natchez Trace Parkway, and Golden Gate National Park and other Federal Lands.
- **Statewide Bridge Inspections, Arizona—**Quality Control Engineer and Project Manager for multiple projects that have included more than 1,000 NBI inspections, 160 bridge load ratings using GT–Strudl and VIRTIS, and development of rehabilitation plans for more than 20 bridges.
- **Bronx-Whitestone Bridge, New York, New York—**Team Leader for NBI inspection of the floor system of this major suspension bridge utilizing adapted rock climbing techniques.
- **Brooklyn Bridge, New York, New York—**Project Manager for installation of accelerometers and other equipment on the bridge using industrial rope access techniques as part of a seismic study of the bridge.
- **Statewide Fracture Critical Inspections, Alaska—**Fracture critical inspections of 30+ steel truss and arch bridges located throughout the state. NBI Team Leader and project Quality Control Engineer. Access to the structures was gained by the use of adapted rock climbing techniques.
- **Local Agency Bridge Inspections, Oregon—**NBI Team Leader and Quality Control Engineer for Local Agency NBI inspection projects completed in Oregon that have included more than 1,500 bridges of a variety of sizes and materials.
- **Peace Bridge, Buffalo, New York/Fort Erie, Ontario, Canada—**Quality Control Engineer for the NBI inspection of this multinational bridge. Inspection reports completed for the NYSDOT, Peace Bridge Authority, and Ontario Transportation Ministry.
- **Concrete Bridge Deck Evaluations, Montana—**Performed detailed condition assessments that included chloride ion sampling, concrete coring and compression testing, half cell testing, and chain drag surveys for 14 interstate bridges.
- **Concrete Bridge Deck Evaluations, Arizona—**Performed detailed condition assessments that included chloride ion sampling, concrete coring and compression testing, half cell testing, ground penetrating radar, and chain drag surveys for 133 bridges located throughout the state.
- **Monroe Street Bridge, Spokane, Washington—**Performed detailed condition assessment of this historic concrete arch bridge in conjunction with an extensive bridge rehabilitation project.
- **Dames Point Cable Stay Inspection, Jacksonville, Florida—**Performed the first ever, detailed hands-on condition assessment of the steel stay cables using adapted rock climbing techniques.
- **Hope Memorial Bridge, Cleveland, Ohio—**NBI Team Leader on inspection of steel truss bridge.
- **Robert O. Norris Jr. Bridge, Williamstown, Virginia—**NBI Team Leader on inspection of steel truss bridge.

Structural Collapse/Disaster Response—Performed structural condition assessments and structural safety inspections in the aftermath of fires, hurricanes, earthquakes, and other incidents. He is a Structural Specialist on the Department of Homeland Security's FEMA Urban Search & Rescue Team for the State of Ohio.

- **Hurricane Katrina, Gulf Coast—**Deployed to Gulfport and Pass Christian, MS, in the aftermath of hurricane to perform structural assessments of damaged buildings in conjunction with search and rescue operations. The USAR team searched more than 2,500 structures.
- **Hurricane Andrew, South Florida—**Evaluated structural damage at 100+ office buildings, warehouses, apartment complexes, homes, etc., and determined the scope of required repairs for damaged buildings. Also involved in a research study for an insurance company that identified the parameters which had a significant effect on the performance of residential structures subjected to hurricane force winds.
- **Deer Island Tunnel, Boston, Massachusetts—**Deployed to construction site in Boston Harbor following fire in a tunnel access shaft. Sewage outfall tunnel was being bored 300 feet beneath harbor. Performed post-fire safety inspection of access shaft and tunnel. Developed debris removal plan and supervised remediation efforts to ensure that the areas were safe for construction operations to resume.
- **Northridge Earthquake, Northridge, California—**Performed structural evaluations of buildings damaged by earthquake. Developed repair scopes and cost estimates.
- **Post-Earthquake Evaluation of Tanana River Bridge, Tok, Alaska—**Deployed immediately following earthquake to perform structural safely evaluation of 1,000-foot truss bridge located on the Alaskan Highway. Industrial rope access techniques were used to achieve hands-on inspection of all portions of structure and avoid the need for heavy mechanical access equipment on the bridge.
- **Taco Cabana Roof Collapse, Las Vegas, Nevada—**Performed forensic structural investigation following roof collapse in restaurant on opening night.

Structural Condition Assessment—Performed condition assessments of existing structures, evaluation of building materials, assessment of integrity of building systems, determination of the cause of failures, and design of repairs for distressed and deteriorated structures. Used computer programs to aid in the analysis of complex structural systems. Some notable projects and structures investigated and assessed include:

- **Peterson v. Mission Viejo Corporation, Highlands Ranch, Colorado—**Evaluated foundation and slab movements for a builder involved in a class-action lawsuit. Over 1,000 single-family homes were involved in the suit. Developed a database to manage and analyze the data collected during inspection and survey work performed on approximately 200 of the homes. Developed foundation repair plans for the homes requiring repairs.
- **Soldier Field, Chicago, Illinois—**Performed a structural condition assessment of the stadium as part of a periodic monitoring program at the facility.
- **Miller Park Baseball Stadium, Milwaukee, Wisconsin—**Condition assessment of steel roof superstructure connections.
- **Heritage Villas, Laughlin, Nevada—**Condition assessment of walls and roofs at 90+ unit condominium complex.
- **Rhodes Tower, Cleveland, Ohio—**Performed a condition assessment of the pre-cast concrete façade on 20-story building. Investigated moisture infiltration problems and used industrial rope access techniques to inspect the façade.
- **Westin Hotel, Kansas City, Missouri—**Performed a condition assessment of specific components of the hotel complex and a structural analysis of a concrete canopy.
- **Executive Tower Inn, Denver, Colorado—**Investigation of masonry façade on 30-story building and structural analysis and rehabilitation of concrete floor slabs.
- **Hyatt Regency Tech Center, Denver, Colorado—**Investigation of foundation movements. Developed parking garage rehabilitation details.

- **Various Facilities—**Performed condition assessments and structural analysis of components or entire buildings at the following facilities:
  - North Star Steel—Youngstown, Ohio
  - Jefferson at Greenwood Apartment Complex—Greenwood Village, Colorado
  - Super Saver Cinema—Denver, Colorado
  - Westminster City Hall—Westminster, Colorado
  - Barton Fieldhouse—Cornell University, Ithaca, New York
  - Proctor & Gamble 6th Street Parking Garage—Cincinnati, Ohio
  - Northview Shopping Center—Westminster, Colorado
  - Rainbow Shoppes—Westminster, Colorado
  - Renaissance Apartments—Los Angeles, California
  - Idlewild Condominiums—Reno, Nevada
  - Westwood Westside Apartments—Iowa City, Iowa
  - Metro Dade County Administration Building—Miami, Florida
  - Cedar Cove Condominium Complex—Aurora, Colorado
  - Cherry Creek Towers—Denver, Colorado
  - Northside Assembly of God Church—Colorado Springs, Colorado
  - Mt. Carmel West Medical Center Parking Garages—Columbus, Ohio

Material Testing—Experience evaluating and testing a wide range of structural building materials including reinforced and pre-stressed concrete, masonry, steel, and timber. Has utilized both destructive and nondestructive testing techniques including the following:

- Magnetic Particle Testing
- Impact Echo
- Ultrasonic Testing
- Concrete Coring
- Sampling for Chloride Ion in Concrete
- Dye (Liquid) Penetrant Testing
- Ground Penetrating Radar
- Half-Cell Potential Measurements in Concrete
- Timber Boring
- Ground Penetrating Radar

Training

Technical Rescue Awareness—Washington State Homeland Security Institute, 2007

Bridge Inspection Training—FHWA/NHI/Alaska Department of Transportation, 2006

Haz Mat First Responder Operations Level Training—Environmental Options, 2006

IS–200 Basic Incident Command System (I–200 for Federal Disaster)—FEMA/US Fire Administration, 2005

IS–700 National Incident Management System (NIMS)—FEMA/US Fire Administration, 2005

Swiftwater/Surface Water Rescue—Ohio Region III Rescue Strike Team, 2005

WMD Terrorism Awareness for Emergency Responders—National Emergency Response & Rescue Training Center, 2005

Urban Search & Rescue Structures Specialist Training—FEMA/USACOE, 2004

Weapons of Mass Destruction Response Operations—FEMA/US Fire Administration, 2004

IS–100 Introduction to the Incident Command System (I–100 for Federal Disaster Workers)—FEMA/US Fire Administration, 2004

Cold Regions Engineering—University of Alaska/University of Washington, 2003

Effective Bridge Rehabilitation—University of Wisconsin, 1999

NDT Techniques (Dye Penetrant, Magnetic Particle, Ultrasonics) Training—Staveley Schools, 1998

Bridgeview Bridge Inspection Software Training—Oregon Department of Transportation, 1998

Confined Space Entry Training, 1997

Bridge Climbing/Industrial Rope Access Training—Burgess & Niple, Limited, 1997

Seismic Design Using the NEHRP Recommended Provisions—Structural Engineers Association of Colorado, 1995

Wood Construction Seminar—Wood Products Council, 1993

Concrete Repair Basics Seminar—Rocky Mountain Chapter ACI, 1992

Papers and Presentations

"Hurricane Katrina—Assessment of Structural Damage During FEMA USAR Operations," Water One, Wilmington, Ohio, October 2005.

"Post-Earthquake Evaluation of Tanana River Bridge at Tok, Alaska," International Bridge Conference, Pittsburgh, Pennsylvania, June 2003.

"Scanning the Spans," Arizona Roads & Streets Conference, Tucson, Arizona, April 2003.

"The Evolution of Bridge Inspection Techniques & Tools," Transportation Systems Center 2000 Workshop, San Antonio, Texas, February 2000, and Ohio Transportation Engineering Conference, Columbus, Ohio, 2001.

"Statewide Bridge Deck Survey Using Ground Penetrating Radar," Structural Materials Technology IV—An NDT Conference, Atlantic City, New Jersey, 2000.

"Non-Destructive Testing of Bridge Decks Using Ground Penetrating Radar," Midwest Bridge Maintenance Working Group, Ft. Mitchell, Kentucky, 2000.

"Condition Assessment of Arizona's Concrete Bridge Decks," Western Bridge Engineers' Seminar, Seattle, Washington, October 1999.

"Bridge Inspection and Rehabilitation," Arizona Public Works Association/Arizona Society of Professional Engineers, 1999 Statewide Conference, Flagstaff, Arizona, August 1999.

"In-Depth Inspection of Arizona's Steel Bridges," Arizona Department of Transportation 1998 Transportation Conference and Expo, Phoenix, Arizona, 1998, and TRB International Bridge Management Conference, Denver, Colorado, 1999.

"Forensic Engineering," ASCE Student Chapter—Colorado School of Mines, Golden, Colorado, 1996.

DISCUSSION

Mr. WU. [Presiding] Thank you very much, Mr. Bernhardt. The witnesses and everyone in the room have been witness to what frequently goes on here. The Chairman has had to step away to introduce his bill in another committee. I apologize to the witnesses. I have two other committee hearings going on right now and had to step away quickly to cast a vote, and my apologies, but I hope I haven't missed too much of the context of your spoken statements and from your written statements. And at this point, we enter into the question phase, and the Chairman recognizes himself for five minutes.

Mr. Bernhardt, you talked about a number of different testing methods, and some of the other witnesses referred to them also in their written testimony. Non-destructive testing has been commonplace in other industries, for example, in aviation for quite some time. And Mr. Judycki and Mr. Tang, your research center has worked on many of these testing methods, and yet bridge inspection continues to be primarily a visual process. Can you discuss for us what some of the barriers to adoption are and not just in terms of cost but also some of the non-cost barriers to adoption? And Mr. Bernhardt, why don't we begin with you, and then we will start at the other end of the table for anyone else who has some input on this.

Mr. BERNHARDT. That is an excellent question. I think some of the primary barriers would be related to just the reluctance to change. I think sometimes within human nature there is always a reluctance to change, and people want to stick with what they are comfortable with and don't want to try new testing methods and techniques; and I think that is part of it. Additionally, I think any time a new testing technique is rolled out and introduced, there has to be an infrastructure behind it to provide the training and the support to the personnel on the field that are going to use that system. If it is a computer-based system, certainly there has to be the infrastructure there to keep pace over the years as the computer system gets updated or the technology gets updated. So it is not just buying a testing tool once, there has to be the commitment from the agency to continue using that into the future and provide the training and resources necessary to make sure the personnel are using it properly into the future, too. Many times an agency will get a new tool or testing technique. They will use it for a little bit, and then that person may move on, that is, the one person in the agency that knows how to use that; and that knowledge will be lost. So that maybe comes into play a little bit when agencies are making a decision on what technology to adopt and what equipment to purchase.

Mr. WU. Mr. Judycki? Mr. Tang?

Mr. JUDYCKI. Let me just pick up on a couple of points, Mr. Chairman. First of all, the Federal Highway Bridge Research and Technology Program is about a $22 million program that is available, and part of that, as Dr. Womack mentioned, it is all designated, in fact over-designated, to the point that we were concerned about the flexibility, or the lack of flexibility, in putting a program together. About $900,000 is available to us and is being used effectively in our non-destructive evaluation laboratory and for non-destructive work on new inspection technologies and techniques. And we can talk about that some more. But on the barriers to innovation, which are critically important, certainly just sheer inertia, is to new technologies. And adopting new technology is very important, as was mentioned. There is also a resource issue, and certainly new technology is very often more costly without clear evidence of long-term benefits; and that is obviously a barrier, as well as the natural unwillingness to accept risk.

So I think that some of the solutions certainly relate to more effective communication as we look to deployment as well as possibly providing incentives, and providing incentives to advancing new techniques, innovations, into the marketplace is something that we think holds a great deal of potential.

Mr. TANG. Thank you, Mr. Chairman. I think Federal Highway has adopted many of the innovative, non-destructive evaluations. Over the past 20 years, we have supported a lot of research, and many of the products are out there on the market as a result of our research. And if you look at some of the non-destructive evaluation, we have different phases of these applications. For example, when you go to visual inspection and you determine that you need a little bit more in-depth look into a specific detail, then we will bring in the non-destructive evaluation methods such as the ultrasonic testing or the acoustic emission. These are more advanced than the non-destructive evaluation that we have used, and we have offered in our training program to include techniques so that we can train inspectors to use them.

Mr. WU. I am going to stretch my time just for a follow-up with Dr. Womack. Dr. Womack, you suggested that perhaps requiring licensed professional engineers would be a step forward in bridge inspection. Would that help also the inertia problem in adoption of new technologies?

Dr. WOMACK. I believe it would help, but one of the reasons that you don't go beyond visual inspection is a human resource issue. How many trained engineers do you have that can go out and perform these inspections? And so it becomes a resource issue in terms of trained engineers, and the number of trained civil engineers is becoming less and less. So that is an issue. It would help, but it is part of the problem. I think kind of following up on the rest of the discussion, there is a convenience issue here as well. It is very convenient and efficient to go out and do visual inspections. They are quick, you get some data, you can put that into the database. Non-destructive evaluation takes more time. Usually you have to set up equipment. Oftentimes you have to have road closures. So the states are a little bit wont to do that because of the inconvenience of it. I think as a follow-up to visual inspections where there are issues, certainly NDE must be used, and I think that is part of this protocol that has to be defined.

Mr. WU. Thank you, Dr. Womack. And with that, Mr. Hall.

Mr. HALL. Thank you, Mr. Chairman. You know, this is just a terrible problem of fear of people in the driving public. In our state, we have a State engineer and we have 254 county engineers; and we have direct access to them to ask them questions about it. I could ask Mr. Bernhardt whether or not the current inspection methods are sufficient. I would like for him to state yes. I doubt seriously that he is going to, but you know, we even have—we have all kinds of fears. We even have the fear of asteroids coming by, and we did a study on asteroids about 15 years ago and found out one had come within 15 minutes of the Earth in 1988 and nobody knew it was here until it came and went by. And it is the size of one of the states up in the northeastern part of this country.

This is the thing that can really be fearful for people. Every time anybody drives up on one of those high arching areas like we have near the big cities basically. I think it strikes some fear into their heart, what can happen. So I guess when I ask you, Dr. Bernhardt, if the current inspection methods are sufficient and you are going to say the factors have a lot to do with it, I guess continuous use of it, the stress of it, the weight at the time that the tragedy occurs, the deterioration of the past, the force of wind or rains or your typical westward wind or your typical eastern wind that could affect a particular bridge or movement of the underlying earth, it is so many things that play into that. I don't know how on Earth with the number of bridges that we have that you can answer that with any degree of finality, but you want to take a shot at it?

Mr. BERNHARDT. Yes, sure. Statistically speaking, with 600,000 bridges, I feel safe driving over a bridge; but on the other hand, I wouldn't be surprised if I read in the paper tomorrow that another bridge fell down. So certainly, like any programs, there are improvements that can be made both in the training of inspectors, the implementation of the program, and then what we do with the data on the back end.

I think one of the larger issues is that we don't have the mechanisms in place now from my perspective to address the deficiencies the inspectors are currently finding. So I mean as an example, if we doubled our inspection frequency and inspected bridges twice as often and produced twice as many inspection reports and twice as many recommendations, the ones——

Mr. HALL. And take twice as much tax money.

Mr. BERNHARDT. Yeah, the recommendations we make now often aren't addressed because the funding is not available. So certainly, on the repair side, there needs to be some changes there to get that caught up with the needs that the inspectors are currently finding now. That being said, I think there are certainly improvements that can be made in the bridge inspection process to make it more uniform throughout the United States, improve the certification of bridge inspectors, both PE's and non-PE's that help in the inspection process. A good example is, you know, in the current NBIS regulations, the program manager position and the team leader position are the two positions that are required to have the 80-hour comprehensive bridge inspection training. The rest of the inspection team is not required to have that training. Certain states have more stringent requirements and require all members of the inspection team to have the inspection training, but according to the federal guidelines, you could go be an inspector on a bridge under the guidance of a team leader who has had the class, but it could be your first day on the job, and you could be inspecting a bridge with probably little or no knowledge about the performance of structures. Errors like that can be addressed in the National Bridge Inspection Standard to improve the quality of the inspections.

Mr. HALL. I guess asteroids are not as normal as Katrinas, but we don't even know when they are coming. How about Dr. Womack if I have a little time left. In your testimony you said new inspection protocol ought to be developed; and I guess that is what Mr. Bernhardt is talking about. Do you want to enlarge on that any?

Dr. WOMACK. Currently there is a standard for the frequency of visual inspections, but beyond that, there is really no defined process. As Mr. Bernhardt said, you know, you can develop a lot of data, but what does it mean and what do you do with it? So I think we need to define a protocol where if the visual inspection shows up issues, that there ought to be some sort of follow-up to that rather than just more frequent visual inspections. Maybe there should be some defined non-destructive evaluation that needs to be performed or something else to be done that is a little more objective than just more frequent visual inspections.

Mr. HALL. Was that standard followed leading up to the I–35 tragedy collapse in Minneapolis?

Dr. WOMACK. From what I know of that situation, they were inspecting the bridge more frequently than required. They had some options to do some things and they just chose to continue the more frequent visual inspection. Now, that is not to say that if they had done something different such as putting instrumentation on the bridge that it wouldn't have collapsed or that we wouldn't have known about it anyway; but perhaps with instrumentation, there might have been some precursor information to some issues on the bridge. And so that is what is not defined. When you do find bad things with a bridge, what do you do next; and that is not at all a well-defined process.

Mr. HALL. I may have to do it by mail later, but I would like to kind of know what new processes are in place and whether or not people are following them and whether or not they are making records of the fact that they follow them and that we can rely on the fact that they are following them and they are effective.

Mr. Chairman, you will leave open the opportunity for us to write and seek answers from them if we don't get to follow-up questions, will you not?

Mr. WU. Yes, I will do that.

Mr. HALL. I yield back the time I don't have.

Mr. WU. Questions will be submitted in writing, and answers will be returned in writing. Mr. Lipinski.

Mr. LIPINSKI. Thank you, Mr. Chairman. I want to follow-up. The end of the answer to the last question there, when you find something wrong, what do you do next? What problems are we facing right now? Is it a real need to have that type of protocol? It certainly makes sense that it would make sense. Is our bigger problem just a lack of taking action because of a lack of funding to be able to do anything when we do find that there is a problem? So is it right now largely a money problem, or is it both a combination of a money problem and where we just do not have the protocol in place as to okay, we find a problem, what do we do next to try to avoid a catastrophe? So who wants to start with that question? Dr. Womack.

Dr. WOMACK. I am probably not the best person to answer that question. I would guess it is somebody from the state who has a better feel on the available dollars would be better put. But I think it is a lack of knowing what to do next, but I think it is maybe an issue in terms of determining how the available monies are spent. And coming from that point of view, I think that you need to take more of a risk assessment approach in terms of utilizing the funds. Where is the highest risk, and inspections non-destructive evaluation can help you determine what the risk is. And then you need to side on a more risk-assessment analysis, where to spend the limited amount of funds.

Mr. LIPINSKI. I will go to Mr. James since you are not the DOT.

Mr. JAMES. Yes, sir. If you will think of a bridge very much like a person, a bridge is born after many months and sometimes years of development, thought and development. They are born, they have a life expectancy when they are first put under traffic, 50, 75, sometimes even 100 years. As the bridge ages due to just the natural deterioration, as we each do our own bodies: We go to a doctor; we have a physical. We look at things. That is an analogy to the bridge inspector out there. He looks, he finds something. If it is something that can be arrested to stop deterioration or to even keep it from becoming a chronic condition, that is what we look to do to basically preserve what we have so that we can get the fullest life expectancy of what we have out there. Many times funding, though, drives those decisions. I think you have heard the term worst first? Many times that is what we have to do because we have no choice. That is not what we would like to do because many times that is not the best of our resources that we have.

So each state is different. We have to look at it from our own perspective. We try to use low-cost construction, maintenance-friendly details when we design and build our bridges. Again, it is one thing if you are looking at an aircraft fuselage in a hanger using non-destructive testing and something else if you are out there 100 foot in the air on the end of a bucket with a rope sling around you trying to manhandle some non-destructive equipment to figure out whether you have got a problem or not.

So, the inspector develops a relationship with a bridge. He goes and looks at it many times, and what he is looking for is change to see what the difference is from what he saw the last time he looked at it.

Mr. LIPINSKI. Thank you. Mr. Judycki, did you want to add something?

Mr. JUDYCKI. Yes, and then I will turn it over to Mr. Tang. I asked him to mention fracture critical members in a moment. But I would just make the observation that there are some process issues here, and I think that one of the things that Federal Highways has very much as part of our culture, is to make improvements in processes and procedures as the need comes to light. We did this after the 2001 NDE evaluation of inspection techniques that really resulted very directly in quality control and quality assurance and additional training being required as well as the operating inspection certification. So, I think that the ability to learn from these experiences and build it into national processes and certification standards in the NBIS program becomes very important.

With that though, I think that if I could turn it over to Mr. Tang, I would.

Mr. TANG. Mr. Lipinski, I think you mentioned about the finding. If an inspector finds something wrong with the bridge, what do you do? In our National Bridge Inspection Standards, we do have a term called critical finding. Then every inspector when they attend training, the first thing they are told to do is if they see an unsafe bridge, close it. That is the immediate action that they have to take. After that, they would have to bring in their more experienced people to determine if they should keep the bridge open for traffic or should they repair it immediately. So in terms of critical finding, if there is such a critical finding on the bridge, they would have to immediately repair it, fix it, or close the bridge. That is in our regulations.

Mr. LIPINSKI. If the Chairman will let me just ask for a brief follow-up. How often does it happen? How often are bridges closed because it is a very difficult thing to do, to close a bridge because of inconvenience in some locations? How often is that done? Do you think—how bad does a bridge have to be and how often is it done?

Mr. TANG. First of all, even during inspection time, when you have inspection equipment on the bridge, there may not be room for opening to traffic; so sometimes they do close part of the bridge to even get the inspection gear into position to inspect it. Now, how often, this is the question that we don't have the answer in the sense of a broad answer for it. It is left up to the inspectors. They are trained to determine that when they need to close a bridge, they will close the bridge.

Mr. LIPINSKI. Thank you very much.

Mr. WU. I would like to thank the gentleman. The gentleman from Georgia, Dr. Gingrey.

Mr. GINGREY. Thank you, Mr. Chairman. Mr. James, I enjoyed your analogy, as you know I would as a physician member. I would say that a follow-on to Mr. Tang's remarks in regard to Mr. Lipinski's question about if you find something, when do you say, you know, we are going to have to inconvenience the public. We are going to have to shut this bridge down for long-term safety, maybe a short time shutting it down. It is kind of like the individual patient. You can tell them that they need to do something, but you can't make them do it. But I think people at the state level, Mr. James, certainly have the ability to say you are going to be inconvenienced. I was in New York a couple of weekends ago, and I had the opportunity to drive through the Lincoln Tunnel and then later on across the Brooklyn Bridge, both aging structures; and after this Minnesota tragedy, I couldn't help but think about when the last time they had been inspected.

But my comments are getting to a question that I am going to address to Mr. Bernhardt. But again, Mr. James, your analogy to the human being, there is a test that is a little bit more than an X-ray that looks for calcium in and around the heart. And I have a good friend that had that test done, and the doctor said, oh, you have got a tremendous amount of calcium showing up on this test. Therefore you need to have an angiogram. You need to have a dye study of your coronary arteries. It was completely normal. And that test is expensive and not without some risk. So what I am saying is, there are certain tests that show something, but it is not significant, though that calcium was all outside of the arteries. It wasn't inside the arteries.

So Mr. Bernhardt, the question is do you think that visual inspection, even though you are talking about professional engineers and highly trained, motivated people, can get the job done? What are the limitations of purely doing it that way, and do we need to move quickly toward better testing? And if there is time, Mr. Chairman, and maybe in the second round if there is not time, I want to go back to Dr. Womack's comments and his opening statement and also Mr. Judycki in regards to this issue of programming or earmarking away a lot of funding in SAFETEA–LU that took the ability out of your hands to use that money to do research programs. You know, I don't want to get too political here. We all have member initiatives, and I am one of them. I got these great programs in the State of Georgia that I want to see funded, but I think we need to talk about that, Mr. Bernhardt.

Mr. BERNHARDT. Yeah, visual inspection, in and of itself, certainly isn't going to give you enough information to gather the data that you need to make effective decisions about bridge rehabilitation. It must be supplemented with testing, both non-destructive and destructive testing; and in some cases the structural health monitoring is what holds so much promise for the future, too, because the structural health monitoring can provide a continuous data stream, whereas if I go out and do NDE, non-destructive evaluation on a bridge today, that is showing me what the conditions are like today. If I have monitoring equipment installed on that bridge that is giving me continual feedback, it can even be set up to have alarms where it is monitoring the stresses in the members. I am getting more of a continuous feed of data. So certainly that is an advantage for that type of testing. Visual is only going to provide you with so much, and it is going to be very qualitative data. It is going to be subjective. I am going to rate something a four, somebody else is going to rate something a six; and I pass that information on to the decision-maker and policy-makers, and they are like, well, what does this mean? I got two different answers coming. And that is because visual is very subjective. The more testing and instrumentation we can do, that helps to make the whole process much more objective. So that is a big benefit for that, too.

Additionally, when you have hard data being supplied to you, you can make more effective decisions about which bridges do I need to direct my funding towards. You may have a condition rating on an element that says that this bridge is in poor condition. Well, the actual stresses in the member may be okay. So by doing some instrumentation and further analysis, you may be able to determine that the bridge doesn't actually need repairs, and that money can be directed somewhere else. And you wouldn't be able to tell that through visual alone, but only through testing and analysis and modeling would you get the answers to those questions.

Mr. GINGREY. I see my time is expired, and I guess the second part of that question I will save to the second round, Mr. Chairman.

Mr. LIPINSKI. I thank the gentleman. The gentlelady from Texas, Ms. Johnson.

Ms. JOHNSON. Thank you very much, Mr. Chairman. I guess that my question could be directed to the representatives. In SAFETEA–LU there were a number of bridges designated because the states had them on their critical list. However, I don't know—in Texas, I have over 50,000 bridges. And I–35, which had the collapse in Minnesota, is one of those bridges designated. And I did earmark the money, and I will do it again; and I am never going to stop earmarking, because if we don't, my areas don't get anything. And so I just want to know that when you decide through examination what bridges are in critical condition, how do you handle it? Do you go to your Congress people or feud about it or what happens?

Mr. JAMES. Ms. Johnson, we work within the resources that we have. If we find a bridge with critical needs, then many times we will direct the resources from one part of the program to that particular area so that we can make a rehabilitation or replacement of that structure so that that problem goes away. It is a matter of prioritization and taking into account many factors in those decision as to which bridges receive the critical treatment first. Of course, if one is about to be closed or hopefully never reaches that state, then obviously many more resources are directed toward it to keep things open. They take into account the impact on the general public as well as the safety of the public as well.

Ms. JOHNSON. Well, you indicated that visual decisions after bridges are inspected usually can be considered accurate. And what other methods do you use to inspect the bridges?

Mr. BERNHARDT. I will take that one. Essentially, are you speaking specifically to what type of testing techniques?

Ms. JOHNSON. Yes.

Mr. BERNHARDT. There is a number of tried and true ones which are commonly used by many state DOTs, magnetic particle, ultrasonics, dye penetrant for steel bridges, ground-penetrating radar, impact echo. Those are all concrete methods that work on concrete bridges. FHWA has a Bridge Inspector's Training Manual, and it details more than a dozen common testing techniques; and the bridge inspection training that team leaders and program managers take cover all these techniques. Additionally, State DOTs have seminars where they train their people on how to use those. So those are kind of the tried and true methods.

And then there is a whole host of emerging technologies. Some work out, some are just a flash in the pan. But those are the main ones.

Ms. JOHNSON. Thank you. You know, the states had rescissions even after the money was sent out the last time. So we still don't have any work going on on those so-called critical bridges, but hopefully it will begin soon. There is no money in Washington, as you know, and I don't think there is very much in states because my state just told me that they had no money for maintenance, which is maintenance that was very important. And so, we have a bipartisan committee out of our delegation. We are going to be getting together to see how we handle it. So if you don't get any federal dollars any time soon for this, how would you handle a critical bridge?

Mr. JAMES. Again, we work with the resources we have. If there are needs of a bridge, we will direct state dollars for it to keep it from being closed to take whatever actions are necessary for it to remain safe and open to the public. Again, we use best management practices, we use details from our design and construction that are maintenance friendly, proven to be very cost-effective during the construction as well as details having longevity and are also friendly to bridge inspection. So you do whatever is appropriate as far as the inspection visual. It is by far, you know, the easiest and the first place to start; and the more complex a bridge structure becomes, you go from there using whatever technologies are available to you. And the same thing would be with the repair, whatever is appropriate. You take whatever actions are necessary. Very similar to Dr. Gingrey's comments about the, you know, a patient. Sometimes you look and you find something and it is there but it is not a problem, so you just continue to monitor it.

Ms. JOHNSON. Unpredicted weather conditions that occurred, have you known any bridges that might have checked okay and then after that, some kind of catastrophe, you find it is in a different shape? I am sorry. I hope I am not giving a confusing——

Mr. JAMES. No, ma'am. I can't speak for every state what each state has found. I know in our state we have not found anything that is, you know, weather related. Obviously the two bridges we lost from Katrina were weather related, but I don't think anybody could have prevented some act of God like that. As far as something that we look at one year and then come back a year later, nothing that has led to any catastrophe or tragedy within our state boundaries.

Mr. BERNHARDT. In terms of weather related problems with bridges, probably the greatest one is what is known as scour. Essentially when you have a bridge, you have a big rainstorm event, the stream fills up with water, the velocity of the water increases, and it will scour out around the foundations for the bridge; and there have been bridge collapses that resulted from scour. So scour is certainly one of those critical items that bridge inspectors pay attention to and monitor stream beds, and if there was one primary weather related cause of bridge failures, it would have to be scour.

Ms. JOHNSON. Thank you very much, Mr. Chairman.

Mr. WU. Thank the gentlelady. The gentleman from Michigan, Dr. Ehlers.

Mr. EHLERS. Thank you very much. My mother always told me that scouring was good. It was a typical Dutch housewife.

When I went off to college, I started out in engineering, and I went astray and became a nuclear physicist; and I have always maintained a great interest in engineering and I have a huge amount of respect for it. I was with Buckminster Fuller once who is one of the more imaginative engineers in the history of the profession. He commented that the first time engineering ever really had to develop as an engineering science was in the design of boats because you had to design the boat very carefully using minimum materials, minimum weight to carry maximum load, whereas before in building buildings, for example, you just kept piling the bricks on until you were safe or even the Roman aqueducts which have survived for 2,000 years. They used a lot more bricks, a lot more material than they really needed to transport that small amount of water. There wasn't a lot of engineering then.

And you know, Buckminster is right in a number of ways. We have really advanced. We have learned to build buildings using the minimum amount of material, minimum amount of money, how to accomplish the goal. I think airplanes are the epitome of success and design in trying to use minimum weight, minimum dollars to accomplish the task.

Bridges are another good example of that, and I am just awed by what engineers have done in bridge design construction; but I am not sure that we have kept up as a society in our examination and inspection of those. And my question is first of all, is it a lack of knowledge, and lack of technology? Aren't we putting enough into research for non-destructive testing techniques and so forth. Or is it another case where we are simply as a society willing to pay for the initial structure, whatever it may be; but we are not willing to pay adequately for the maintenance. Can you give me any comments indicating where we have gone wrong? Is it a lack of resources or is it a lack of research in non-destructive testing techniques? Any comments from anyone?

Dr. WOMACK. I guess I can go first. I don't think it is due to a lack of research. We have technologies, many testing methods that have been mentioned at this table. So we have the ability to do it. I think you are more right in terms of we are willing to pay the first cost, although that first cost that we are willing to pay is the lowest we can get, which isn't always the best. But we are willing to make that first cost. Then we are trying to catch up with other new bridges and other repairs, so we tend not to go back and spend the money that should be spent in terms of monitoring the infrastructure that we have. And so I think we need to continue to do research to develop new technologies, but it is not a shortage of technologies that is creating the problem.

Mr. EHLERS. Okay. So, Mr. Bernhardt. You advocated continuous inspection. Is there much of an additional price tag to that compared to the periodic investigations?

Mr. BERNHARDT. Certainly. It is much more expensive to instrument a bridge up that initial time. Once the bridge is instrumented, then you get that continuous data stream. I will just make clear too that I certainly don't advocate that for every type of structure. Certainly focusing that on the more high-risk structures, the structurally deficient bridges, the fracture critical bridges, I mean, that is a good use of that type of technology. Certainly for a 20-foot span that doesn't see much traffic and it is very simple structurally, there is really no need to go to that kind of expense. It is the more sophisticated structures that you want to use that technology on. And certainly as Dr. Womack indicated, technology exists now to do those things, so it is not on the research end. It is getting the projects funded to put into practice where the shortfall is.

Mr. EHLERS. Thank you. Mr. James, you were kind enough to single out the State of Michigan as having an excellent bridge management system. Frankly I don't know of any bridges that have collapsed recently in the State of Michigan, and we have built the Big Mac which has stood firm for 50 years now this year. I appreciate your comments. But again, this is another related question about causes of bridge failure. You mentioned scouring. That applies to any bridge. Michigan, as well as Minnesota, suffer a lot of damage through the freeze-thaw cycle, Michigan much more than Minnesota because Minnesota, for better or for worse, freezes over in November and doesn't thaw until March sometimes. I used to live there so I know. Whereas Michigan has probably 15 freeze-thaw cycles they go through in the course of a winter. Maybe that is extreme but doesn't that cause a lot of damage to bridges? I know it does to highways, but what about bridges? Is that a factor there, too, the constant temperature changes?

Mr. JAMES. Yes, sir, it is, and that is taken into account in the design of bridges and their construction and the materials and the properties of the concrete for instance in the deck when they are constructed. There are many things that can be due to prescribe a particular mix that will minimize or at least mitigate these temperature changes that you mentioned. We are fortunate in the south that we don't experience things like that. We typically don't use salt, either, because we don't have the ice and snow to deal with except, you know, those very few times within any season. There are things that, you know, can be done. Again, it goes back to doing what is appropriate, trying to narrow the focus of where these technologies are needed to the high-risk bridge candidates as much as possible using engineering—experience counts a lot for what you are doing. Bridges again have lives 50, 75, even 100 years in some cases. Many times that is not by design but just by necessity that bridges have to last longer than they were ever thought to. With that, if you look at a bridge that is 50 to 75 years old, I have been with the state DOT almost 26 years. That is nearly two careers for somebody in my position to see, you know, the life of a bridge; and many times, it takes a structure that is, you know, 30 to 40 years old before something comes up, very similar again to the analogy with a person; and you do whatever is appropriate. You know, you find something that requires constant monitoring, you look at it until you get it arrested or corrected. If you find something else that you need to look at, you look at it once and then you don't go back in there. You wouldn't expect to find it again for five to 10 more years. However you would still do the routine physical so to speak, the visual inspection of the bridges.

Mr. EHLERS. And one last quick question on a slightly different subject but same problem. Dams, and I am not talking now about the huge dams, I am talking about the smaller dams that we have dotting the landscape of our country that we used for power generation years ago. Is it as important to have a constant inspection program for the dams? Is that as much of a problem or don't they suffer as much stress or as much failure as the bridges?

Mr. JAMES. While those are not under my purview as highway engineer, in many cases we have dams adjacent to roadways, and obviously we are concerned with them. Many states or most states have monitoring procedures whereas dams have to be inspected on some frequency, just similarly to bridges; and where appropriate, they could be monitored and from that monitoring you could determine whether or not that you have an intrinsic or chronic problem with a structure.

Mr. EHLERS. My time has expired. I yield back. Thank you.

Mr. WU. Thank you very much, Dr. Ehlers. We have a floor vote coming up fairly soon, so we are going to proceed with another round of questions. We will probably proceed pretty quickly, and the Chairman recognizes himself.

There are bridges in this country that have lasted 50 or 100 years. There are bridges elsewhere, the Roman aqueducts, bridges in China, that have lasted 1,000 years; and the bridges that have lasted a long time were both conservatively, perhaps over-engineered, they have lasted a long time. We have newer bridges that are being built with the assistance of computer modeling and, you know, just going if you will closer to the limits of what design and materials can do. Do these new designs necessitate different approaches to bridge inspection and bridge safety?

Mr. BERNHARDT. Yeah, I would certainly answer yes to that question. A good example would be the use of post-tensioning or pre-stressing of concrete beams in bridges. You may have post-tensioning cables inside of a bridge to give it strength, but you could never see through those cables. So certainly you constructed a bridge where one of the primary structural elements you will never be able to visually see. In that case, you must have some type of sophisticated, non-destructive evaluation method to examine those structural elements 25 years from now, 50 years from now as those elements start to deteriorate inside the bridge itself.

Dr. WOMACK. Let me add a couple of words to that. This is where I think the research in non-destructive evaluation can occur. We have developed technologies to look at the bridges we have. Now, with these newer bridges and newer construction methods, we don't necessarily have the technologies to assess those as in post-tension or pre-tension bridges. So we need to develop through research concepts that we can use to non-destructively evaluate these newer types of bridges. So along with the new design, we need to come up with new ways of evaluating them through testing.

Mr. JUDYCKI. Let me just add a couple of things and then just ask Mr. Tang to follow up. Quite a lot of the research investments now are in new materials for bridges and it is critically important that as we explore the application of new material, ultra-high-performance concrete, high-performance steels and so forth—that we assure in advance that we build that into codes and standards and specifications as we implement around the country. SAFETEA–LU in fact directs quite a lot of resources into research into new materials that will lead to new designs as we conduct our research.

Also, I had mentioned earlier the Bridge of the Future. Much of what we are talking about really needs to be put in the context of where we should be looking for the future and where research can bring us in the future. The Long-Term Bridge Performance Program was mentioned by a couple of people here at the table. And it is critically important that we collect information and data over a long-term so that we can develop predictive models on deterioration and impacts of maintenance on bridge systems. When we are really talking about a bridge of the future, that we will have bridges that are not only constructed with ultra-high-performance materials but also sensing systems that will help us a great deal in overcoming some of the barriers that we are now facing with inspection programs.

Mr. TANG. Mr. Chair, I believe when you mentioned about the deterioration rate of different types of bridges, they indeed have differences. Most of the damage comes from corrosion, and if you look at the bridges that we built in the past, corrosion has been the major contributor to bridge deficiency; and as a result, Federal Highway has done a lot of research on corrosion aspect of it. If you look at 20 years ago, 25 years ago, we didn't have any corrosion protection on our deck. Federal Highway went out and did the research, and using the results, we are now requiring, or we then have required a corrosion protection system on our deck system to make it last longer. And also, our corrosion research in our Turner-Fairbank Facility has also looked at epoxy-coated rebar, and now we are looking at galvanizing those rebar and stainless steel, which we are implementing in our projects now. And in the design code, the AASHTO LRFD code requires a 75-year design life, and they actually have criteria specifying that design life to be considered in the design.

Mr. WU. Thank you very much. My understanding is that Mr. Hall has no further questions at this point. Dr. Gingrey?

Mr. GINGREY. Thank you, Mr. Chairman. I want to state at the outset when I made that comment about directed initiatives and the concern that it might handcuff the bureaucrats as we like to say sometimes, not meaning that in a pejorative way from making decisions, certainly my colleague from Texas, if every Member's member initiatives were as good and honest and forthright as hers are, we wouldn't have a problem with earmarks I am sure. But I just, you know, brought that up because I am concerned that maybe there are certain areas in which member initiatives may not be appropriate if it takes funding away from something that we need to do.

But let me get to my question. I just wonder if there is some technique other than visual inspection. We talked about that a lot at this hearing, and we know that we have good visual inspectors. But is there some technique non-destructive that can be used as a retrofit for existing bridges? The bridge of the future, I think that is probably easier to deal with in how we construct new bridges and sensors and things that we can put. But is there something that we can use in existing structures in a non-destructive way that goes far beyond visual inspection?

Mr. BERNHARDT. I will take a stab at that one. Basically I think what you are asking is—I mean, there is no magic bullet, first of all. There are many different types of bridges, and what technique works on one certain type of bridge will not work on another one. So there are many specific types of testing that work on specific bridges. I think what holds the greatest promise would be structural health monitoring. If you can instrument a bridge and thus know day to day a little bit more about what is going on inside that bridge, that reduces your level of risk. I mean, engineers tend to be conservative by nature, and if I have to make a decision to close a bridge or keep it open, I am going to typically be conservative. But if I have hard data that I can look at each day that lets me know how that bridge is behaving, then maybe I can stretch the life of that bridge a little bit longer because I get a better comfort level since I am getting that data. So instrumentation can give you that.

Mr. GINGREY. Anybody else want to comment on that?

Mr. TANG. Yes, I believe some of the sensor technology is very good, and some of the existing bridges we have used acoustic emission monitoring or ultrasonic type testing device and sensor technology on that now we are hoping to research to find ways to put them into practice. For example, it is not like one-size-fits-all as Mr. Judycki mentioned earlier. We have to look at the specific problem and the nature of the needs of the bridge. I think there are technologies out there that will be appropriate, and we just need to further develop them because right now a lot of that information is available, but it is not proven. And as Mr. James mentioned earlier, we are looking at proven technology. And so it would take time to develop some of these into usable results so that you don't just have a lot of data coming in and not knowing what to do with those data.

Mr. GINGREY. Thank you, Mr. Chairman. I yield back.

Mr. WU. Thank you. And as we bring this hearing to a close, I want to thank our witnesses for coming, in some instances, very long distances and for testifying before the Committee today. The record will remain open for additional statements from Members and for answers to any follow-up questions the Committee may ask of witnesses. The witnesses are now excused, and the hearing is adjourned.

[Whereupon, at 11:38 a.m., the Committee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dennis C. Judycki, Associate Administrator, Research, Development, and Technology, Federal Highway Administration, U.S. Department of Transportation

Questions submitted by Chairman Bart Gordon

Q1. One of the major challenges facing the Nation's bridges is significant growth in traffic loads, including a greatly increased number of long haul trucks, which stress bridges far beyond the loads engineers originally anticipated. In his testimony, Mr. James said that the volume of freight is actually expected to double in the next 20 years. How do current research projects, such as the Bridge of the Future project at FHWA, take into account the continuing growth in the number of cars and trucks using bridges? Do we need additional research or data to accurately model the types of loads bridges will be handling in 50 or 100 years?

A1. The issue of traffic growth impacts existing structures more so than newly designed structures. Today's bridge codes and standards account for the current legal weight of trucks, regardless of the number of vehicles. Assuming that truck weights do not increase significantly, structures designed today should be able to accommodate the volume of, and growth in, the number of vehicles crossing a typical highway bridge in the United States.

However, traffic growth will impact existing structures, especially those that were constructed in the 1940s through 1970s, more directly. Legal truck loads have increased over this time, resulting in a number of "load posted" bridges throughout the United States. In addition, our knowledge of how certain types of steel and concrete members and details perform under repetitive loading has increased since these structures were designed and constructed. Bridge owners are fully aware of the potential impacts and solutions required to provide adequate levels of safety in these existing structures under the current maximum legal vehicle weights. This is typically done by limiting the maximum loading, inspecting important structural details with more advanced tools and on a more frequent basis, or by retrofitting these structural details.

Two FHWA programs, the Bridge of the Future and the Long-Term Bridge Performance Program, are directly focused on providing better knowledge and tools for ensuring long, reliable service of the Nation's highway structures. The Bridge of the Future project is focused on design, materials, and construction practices that will make possible significantly longer performance for newly constructed (or reconstructed) bridges, so that they require less maintenance in the future, while also being more readily adaptable to meet changes in demand (for example, simple methods to add additional lanes when traffic volumes increase significantly). The Long-Term Bridge Performance Program is focused on developing quantitative data on the things that impact existing bridge performance, such as load, environment, and typical maintenance practices. This program will result in better knowledge and tools to more effectively and economically manage the hundreds of thousands of highway structures in the future.

Q2. Many bridge inspection technologies are not adopted by State DOTs because inspectors simply find them too technical and difficult to use. How can we balance the need for detailed, accurate information and user friendly design?

A2. The problems that bridge inspectors experience are similar to problems experienced in the inspection of other types of infrastructure, including buildings, pipelines, offshore oil platforms, and dams. There is therefore a significant amount of effort ongoing throughout the United States and worldwide to develop new and improved infrastructure inspection tools and approaches. As a result, the state-of-the-art in infrastructure inspection is changing and improving on a continuous basis and we anticipate dramatic improvements in these inspections tools and their availability in the next five to ten years.

There are several impediments, however, to the adoption of these new tools and technologies by bridge inspectors. As pointed out, some of the current tools are too technical or difficult to use, especially in the harsh environments and difficult access typically found at bridges. This is being overcome by continuous improvement in these technologies—by making the information provided more readily understandable; by making the tools smaller, lighter, and more portable; and by decreasing the cost so that bridge owners and inspectors can better afford these new tools. However, education and training on the use of these new tools is also required. Through the training courses developed and delivered by our National Highway Institute, FHWA educates inspectors on new technologies to overcome the issues of technical complexity. FHWA is committed to working with industry and bridge owners to address each of the potential impediments.

Q3. Of the new technologies developed at Turner-Fairbank Highway Research Center or in collaboration with FHWA, how many are currently in use by bridge inspectors? Which programs, such as the Local Technical Assistance Program or National Highway Institute courses, have been most effective for technology transfer? What have been the biggest barriers to adoption, and what has FHWA done to try to overcome those barriers?

A3. Over the past 15 to 20 years, a number of bridge inspection and monitoring technologies have been developed or supported through the efforts of FHWA's Turner-Fairbank Highway Research Center (TFHRC). Overall, we can identify approximately 15 specific sensors and system types, many of which have been commercialized or are currently being refined for use by the commercial sector.

Examples of these technologies include the following:

- FHWA developed a system to measure vertical and rotational stiffness of bridge foundations using truck loads as a method to differentiate between shallow and deep foundations on bridges where the foundation type is unknown. The methodology was subsequently commercialized and is currently available from a firm located in Arlington, MA.
- FHWA developed three-dimensional imaging capabilities using ground penetrating radar (GPR) technology, enhancing the ability of GPR to detect deterioration in concrete bridge decks. The technology has been adopted by commercial GPR venders and is used for rapid evaluations of multiple bridge decks, providing information for bridge management and asset management decision-making.
- FHWA developed a sensor to passively measure the maximum strain experienced on a bridge to detect and quantify overloading. The sensor has been commercialized and is currently available from a firm in Alpharetta, GA.
- In cooperation with Southwest Research Institute (San Antonio, TX), FHWA developed and evaluated systems for testing large bridge cables using the magnetic flux leakage principle. The technology has since been commercialized and is being marketed by several companies.
- FHWA developed methods and engineered systems for rapidly applying thermal imaging for the detection of defects in concrete bridge components. This has since been commercialized and is marketed as Infrared Thermography, and is used on a limited basis for bridge inspection.

FHWA continues to support the development of new bridge inspection and monitoring technologies and to assist in the improvement of existing technologies. We also actively promote and provide assistance in the use of these systems. Ultimately, however, a key measure of success of any highway technology depends on its acceptance by stakeholders on a national scale. FHWA's responsibilities for research and technology (R&T) include not only managing and conducting research, but also sharing the results of completed research projects, and supporting and facilitating technology and innovation deployment.

The FHWA Resource Center is a central location for obtaining highway technology deployment assistance. Similarly, education and training programs are provided through the FHWA National Highway Institute. These, along with the capabilities provided by the Local Technical Assistance Program (LTAP), Highways for LIFE, and other similar DOT-sponsored programs and activities provide the basis for an effective technology transfer program.

There are, however, a number of barriers to technology deployment that may explain the relatively slow adoption of highway technologies that appear cost effective. Lack of information about new technologies is one barrier that may be overcome with information and outreach programs. Long-standing familiarity with existing technologies, gained through education or experience, also may hamper the adoption of newer technologies, but the education and training programs provided by FHWA and others often help to transcend these types of barriers.

It also may be difficult for stakeholders to envision the long-range benefits of a new technology relative to initial investment costs, especially if the payback (break-even) period is long. Even if stakeholders are aware of eventual cost savings from a more efficient or effective highway technology, they may have confidence in traditional methods. Demonstration projects that provide hands-on experience can help tip the scale so that stakeholders are willing to apply innovative technologies to long-standing safety and asset measurement and protection problems.

Despite these efforts, technology deployment often is slowed by residual uncertainties about performance, reliability, installation, and maintenance costs; availability of the next generation of the technology; and the need for the necessary technical and physical infrastructure to support the technology in question.

Q4. In his testimony, Dr. Womack argues that the laboratories at Turner-Fairbank Highway Research Center (TFHRC) are underutilized. At what percentage of capacity are the labs at TFHRC being used? What types of projects are being delayed or foregone because of budgetary and other limitations?

A4. Research and development work conducted by the Federal Highway Administration is managed and directed by FHWA technical experts, and is primarily awarded through competitive contracts. Much of the work is done at the TFHRC—the only national highway research center in the United States—or is managed by FHWA research staff. In addition to competitive contracts, FHWA also works in close collaboration with University Transportation Research Centers (UTCs), and with other organizations in limited situations via cooperative agreements and research grants.

The FHWA bridge and structures R&T program is authorized in SAFETEA–LU through the Surface Transportation Research, Development, and Deployment Program (STRDD). However, statutorily designated projects and programs in STRDD actually exceed the authorized contract authority of $196.4 million for fiscal years (FYs) 2006–2009. The over-earmarking of all authorized STRDD funding necessitates across-the-board funding reductions and results in FHWA being unable to provide for any discretionary or flexible spending beyond those earmarks. This lack of flexible funds severely limits FHWA's ability to investigate and respond to current or emerging research needs that do not have specific statutory funding.

In addition, this lack of R&T funding flexibility within SAFETEA–LU does not allow FHWA to carry out some critical programs and initiatives. For example, as a result of the I–35W bridge collapse in Minnesota, the country recognizes the need for a higher level of investment to improve bridge inspection and evaluation technology. The lack of flexibility and the full designation of all SAFETEA–LU R&T funds, however, prevent FHWA from adjusting priorities as a result of tragedies like I–35W.

Some TFHRC structures R&T program laboratories, including the main structures testing facility, are essentially at capacity as a result of programs authorized in SAFETEA–LU and included in the annual FHWA appropriations. Other laboratories, such as the aerodynamics, hydraulics, and bridge management information systems laboratories, have only marginal funding via SAFETEA–LU, but have effectively leveraged other sources of funding so they can continue to conduct important research and technology studies. Leveraging funding from multiple States via the Transportation Pooled Fund (TPF) program is an example. However, the lack of flexibility noted above does impact FHWA's ability to address national research needs and priorities to which these laboratories could contribute.

Questions submitted by Representative Ralph M. Hall

Q1. In 2004 the Federal Bridge Program provided $6.6 billion in aid in addition to $3.9 billion in State and local funding yielding approximately $10.5 billion a year in bridge rehabilitation and construction investments. Compared to this amount, how much money is invested in bridge safety research and development? How does the funding for bridge related research compare to the total research investment in the transportation sector? Has the funding received by Turner-Fairbank been sufficient to keep your experts working at full capacity?

A1. The Surface Transportation Research, Development, and Deployment Program (STRDD) has contract authority of $196.4 million but, in FY 2007, was funded at only $180.8 million due to the limitation on obligations. Of the $180.8 million, about $22.4 million (12.4 percent) was designated for bridge and structures research and technology.

For STRDD, statutory earmarks and statutorily designated programs authorized in SAFETEA–LU total $228.8 million in FY 2007, which exceeds the authorized funding level. With the cuts required to all STRDD programs in order to stay within contract authority and those required to stay within the obligation ceiling, only about 79 percent of the authorized funds were made available.

However, the designation and earmarking of all authorized STRDD funding for FYs 2006–2009 created more of an issue than a funding cut. Over-designation and over-earmarking also resulted in the inability to provide for any discretionary spending. Thus, there is no funding for a number of programs that are authorized by Congress, and FHWA believes are critical to delivering a sound R&T program, but which do not have specific statutory funding. Annually, there are about $30 million in research and technology activities and programs that were funded in the Transportation Equity Act for the 21st Century (TEA–21), the authorizing legislation prior to SAFETEA–LU, that are not able to be funded in SAFETEA–LU because all STRDD funds are designated.

In addition to bridge and structures research being conducted by FHWA, a number of other organizations sponsor bridge research, and a much larger group of agencies conducts bridge R&T. Included among these are State DOTs, industry, other federal agencies, and academia. FHWA actively coordinates the National research program with our partners and stakeholders for agenda-setting, and in the conduct of research and delivery of new innovations. FHWA staff participate in numerous national and international organizations and serve on committees focused on bridge research, development, and technology transfer. FHWA organizes formal technical advisory groups and technical working groups, comprised of federal, State, and local transportation officials; bridge engineering consultants and industry groups; and academia. Further, numerous organizations in other countries also conduct bridge research, and other transportation modes, including the railroad industry, conduct a limited amount of bridge research.

FHWA technical staff at the Turner-Fairbank Highway Research Center fulfill several important roles. In addition to the conduct of applied and advanced research, they support the deployment and transfer of new technologies, and also provide technical assistance to states, the National Transportation Safety Board, and others. The range of needs, whether it be important research studies or technical assistance requests, far exceed the time and resources available to address these needs. FHWA staff therefore work on a continuous basis essentially at capacity.

Q2. How many privately owned bridges are part of the public roadway system? Since these bridges are not required to be inspected as part of the National Bridge Inventory, do we have any data reflecting the structural health and safety of privately held bridges?

A2. The December 2006 National Bridge Inventory (NBI) identifies roughly 1,865 privately owned highway bridges. However, the actual total number of privately owned highway bridges is unknown because the states are not required to report them to the FHWA.

Condition information is available for those privately owned highway bridges that are currently identified in the NBI.

Q3. In Mr. Bernhardt's testimony, he aptly notes that, simply collecting more data and providing more frequent inspections will not improve overall bridge safety: and that eventually bridges must be rehabilitated or replaced. The age distribution for all U.S. bridges is remarkably flat, however. Twenty-five percent are under 20 years old. Over half the bridges in the U.S. are under 40 years old, and over eighty percent are under 55 years old. How much do we know now about the rates of deterioration for bridges and how those rates change over time? Are we confident that current levels of investment for bridge replacement will not keep up with rehabilitation needs?

A3. Significant research has been conducted on the deterioration rates of bridges and the individual elements comprising bridges. The rate of deterioration is influenced by many factors. These include the original design of the structure, the climate where the bridge is located, the load carried by the bridge over time, and the type of maintenance activities performed on the bridge. The combination of this wide number of factors complicates the prediction of the rate of deterioration for an individual structure.

It is widely recognized by FHWA and others that the type of data currently collected and maintained in the National Bridge Inventory (NBI) is not adequate for developing sophisticated deterioration and life cycle cost models for bridge components and structures. That is why the Administration requested, and Congress authorized, the Long-Term Bridge Performance Program (LTBPP) in the surface transportation reauthorization legislation that ultimately became SAFETEA–LU. The LTBPP is intended to collect much more detailed information and quantified data on specific bridge elements for a small but representative population of bridges. Much of this data will be obtained through advanced testing and analysis. This detailed data can then be used to enhance and improve existing deterioration models, improve design and inspection practices, and identify cost-beneficial preservation activities.

While it is understood that the collection of more data will not in itself improve overall bridge safety, the information gathered through such activities can be useful in the selection and timing of maintenance procedures to be conducted on the bridge. The application of properly timed and appropriate maintenance procedures can significantly extend the normal service life of structures, allowing many older bridges to function adequately well beyond their original estimated design life.

The *2006 Status of the Nation's Highways, Bridges and Transit: Conditions & Performance* report to Congress had projected that the combined level of bridge rehabilitation and replacement investment by all levels of government in 2004 of $10.5 billion would be adequate to reduce but not eliminate the current backlog of economically justifiable bridge investments, if this spending level were sustained in constant dollar terms over 20 years. The Maximum Economic Investment scenario presented in the report projected that an average annual investment of $12.4 billion (in 2004 dollars) by all levels of government would be needed to eliminate the existing bridge investment backlog and correct other deficiencies that are expected to develop over the next 20 years.

Q4. Mr. Bernhardt testimony notes that a FHWA study in 2001 determined that less than eight percent of inspectors could successfully locate certain defects in test bridges. How confident are you in the current inspection regime's ability to consistently identify potential safety hazards? How confident are you that they identify needed repairs before they become major reconstruction? How does FHWA ensure that its training courses are up to date and effective in transferring knowledge to the trainees?

A4. The 2001 FHWA report identified several concerns with the type and quality of inspections at that time. However, it must be recognized that this was only a very limited sample and did not completely represent actual bridge inspection practices. The research methodology that was used had several important limitations, including the following:

- The inspectors involved in the project were not necessarily representative or had the level of training required of those who conduct in-depth or fracture critical member inspections, yet they were tasked to do so as part of this study.
- The inspectors involved in the study were not provided with any history on the sample bridges and were not able to take advantage of previous engineering analysis or information. Such information is typically reviewed by the inspector prior to conducting the next inspection on that same structure.

As a result of the study and its recommendations, a number of improvements were made to the National Bridge Inspection Standards. Specifically, the regulations were revised to incorporate a requirement to establish quality control/quality assurance procedures, along with additional training and refresher training requirements. Inspector training courses and certification requirements were also upgraded, providing for a higher level of inspector competency. And, a number of clarifications were provided to the definitions and descriptors that inspectors use in reporting the results of the inspections.

The results of this study were widely publicized by FHWA, thereby creating a broad awareness of the issues and greater attention to the need for improved quality. This report certainly provided a wakeup call regarding some aspects of the national bridge inspection program, and spurred significant improvements in the program. However, it is important to note that for the current investigation on the I–35W bridge in Minneapolis, there are no indications that the collapse occurred as a result of deficiencies in the State's inspection program.

Q5. Many of the witnesses mentioned the Long-Term Bridge Performance Program in their testimony as particularly critical to bridge construction, inspection, and rehabilitation research programs. As I understand it, the program is to provide longitudinal data on the wear and tear on a variety of common bridge structures in the U.S. How does this data differ from what's been collected as part of the National Bridge Inventory for the past 40 years? Why don't we have records of the actual performance data of all bridges in the NBI and why can't those records be used for statistical studies of the effects of deterioration and increased use?

A5. The National Bridge Inventory (NBI) contains information at the bridge component level. For example, no matter how large a bridge, the overall condition of an entire superstructure is represented by a single number on a scale of 0 to 9. While the overall ratings contained in the NBI can be used to some extent to judge bridge performance, they are limited in their level of detail and sophistication.

It is recognized that the NBI component ratings are based primarily on visual observations. Through the Long-Term Bridge Performance Program (LTBPP), the intent is to collect much more detailed information and quantified data on specific bridge elements for a small but representative population of bridges. Much of this data will be obtained through advanced testing and analysis. This detailed data can then be used to enhance and improve existing deterioration models, improve design and inspection practices, and identify cost-beneficial preservation activities.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Harry Lee James, Deputy Executive Director and Chief Engineer, Mississippi Department of Transportation; Member, Standing Committee on Highways, American Association of State Highway and Transportation Officials

Questions submitted by Chairman Bart Gordon

Q1. In his testimony, Dr. Womack argued that the bridge deficiencies which garner the most public attention are usually fixed most quickly, which typically means potholes are given greater priority than structural problems that are not part of the deck or roadway. What can the Federal Government, State governments, academia, and the private sector do to better communicate about bridge dangers to the public?

A1. While no one should intentionally hide any bridge deficiencies from the traveling public, deficiencies are generally of a technical nature such that the general public may not understand the problem. Bridges carry loads across them and the practice of load posting a bridge with a deficiency is the best way to communicate with the public about this subject. A public awareness campaign to inform the public what load posting a bridge means would be most beneficial. When appropriate precautions are taken on a bridge that has load restrictions the bridge is not dangerous. We as a SHA do not operate unsafe bridges—we close them before they becomes dangerous.

Q2. In your testimony, you mention that 40 states employ an element-level inspection protocol that is beyond the federal requirements. How does this additional level of detail help you prioritize repairs and rehabilitation for your state's bridges? Should this type of inspection be required for all National Highway System bridges?

A2. The additional level of detail provided by the element-level inspection allows us to further prioritize repairs that are needed and determine the urgency of making those repairs. This level of inspection should be used where appropriate. It does not provide any additional or useful information for certain type structures.

Q3. Has the Mississippi DOT adopted any new technologies for bridge inspection? What kinds of technologies were most successful, and why? What sort of training did your inspectors need to effectively use the new technology? For those technologies you decided NOT to adopt, what was your reasoning behind that decision?

A3. A few years ago MDOT purchased and received training for an ultrasound unit that can detect material flaws in metal structures in certain instances. While this is not new technology it was a new tool for us to have on hand. The training was provided by the vendor and by a consultant whom we had contracted with in the past to perform this type of work for us. It was helpful to have the capability in-house to use an advanced technology of this type. However, it also takes almost constant use of the device to remain proficient with this technology. Consequently, we still rely primarily on consultants to perform inspections using this technology.

Questions submitted by Representative Ralph M. Hall

Q1. In 2004 the Federal Bridge Program provided $6.6 billion in aid in addition to $3.9 billion in State and local funding yielding approximately $10.5 billion a year in bridge rehabilitation and construction investments. Compared to this amount, how much money is invested in bridge safety research and development? How does the funding for bridge related research compare to the total research investment in the transportation sector?

A1. From my experience 6–8 percent of total research dollars are spent on bridge related research. This number is consistent with the expenditures for research that is conducted at the State level in MS as well.

Q2. In your testimony you suggest that the State of Michigan has successfully developed an asset management system that is improving bridge safety in that state. However, according to 2005 and 2006 National Bridge Inventories, Michigan had approximately sixteen percent of its bridges listed as structurally deficient, four percent above the national average. What metrics are not being captured by the NBI that point towards Michigan's success in this area?

A2. One would have to know what their percentage of structurally deficient bridges was when an asset management system was implemented in MI and how long it has been used. To see noticeable results after implementing an asset management system may take eight to ten years or more as it would have to be worked into the project development process with ongoing projects that were not prioritized under an asset management system. It would not be prudent to stop work on a project that has a large investment in it already and that may be on the verge of correcting a deficiency or situation. Stopping work on a project just because it has not gone through an asset management system just doesn't make sense.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Kevin C. Womack, Director, Utah Transportation Center; Professor of Civil and Environmental Engineering, Utah State University

Questions submitted by Chairman Bart Gordon

Q1. In your testimony, you argue that the laboratories at Turner-Fairbank Highway Research Center (TFHRC) are underutilized. How does this affect bridge safety? If additional funds were available, what types of projects should be prioritized?

A1. The underutilization of laboratories at the Turner-Fairbank Highway Research Center (TFHRC) has a significant impact on bridge safety. These laboratories are state-of-the-art, and capable of being utilized to research new materials, designs, instrumentation, etc. Allowing these labs to sit idle delays the opportunities that the country has of implementing new technologies that could close the infrastructure investment gap. As for the issue of safety, concerns for the structural safety of bridges that should be researched may not be, due to the lack of funding to run the TFHRC laboratories. These could be issues arising from the I–35W bridge collapse to the falling of panels in the Ted Williams Tunnel in Boston.

If additional funds were made available, the types of projects that should be executed at TFHRC are of two types: First, the type that might be too large to do elsewhere. The main structures lab at TFHRC is quite large and can handle very large structural elements that few other places can deal with. Second, special types of projects; those that might relate to unique types of bridges. The I–35W is an example of this. It is of a fairly unique design, which raises unique types of issues. Other bridges of this "unique" type could range from the Brooklyn Bridge to the Key Bridge in Baltimore to the Sunshine Skyway Bridge in Florida.

The Long-Term Bridge Performance (LTBP) Program will handle the most common types of bridges that are of similar designs, structural make-up and construction. The majority of Interstate bridges fall into this category. They are bridges with simple steel or pre-cast concrete girders with cast-in-place decks. This type of bridge probably occupies about 80 percent of the NHS bridge inventory. These bridges can be well studied under the LTBP Program, and would not be good candidates for work in the TFHRC laboratories.

Q2. In your testimony, you argue that a new inspection protocol needs to be developed for bridges. How would an updated inspection protocol differ from the current inspection protocol? What types of technology would be necessary to carry out the updated inspections? Are these technologies currently available to inspectors, and if not, what are the barriers to their adoption?

A2. A new well defined inspection protocol would differ from the existing in that a well defined existing protocol does not really exist, as far as I am aware. The I–35W bridge is a good example of that. It was inspected, determined to be structurally deficient, but then there was a quandary about what to do next? More frequent inspections, repair, instrumentation, etc., what to do? In the end, the decision to inspect annually, rather than biannually, was made. Did that work, in hindsight and all fairness to the Minnesota DOT, no; but would other DOT's done differently? Probably not. The issue becomes one of cost. To instrument such a bridge in a way that could provide real time data on its behavior could cost $500,000. To perform one time types of tests, to check for cracks, etc., could cost upwards of $100,000. To repair, possibly millions of dollars along with shutting bridge down and the inconvenience that would cause. To perform more frequent visual inspections, a few thousand dollars. But in the end, the cost could near $1 billion in terms of reconstruction and costs to individuals (not to mention the indeterminable cost of the loss of life). So are we being penny wise and pound foolish? Perhaps. This is not to say that if things were done differently the I–35W Bridge would not still have collapsed, you simply cannot cover all the possibilities, but a better chance of saving the bridge, and the lives, might have existed had things been done otherwise.

The new protocol would indicate the next steps that should be taken after visual inspection determines a bridge to be structural deficient. The precise reasons for such a rating would be determined and the next steps would be based the causes of the structural deficient rating. Should the next steps be one time testing of bridge elements or an overall load rating test; or constant, real time monitoring through instrumentation; or minor repairs; or immediate closing of the bridge; all of this needs to be determined and developed through research that has the mandate of developing such a protocol.

As for the technologies, they do exist, but can be expensive, thus they are not readily available to inspectors today. They can also be technically sophisticated and need trained personnel to operate. Again, this costs money. If a DOT wanted to instrument a bridge to provide real time performance data it can be done, and has been done on a segment of an Interstate bridge in Utah, but it is expensive. Such instrumentation could consist of accelerometers, velocity transducers (geophones), strain gauges, cameras, etc. All of which is available.

Currently, NBIS regulations have the first option to have a Professional Engineer with the requisite experience and training to perform bridge inspections but they do have other lesser options which do not require bridge inspectors to be Professional Engineers. ASCE believes that non-licensed bridge inspectors and technicians may be used for routine inspection procedures and records, but the pre-inspection evaluation, the actual inspection, ratings, and condition evaluations should be performed by licensed Professional Engineers experienced in bridge design and inspection. The NBIS regulations should be changed to require just Professional Engineers with appropriate experience such as the expertise to know the load paths, critical members, fatigue prone details, and past potential areas of distress in the particular type of structure being inspected as the lead bridge inspector. They must have the ability to evaluate not only the condition of individual bridge components, but how the components fit into and affect the load paths of the entire structure. The bridge engineer may have to make immediate decisions to close a lane, close an entire bridge, or to take trucks off a bridge to protect the public safety.

Questions submitted by Representative Ralph M. Hall

Q1. In Mr. Bernhardt's testimony, he aptly notes that, "simply collecting more data and providing more frequent inspections will not improve overall bridge safety" and that eventually bridges must be rehabilitated or replaced. The age distribution for all U.S. bridges is remarkably flat, however. Twenty-five percent are under 20 years old. Over half the bridges in the U.S. are under 40 years old, and over eighty percent are under 55 years old. How much do we know now about the rates of deterioration for bridges and how those rates change over time? Are we confident that current levels of investment for bridge replacement will not keep up with rehabilitation needs?

A1. We do not know a lot about the rates of deterioration of bridges and how those rates change over time. This is one objective of the Long-Term Bridge Performance (LTBP) Program, to provide data that will give an indication as to how deterioration occurs, under what circumstances, and how it changes with time. I am very confident that the current levels of investment will not keep up with the future repair and replacement needs.

One very simple reason for that is the increase in the cost of commodities that have occurred over the past five years. Prices for steel, cement, aggregate, and last but not least, oil have increased dramatically. Much of this is due to development overseas, China chief among these countries. There is little evidence that these countries are going to slow down their development in the near future.

You state in your question that over half the bridges in the country are less than 40 years old, looking at this a different way, then a number approaching half the bridges in the country are more than 40 years old. This is a second reason I am sure that we will continue to experience an investment gap. A typical design life for a bridge is 50 years, as these bridges approach this age, they will need to be repaired or replaced. This is an astronomical number of bridges, the likes of which we have not had to deal with in the past, and we cannot even keep up with the current surface transportation system investment needs.

Q2. Many of the witnesses mentioned the Long-Term Bridge Performance Program in their testimony as particularly critical to bridge construction, inspection, and rehabilitation research programs. As I understand it, the program is to provide longitudinal data on the wear and tear on a variety of common bridge structures in the U.S. How does this data differ from what's been collected as part of the National Bridge Inventory for the past 40 years? Why don't we have records of the actual performance data of all bridges in the NBI and why can't those records be used for statistical studies of the effects of deterioration and increased use?

A2. The National Bridge Inventory does not have any of the type of data that would be collected from the Long-Term Bridge Performance (LTBP) Program. The LTBP data will be collected mainly through live load testing, instrumentation to provide constant monitoring of bridge behaviors, and forensic testing of bridge elements that will be taken from razed bridges. This will provide data outside the NBI, and will help us to answer your first question about bridge deterioration.

We don't have the records of performance data for bridges over the past 40 years because the technologies in instrumentation and data collection that we have today has not existed over that time period, and it is very expensive. Without a special program like the LTBP Program, with funds dedicated to this purpose, this type of data would still not be collected on a large scale.

Question submitted by Representative Daniel Lipinski

Q1. In your written testimony, you reference a current shortage of civil engineers in the United States, as well as a clear need for increased licensed professional engineers. How do you believe we can encourage more students to enter this field of work?

A1. The shortage of civil engineers and civil engineering students directly impacts the number of civil engineers that are currently licensed and will be licensed in the future. Much of this problem is the fault of the civil engineering profession. We, as a profession, have done a poor job of marketing civil engineering as a profession. Engineering students have to go through an undergraduate curriculum that is harder than any other that exists on a college campus, more difficult than even those that are used to enter MBA programs, law, medical or dental schools. Unless young people are really set on going into civil engineering they do not see the point in going through such a difficult curriculum to be a civil engineer when they can be a doctor, lawyer, dentist, aerospace or computer engineer and make much more money.

As a profession, we need to do more to attract young people to civil engineering. We need to let them know of the dire need for civil engineers, particularly in transportation. We also need to make salaries that young civil engineers will get more competitive with the aerospace and electrical engineers. When articles such as the one in *USA Today* on October 12th (Engineers Step up Recruiting Efforts) appear and show the salary disparity in the different types of engineering professions, with civil engineers at the bottom, it is difficult to recruit civil engineers. The market will take care of some of this difference, but by the time the market really does react and the principal of supply and demand creates a rise in the salaries for civil engineers, the shortage of civil engineers will be extreme, and I believe harmful to the infrastructure of this country due to the lack of properly trained engineers.

As for what the Congress might do to assist in this recruitment of civil engineers, one thing that comes to mind is a loan forgiveness program as is done for educators. If a person graduates in an accredited civil engineering program and goes to work for a city, county, state or other type of governmental agency their students loans could be forgiven based on some sort of schedule. In the short-term, this could alleviate some of the salary disparity. Another approach would be to encourage the exposure of engineering (all types) to K–12 students. Right now they see the sciences, and are exposed to other professions in their daily lives, but K–12 age kids really have little exposure to civil engineers.

Ultimately, ASCE believes that it is critical to provide all students, no matter what careers they ultimately pursue, with a strong background in basic mathematics and science to enable them to participate in our increasingly technical society. We must prepare those students who want to pursue careers based in mathematics and science with the necessary skills in these subjects. And finally, we must encourage highly qualified students to pursue careers based in mathematics and science and more specifically in civil engineering.

Over half of the economic growth today can be attributed directly to research and development in science, engineering and technology. Our ability to maintain this economic growth will be determined largely by our nation's intellectual capital. The only means to develop this resource is education.

Recent assessments by the U.S. Department of Education of the progress of students' performance in various subject areas, including science, math, engineering and technology education, have concluded that the grasp of science and math by U.S. students is less than that of their international peers. It is also notable that over half of U.S. graduate students in science and math are foreign-born.

For these and other reasons, the implementation of the recommendations of the NSB in their report on math and science education is critical. The proposal to coordinate and facilitate STEM programs through a National Council for STEM Education has merit and should be supported by Congress. Other recommendations to focus attention on STEM education in federal agencies also have merit.

Civil engineering professionals, however, hold the final responsibility of growing the pool of civil engineers and civil engineering students that can become licensed professional engineers. This needs to be a PR effort and a financial one by the consultants and government employers to increase the salaries of young civil engineers. The American Society of Civil Engineers can, and has in the past, play a major role in this effort and in working with Congress to improve the environment for young people to enter the civil engineering profession.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mark E. Bernhardt, Director, Facility Inspection, Burgess & Niple, Inc.

Questions submitted by Chairman Bart Gordon

Q1. You discuss your company's involvement in the inspections of steel truss bridges following the I–35W collapse in your testimony, but point out that "in general, the inspections were carried out in the same manner as those completed prior to the I–35 collapse." In your opinion, what was the value of these new inspections? What sort of guidance or technical assistance could FHWA provide to make these inspections more valuable? Did the re-inspection alert you to any new problems, and how did you or the relevant state DOT deal with those problems?

A1. The primary value of the supplemental deck truss inspections performed in the aftermath of the I–35W collapse was to help in reassuring the American public that bridges are indeed safe. Since it has not yet been determined what caused the I–35W bridge collapse; i.e., latent design defect, construction overload, ongoing deterioration of primary bridge members, etc., it would be premature to redefine NBIS procedures at this time. It may turn out that the collapse is not something that could have been prevented by enhanced bridge inspection practices. Once the cause has been determined, the FHWA, along with the bridge engineering community, will be able to determine if modifications to inspection procedures are indeed warranted. The re-inspections of deck truss bridges performed by Burgess & Niple found no new significant deficiencies that required immediate repairs. All findings were transmitted immediately to the appropriate state transportation agency personnel.

Questions submitted by Representative Ralph M. Hall

Q1. In your testimony, you note that, "simply collecting more data and providing more frequent inspections will not improve overall bridge safety" and that eventually bridges must be rehabilitated or replaced. The age distribution for all U.S. bridges is remarkably flat, however. Twenty-five percent are under 20 years old. Over half the bridges in the U.S. are under 40 years old, and over eighty percent are under 55 years old. How much do we know now about the rates of deterioration for bridges and how those rates change over time? Are we confident that current levels of investment for bridge replacement will not keep up with rehabilitation needs?

A1. Many studies have been done with respect to methods by which to accurately model bridge deterioration. In one accepted approach the condition of a bridge or an element of a bridge is characterized in terms of a set of possible condition states. The deterioration of that element is represented as the successive occurrence of transitions from one state to another. The likelihood of these transitions occurring during a certain time period is dependent on such factors as loading conditions, environmental effects, levels of maintenance and repair, etc. Markov process assumptions are used to estimate transition probabilities from one condition state to the next with a key assumption being that transition probabilities are independent of the element's previous states. Another common approach uses statistical regression to develop relationships between condition measures and parameters presumed to have a causal influence on condition. More knowledge of the physical and chemical deterioration mechanisms and further detailed study of bridge behavior would likely improve the accuracy of these deterioration models. Although, the issue is not that we do not know now when repairs should be made, it is that transportation agencies lack the funding necessary to repair and maintain their bridge inventories to the desired condition standard.

ASCE's *Report Card for America's Infrastructure* from 2005 concluded that $9.4 billion per year over the next 20 years is needed to eliminate bridge deficiencies and an additional $7.3 billion annually is needed to prevent the bridge deficiency backlog from increasing further.

Q2. In your testimony you describe a "general consensus within the engineering community that visual inspection practices must be supported by rigorous training, certification, and quality assurance programs." In your opinion, how does the current training regime offered by the National Highway Institute stack up in these areas?

A2. The FHWA/NHI Bridge Inspection Training Program, namely the three-week comprehensive training, is designed to bring individuals with at least a high school diploma to entry level participation in bridge inspection related work, notably field inspection activities. However, in 23 CFR 650 Sub Part C National Bridge Inspection Standards, sections 650.309 Qualifications of Personnel, only three classifications of bridge inspection staff, "Program Manager," "Team Leader," and "Underwater Bridge Inspection Diver," have minimum qualification requirements. Each of these classifications uses the comprehensive training as a baseline for qualification but none of them are entry level positions. The current minimum specifications in the NBIS for training and qualifications for Program Managers and Team Leaders are somewhat sound, however clear statements should be added that address the following recommended improvements:

- The current Team Leader classification title should be modified to Team Leader I. The minimum qualifications in NBIS for this classification are adequate for bridge structures that are not deemed complex and for structures that are not already classified as structurally deficient.
- A new classification for "Team Leader II" should be introduced for structures deemed complex and for structures that are already classified as structurally deficient. Minimum qualifications for this classification should include: A BS in engineering from an ABET accredited institution, passing of the Fundamentals of Engineering exam, at least two years experience with bridge safety inspections and completion of FHWA comprehensive training.
- Engineering judgment is frequently required to assign condition ratings to important structural components of a bridge. Since the PE in responsible charge may not personally inspect all items at arm's length, he or she must be able to rely on a person with sufficient understanding of structural systems to assist in the assignment of condition ratings to structural components. The Team Leader I and Team Leader II concept support this.
- State agencies across the United States have the ability to utilize personnel other than licensed Professional Engineers to inspect bridge structures. This is being done primarily because the National Bridge Inspection Standards (NBIS) allows experience to substitute for a professional engineering license. Under NBIS guidelines, a person without any formal educational training in structural engineering can be a Program Manager or Team Leader with ten and five years experience, respectively. This should be changed to mandate professional licensing *in addition to* accumulated relevant experience for the Program Manager position. The proposed Team Leader II classification addresses this issue with team leaders.
- Alternate specifications for comprehensive bridge inspection training for licensed engineers and persons with a secondary education that includes bridge engineering.
- There should be a correlation between complexity of structure, and level of training and experience. The Team Leader I and Team Leader II concept support this.
- Improvements can also be made to the certification process. See below.

Many State DOTs already have some form of bridge inspector certification process in place to support qualification requirements. They review individual's experience and qualifications and issue a unique CBI (Certified Bridge Inspector) Number to qualified inspectors (Florida and Oregon are examples). States that do not have a formal process often request certificates of NHI training and PE licensure from consultants that they hire to perform inspection work as a way to verify credentials.

Also, in many states, consultants need to be "pre-certified" for bridge inspection work, just like any other engineering service, prior to submitting on contracts.

Greater accountability demands a higher level of competency and this can be achieved through a certification process that incorporates rigorous testing. The current FHWA/NHI training program provides the information necessary for competent performance. However the testing in place primarily evaluates learning to satisfy IACET requirements for continuing education eligibility. For the proposed entry level "Bridge Inspector" and the proposed "Team Leader I," this is adequate; however for the proposed "Team Leader II" classification, it is not.

The introduction of a Federal Certification process would normalize skill levels of personnel performing bridge inspections nationwide and should include the following:

- Definition of inspector classifications based on skill levels (i.e., Bridge Inspector—1, Bridge Inspector —2, Team Leader I, Team Leader II, Bridge Inspection Diver, Program Manager).
- Documentation of background education.

- Documentation of completed bridge inspection training.
- Documentation of skill level proficiency test scores.
- Documentation of relevant experience.
- Assignment of a unique certification number/designation that reflects the classification/skill level achieved.
- Issuance of a federal certificate that reflects the classification/skill level achieved.

The NHI has the ability to track and maintain inspector certification on a national basis. State agencies could build on a federal certification process for specific needs and applications within their state.

Q3. One method to push new promising technologies has been to widely disseminate results from specific demonstrations. Are individual demonstration projects sufficient to jump-start a transportation technology, given the risk aversion and conservative nature of the civil engineering profession?

A3. Demonstration projects provide the hard data that can demonstrate the viability of emerging technologies and weed out those that do not provide useful results. Many of the newer technologies have higher initial costs than traditional visual inspection techniques, but are likely to result in more cost-effective bridge management over the life of a structure. Engineers are probably reluctant to adopt technologies if they are skeptical of the long-term cost benefits. Proposed projects such as the FHWA's Long-Term Bridge Performance Program will be structured to gather the data necessary to answer questions related to the actual cost benefits of emerging bridge testing and monitoring technologies.

Q4. Mr. Bernhardt, you note in your testimony that a FHWA study in 2001 determined that less than eight percent of inspectors could successfully locate certain defects in test bridges. How confident are you in the current inspection regime's ability to consistently identify potential safety hazards? How confident are you that they identify needed repairs before they become major reconstruction?

A4. If an inspector is properly trained and certified; is focused on the job at hand; understands the responsibility associated with bridge inspection; has had the opportunity to gain experience while working under the direction of more senior bridge inspectors; is comfortable working within a particular bridge's environment; has adequate time allotted and equipment provided to permit the inspector to get within arm's length of all critical members; has at least a basic understanding of structural mechanicals; and established quality control and quality assurance procedures are followed, potential safety hazards, structure deficiencies, and needed repairs can be successfully identified.

Appendix 2:

Additional Material for the Record

STATEMENT OF CHRISTOPHER C. HIGGINS
OREGON STATE UNIVERSITY COLLEGE OF ENGINEERING

I thank the Committee for the opportunity to provide this written testimony on research needs and actions necessary to help ensure the safety of the Nation's existing bridge inventory. On-going research at Oregon State University, funded through the Oregon Department of Transportation, has focused on field and laboratory testing, nondestructive evaluation, analysis, rating, and evaluation of existing aging and deteriorated bridges. We are also applying high-performance materials and techniques for repair and strengthening of existing bridges as well as developing tools to more directly quantify risks associated with operational conditions thereby enabling better informed bridge management decisions. This testimony reflects these experiences and addresses some of the current limitations in understanding aging and deteriorated bridges and highlights some of the pressing research needs.

Bridges are a unique type of structure that must withstand a wide array of forces including wind, earthquakes, floods, impacts, and traffic loads, among others. Further, they are exposed to variable seasonal climatic conditions and millions of repeated cycles of load with magnitude and volume that have continued to increase over time. These combined influences can result in strength deterioration of the bridge members and connections and without sufficient inspection, maintenance, and intervention can result in collapse. Engineers have little information on the combined influences of applied structural loading with variable environmental conditions such as freeze-thaw, chloride exposure, and extreme seasonal temperature changes. Some of the new materials being developed for bridge strengthening rely on bonding to the bridge surfaces that may be more susceptible to environmental factors. Significant additional research on large-sized bridge members under combined structural and environmental loading are required to ensure performance of new strengthening techniques and materials.

We must better address the large number of aging bridges that remain in the national inventory. These aging bridges contain materials and structural details that are very different from our modern design and construction practice. Better quantifying the safety of these bridges is a national need. Engineers commonly apply design and rating tools developed for new bridges to older bridges often without sufficient data to know if these are applicable. As an example, engineers are now rating some bridges for strength (collapse state) that were designed by an older method called working stress design (service level state). We cannot now be certain how some of these older designs will perform at the strength condition. There is a significant research need to better quantify the actual strength of older bridges that will remain in the national bridge inventory. An important focus should be on in-situ testing to failure of decommissioned bridges using realistic loading conditions. These tests need to be supported with laboratory tests to make the best linkage with existing data. Research programs like this are very expensive, but can provide significant savings if engineers can have confidence in the tools used to quantify remaining capacity of existing bridges and preclude unnecessary replacement or restrictions.

Bridges often sustain damage and deterioration over time. The most significant contributor to deterioration is corrosion. Current data available to evaluate corrosion damaged bridge members is exceedingly limited and generally based on small-sized laboratory specimens. This lack of data leads to great uncertainty in predicting remaining strength and ductility of corrosion damaged bridges. Current techniques often assign crude reduction factors based on subjective visual inspection of overall condition. These factors have no scientific basis. Research is needed to develop techniques for evaluation of corrosion damaged bridge members. This research must be on large-size samples that realistically reflect actual bridge members and the combined influences of applied fatigue loading with impressed corrosion need to be considered. Additional investment in laboratory research facilities is required to adequately address this need.

Advancement generally relies on more sophisticated techniques and physical resources that may not be readily available within a transportation agency or consultancy. These include more complicated analytical and computational methods (nonlinear models, probabilistic methods, etc.), as well software and hardware resources such as finite element software and computing power. Having knowledgeable in-house technical staff that can understand and fairly evaluate advancements are critical for research adoption/adaptation. We need to be able to educate the next generation of engineers that can supply this technical competence and can better handle the probabilistic nature of the problems we encounter, can understand and apply the more sophisticated analytical techniques being developed, and can effectively communicate with public stakeholders and inform public policy.

Additional research funding or reallocation of existing resources between "research" and "planning," as well as a greater focus on bridge infrastructure by University Transportation Centers is needed. A national research center focused on safety evaluation of existing bridges that draws on expertise from across the country, as in the framework of the National Science Foundation's Earthquake Engineering Research Center program, would be a logical and fruitful outcome. There is much research to be done to enhance our understanding of bridge deterioration and our ability to evaluate the safety of existing bridge members, connections, and systems. We need to develop new techniques for evaluation of bridge infrastructure deterioration, develop health monitoring and effective strengthening/rehabilitation approaches, consider more directly safety and risk (specifically quantify risks) for bridges and operating conditions, and indeed look at system level performance to facilitate ideal resource allocation. With such compelling research outcomes it is possible to transform the state-of-the-art to protect the safety of the Nation's bridges.

Respectfully,

Christopher C. Higgins, Ph.D., P.E.
Associate Professor
Oregon State University

STATEMENT OF
MICHAEL TODD
ASSOCIATE PROFESSOR OF STRUCTURAL ENGINEERING
UNIVERSITY OF CALIFORNIA–SAN DIEGO

AND

CHARLES FARRAR
LEADER, THE ENGINEERING INSTITUTE
LOS ALAMOS NATIONAL LABORATORY

First we wish to sincerely thank the Committee on Science and Technology for holding this hearing, and for the opportunity to present this supplemental written testimony. We hope to add a perspective that complements the very informative discussions provided during the live testimony by representatives of FHWA, AASHTO, ASCE, and ACEC. It is encouraging that the Committee has taken up the very important issue of infrastructure (and specifically, bridge) condition and safety. Our nation's infrastructure safety has direct impact upon our country's economy and security, and we agree that there is no better time than the present to investigate the current state of infrastructure damage assessment technology to determine both what is being done and what could be done for future improvements. While the engineering community of bridge experts does not yet know what led to the recent I–35 bridge collapse in Minneapolis, this disaster nonetheless unfortunately brought to popular consciousness the dramatic consequences of such a structural failure.

By way of introduction, we are mechanical (Michael Todd) and civil (Charles Farrar) engineers who currently co-lead the Engineering Institute (*http://www.lanl.gov/projects/ei/index.shtml*), a joint research and educational collaboration between the University of California–San Diego Jacobs School of Engineering and the Los Alamos National Laboratory that focuses upon the fields of structural health monitoring and damage prognosis. Prior to joining the University of California San Diego, Prof. Todd had a seven-year career in leading DOD research and development programs at the U.S. Naval Research Laboratory, and Dr. Farrar has spent 25 years in numerous forms of technology development, transition, and leadership at Los Alamos National Laboratory. Prof. Todd and Dr. Farrar together have 23 years experience in the structural health monitoring and damage prognosis fields.

The process of implementing a damage detection strategy for aerospace, civil and mechanical engineering infrastructure is referred to as structural health monitoring (SHM). This process involves the observation of a structure or mechanical system over time using periodically spaced dynamics response measurements, the extraction of damage-sensitive features from these measurements, and the statistical analysis of these features to determine the current state of system health. For long-term SHM, the output of this process is periodically updated information regarding the ability of the structure to continue to perform its intended function in light of the inevitable aging and degradation resulting from its operational environments. Under an extreme event, such as an earthquake or unanticipated blast loading, SHM is used for rapid condition screening. This screening is intended to provide, in near real time, reliable information about system performance during such extreme events and the subsequent integrity of the system. Damage prognosis (DP) extends the SHM process by considering how such an assessment, when combined with a probabilistic model of future environmental and operational loading conditions can be used to forecast metrics of system performance useful to the owners, such as remaining system life and maintenance scheduling. The Engineering Institute is the only university/national laboratory collaboration, to the best of our knowledge, in the United States that is promoting a focused research-driven graduate education in the SHM and DP fields, leading to next-generation engineers trained in critical inter-disciplinary skills required to solve the complex SHM/DP problems associated with long-term infrastructure life cycle engineering and management.

This testimony will pose five questions for consideration by the Committee. We believe that these are among the important questions that both the engineering/technical community and the policy-makers should be addressing as we jointly assess how the SHM/DP fields are being applied or could be applied to infrastructure condition monitoring and remediation.

(1) What is the current state-of-the-art in damage detection strategies for infrastructure such as bridges?

In 1992, an extensive survey of bridge failures in the United States since 1950 was presented by Shirole and Holt.[1] These authors point out that at that time the responses of engineers to bridge failures was reactive as is the case with most unanticipated failures of engineered systems. Bridge design modifications and inspection program changes were made in response to catastrophic failures. The collapse of the Tacoma Narrows Bridge more than a half century ago is a classic example of this reactive approach because it led to the inspection and design modifications of other suspension bridges. The widespread introduction of the current federally mandated systematic bridge inspection program was directly attributed to the catastrophic bridge collapse at Point Pleasant, WV, in 1967.[2] Design modifications for seismic response of bridges have been made as a direct consequence of damage sustained by these structures during the 1971 San Fernando Earthquake (Gates, 1976).[3] Damage leading to bridge collapse also occurs as a result of collisions and scour (the process where increased fluid velocity usually associated with a flood removes supporting soil from the base of a bridge pier). For example, the AMTRAK railroad bridge collapse near Mobile, Alabama, in 1993 resulted from the collision of a barge with the bridge pier.

At present, bridges are required to be rated and monitored during biennial inspections, largely with the use of visual inspection techniques. As needed, these visual inspections are augmented with traditional local nondestructive evaluation (NDE) techniques. However, because these NDE techniques inspect only a very small area of the structure, they require some *a priori* knowledge of the possible damage location before they can be used effectively. These techniques are not employed in a continuous manner and, in general, they require that the portion of the structure being inspected is readily accessible. There is the possibility that damage can go undetected during the visual inspections or that damage in load-carrying members can grow to critical levels between inspection intervals as the recent collapse of the I–35 Bridge in Minneapolis has made all too clear.

In an effort to move from the current qualitative visual assessments to more continuous and more quantified structural health monitoring procedures, the civil engineering community has studied global vibration-based damage assessment of bridge structures since the early 1980's. The fundamental premise of these methods is that the measured vibration response of the bridge is a function of the mass and stiffness properties of that structure. Damage will alter the stiffness properties of the bridge and these changes will be detected in the measured vibration response. To date, these methods, which make use of off-the-shelf sensing technology, have only been shown to be effective after significant damage had been sustained by the structure. These damage levels are well beyond those that would be considered necessary to safely shut the structure down before catastrophic failure. In addition, environmental and operating condition variability as well as the physical size of these structures has presented significant challenges to the implementation of such bridge monitoring approaches. Although numerous studies focused on the development of more advanced structural health monitoring approaches have been undertaken, none have been shown to be more effective than the current biannual visual inspection techniques currently in use by state highway departments.

(2) What new technologies are under development that could aid in infrastructure SHM/DP health management strategies?

SHM/DP technologies can roughly be categorized into *sensing/networking,* which is the way various data are obtained from the structure and managed through networks of sensors and possibly actuators, and *data interrogation,* which are the algorithms used to extract meaningful damage-related information from the data and then use that information to form robust assessments about the structure's current health state. Stated succinctly, SHM/DP has been enabled by the revolution in microelectronics over the past few decades. These advances are making more ubiquitous sensing on large-scale structures economically feasible. Systems with greater sensor density include traditional wired sensor networks and more recently, new wireless sensor networking paradigms. Wireless sensor networks can potentially better address the need for more continuous monitoring in the field, where the traditional design of wired sensors connecting to a centralized data acquisition and storage hub is not always practical. Many bridges or other infrastructure simply do

[1] Shirole, A.M. and R.C. Holt, 1991, "Planning for a Comprehensive Bridge Safety Assurance Program," *Transportation Research Record,* 1290, pp. 39–50.
[2] White, K.R., J. Minor, and K.N. Derucher, 1992, *Bridge Maintenance, Inspection and Evaluation,* Marcel Dekker, New York.
[3] Gates, J.H., 1976, "California's Seismic Design Criteria for Bridges," *ASCE Journal of Structural Engineering,* 102, pp. 2301–2313.

not have a convenient AC power supply to which one can "plug in" their sensor network. Decentralized sensor network architectures rooted in wireless sensing and telemetry can address this issue by providing local sensing "nodes" where sensing, control, computing, and telemetry are all integrated in relatively low-power platforms. These platforms can communicate with each other as needed to move information through the network using an energy efficient "hopping" protocol where data are transmitted from node to node and eventually to a base station. While many researchers have advanced (and continue to advance) such wireless sensor nodes in the last 10 years (e.g., see the work by Lynch, et al.[4]), these nodes still have some limitations in bandwidth (how much data or information can move around the network in time), local data storage (how much data or information can reside on the node during local processing), and what types of specific sensors can interface with them. These limitations are all related to the availability of power. Currently, the majority of these sensor nodes use batteries as the local power source. Although the nodes are designed to be extremely power efficient, the batteries represent a limited-life component that has to be periodically replaced. For large bridge structures, the locations where one might need such a sensor node can make it very costly to replace the batteries and can pose a safety concern for the technician who has to perform this duty.

Consequently, researchers are also currently investigating strategies that employ energy harvesting or an alternate "on demand" energy delivery system that makes use of power supplied by autonomous vehicles such as small robotic helicopters or cars.[5] The Engineering Institute team recently demonstrated such a system for the first time on an out-of-service bridge near Truth-or-Consequences, New Mexico.[6,7] Here the term "energy harvesting" refers to the process of converting ambient energy sources available in the bridge's operating environment to useful electric energy. Available energy sources include solar and the bridge's own mechanical vibration energy from traffic loading. Small commercially available off-the-shelf solar cells are readily available to power these sensor nodes. Mechanical energy typically is transformed into electric energy by actuating a piezoelectric material that produces an electrical charge when strained.

From the sensing perspective another area of emerging technology is the use of active sensing technology. Most earlier work on structural-health monitoring strategies for civil engineering infrastructure relied on the ambient loading environment as an excitation source and, hence, are referred to as passive sensing systems. The difficulty with using such excitation sources is that they are often variable and distributed over a wide area of the structure making these inputs almost impossible to measure. The variable nature of these signals requires robust data normalization procedures to be employed in an effort to determine that the change in the measured data is the result of damage as opposed to changing operational and environmental conditions. Also, there is no control over the excitation source, and it may not excite the type of system response useful for identifying damage at an early stage. As an alternative, a sensing system can be designed to provide a local excitation tailored to the damage detection process. Piezoelectric materials are being used for such active sensing systems. Because these materials produce an electrical charge when deformed, they can be used as dynamic strain gauges. Conversely, the same materials can also be used as actuators because a mechanical strain is produced when an electrical field is applied to the patch. This material can exert small predefined excitation forces into the structure on a local level. The use of a known and repeatable input makes it much easier to process the measured response signal for damage detection. For instance, by exciting the structure in an ultrasonic frequency range, the sensing system can focus on monitoring changes of structural properties with minimum interference from variability in traffic loading, which tend to be low-frequency in nature. Faculty and staff from the LANL/UCSD Engineering Institute (Prof. Lanza di Scalea and Dr. Gyuhae Park, as well as the authors) are

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[4] A.T. Zimmerman and J.P. Lynch, "Automated Damage Estimation in Wireless Sensing Networks Using Parallelized Model Updating," 6th International Workshop on Structural Health Monitoring, Stanford, California, September 11–13, 2007.

[5] G. Park, C.R. Farrar, M.D. Todd, W. Hodgkiss and T. Rosing, *"Power Harvesting for Embedded Structural Health Monitoring Sensing Systems,"* Los Alamos National Laboratory report, LA–14314–MS (2007).

[6] D. Mascarenas, M.D. Todd, G. Park, and C.R. Farrar, "A Low-Power Wireless Sensor Node for Peak Displacement and Bolted Joint Preload Measurements," 6th International Workshop on Structural Health Monitoring, Stanford, California, September 11–13, 2007.

[7] M.D. Todd, D. Mascarenas, G. Park, C. Farrar, K. Farinholt, T. Overly, and M. Nothnagel, "A Different Approach to Sensor Networking for SHM: Remote Powering and Interrogation with Unmanned Aerial Vehicles," 6th International Workshop on Structural Health Monitoring, Stanford, California, September 11–13, 2007.

among a small group of researchers in the U.S. leading the development of these active sensing approaches for civil engineering infrastructure damage assessment.

From the data interrogation approach, researchers have recognized that the damage detection process is fundamentally a problem in statistical pattern recognition. Basically, the damage detection process requires one to identify changes in the pattern of the sensor readings that result from damage. Therefore, the extensive sets of machine learning and pattern recognition tools developed for applications such a speech pattern recognition and credit card fraud detection are also directly applicable to the damage detection problem. The adaptation and further development of such algorithms for the data interrogation part of the damage detection process has been pioneered by researchers at the Engineering Institute (Prof. Hoon Sohn of the Korean Advanced Institute of Science and Technology while a staff member at Los Alamos) working in conjunction with faculty from the University of Sheffield in the U.K. (Prof. Keith Worden). Such algorithms are now being embedded on the microprocessors that are integrated into the wireless sensing nodes in an effort to distribute the damage assessment process to the individual sensor nodes. The combination of this more ubiquitous sensing along with more robust data interrogation algorithms is giving engineers the hope that in the not too distant future continuous monitoring of damage initiation and accumulation in civil infrastructure will one day be a reality.

(3) What are the barriers to transitioning SHM/DP technologies from research to practice?

Other than in a very few areas such as the rotating machinery industry, SHM/DP technologies are still largely confined to laboratory demonstrations and not to industrial practice, despite the fact that SHM/DP technology traces its modern roots to the 1970s and 1980s, when the offshore oil, civil engineering, and aerospace communities first began exploring it. These technologies grew out of the more mature field of nondestructive evaluation and inspection, and it was motivated by engineers' desire to detect damage in an online manner (i.e., while the structure is in operational service) on a more global scale. There are several reasons why SHM/DP has not made the transition from research to practice, some technical and others not. One of the primary technical difficulties in shaping an SHM/DP strategy for something as complex as a bridge is the wide range of length and time scales over which different forms of damage can initiate and proceed. Fatigue cracking or stress corrosion cracking initiates on a very small (micrometer-level) length scale that is most probably detected only by a nondestructive inspection technique like ultrasonic inspection, which is very difficult to implement in an online, cost-efficient manner for large-scale structures. Also, depending upon loading and environmental conditions, cracks grow on both very slow (initially; measured over months or years in many cases) and very fast (near failure; measured over seconds) time scales. Furthermore, complex structures such as bridges can have a great diversity of degradation mechanisms (e.g., steel fatigue, concrete cracking, scour of soil around bridge piers, corrosion) that may all be occurring simultaneously, each on its own length and time scales. Such wide ranges in length and time demand very different sensing and data interpretation strategies, all of which make any sort of "one size fits all" SHM/DP strategy highly unlikely.

A second challenge is that most SHM/DP technologies are being developed in research-oriented environments (such as a university) where there is limited ability to test the technologies on actual full-scale structures in the field. A consequence of this limitation is that we in general have very little knowledge about the long-term durability of sensing networks that could be deployed as part of an SHM/DP strategy. The only experience with long-term sensor system deployment and monitoring of bridges comes from the relatively few bridges that are instrumented for seismic monitoring as part of the California Strong Motion Instrumentation Program. These arrays have provided the community with bridge (and other infrastructural) response to earthquake ground motion, which has served to significantly advance the fields of seismic retrofitting and new design paradigms. However, these arrays were not specifically designed or deployed for damage identification and monitoring studies. In addition, there are very few out-of-service bridges still standing that can serve as test beds for destructive testing on which researchers can validate their SHM/DP strategies under realistic operational and environmental scenarios. However, we are greatly encouraged by the FHWA's "Long-Term Bridge Performance Program," as described by Dr. Steven Chase in a keynote lecture at the 6tn International Workshop on Structural Health Monitoring at Stanford University, on September 11–13, 2007. This program plans to develop the necessary long-term test beds needed to validate new SHM technology.

Moreover, the funding levels normally accorded such researchers is not sufficient to sustain tests long enough to establish true proof-of-concept. We applaud some of the state transportation agencies with whom we or our immediate colleagues have worked, such as CALTRANS and the New Mexico Department of Transportation, for their forward-thinking efforts in funding and/or facilitating research and development in SHM/DP technologies for bridges. Overall, however, the funding levels that are typically allocated to such projects are well short of what is required. The model used by most funding agencies—the single Principal Investigator three-year award—typically amounts to between $250,000 to $300,000 total funds invested in the complete development, testing, and validation of the given technology. This funding level is not sufficient to transition a proof-of-concept *demonstration* to a reliable, field-deployable *system.* Moreover, these single-investigator funding levels are not nearly sufficient to integrate the many components required by the multi-disciplinary nature of SHM/DP technology development.

As we alluded previously, there are non-technical challenges as well. Traditionally, many universities are not really established to support the kinds of large multi-disciplinary efforts required to bring such a technology to bear. Universities generally offer relatively narrowly-defined degrees (e.g., *electrical* engineering, *mechanical* engineering, etc.), when in fact the person optimally trained to develop SHM/DP technologies should be trained in aspects of many such degree programs. Additionally, universities also do not generally tend to encourage or reward the professoriate for undertaking such projects. Promotion and tenure is typically based on individual merit, not the success of teaming arrangements, particularly for junior faculty seeking tenure. Such a system does not encourage faculty to work together to solve complex problems or develop complex technologies that demand multi-disciplinary contributions. Clearly these are cultural issues that exist and must be addressed at the university level, and we recognize and commend the Committee for its efforts to promote interdisciplinary research, particularly via the National Science Foundation. The Engineering Institute has attempted to tackle some of these barriers by offering graduate degrees at the University of California San Diego that require course work in several departments and by funding graduate research projects that span several departments. It is our hope that such efforts will be replicated on a broader scale, and further encourage the university community to deconstruct these 'silo' models and to seek partnering opportunities not only across departments but also with each other in order to meet the multi-disciplinary needs of tomorrow's technologist.

(4) How does the United States compare to other countries with respect to implementing SHM/DP technologies in infrastructure health management?

A number of Asian countries have taken an increasingly proactive approach to infrastructure assessment and management. The Hong Kong (China) government, through the Highways Department of Hong Kong, has implemented a large-scale monitoring program on the Tsing Ma suspension bridge (and subsequently on another suspension bridge in the vicinity) whereby real-time data streams of bridge vibration/deflection, load, cable forces, wind speed, temperature, and visual camera images are synthesized in a master control center from which bridge management decisions regarding traffic patterns, speed regulations, load limits, and other such similar performance variables are continuously updated. Data are also being collected for long-term research efforts to identify damage detection and tracking algorithms that correlate with normal visual inspections and subsequent maintenance actions so that SHM/DP technologies may be field-validated over long times. The cost of this system has been reported as somewhere between $15–20 million. Even with this significant investment it is not clear that these researchers have a robust damage detection strategy in place. However, by allocating the resources for this system and by making a long-term commitment to acquire and analyze the data obtained, these researchers are better positioned to learn how to make accurate damage assessments. This project is just one of many significant bridge monitoring systems being deployed in China that we have heard about at international conferences on structural health monitoring. We are unaware of similar bridge monitoring projects of this magnitude in the U.S.

In Seoul, Korea, the Seongsu Bridge collapsed suddenly in 1994 due to a structural failure, killing 32 people. As a result, the Korean government mandated that the infrastructure construction companies must provide monitoring systems for that infrastructure. Currently, these monitoring systems have only a limited number of sensors, and it is questionable if they will provide the necessary local information needed to identify local damage at its onset.

We are also aware of other bridges in Thailand, Singapore, Taiwan, and Japan that have installed monitoring systems. Some of these monitoring systems have been purchased from U.S. companies such as Kinemetrics, Inc. in Pasadena, CA. However, to the best of our knowledge this company has not sold a system for monitoring a bridge in the U.S. Although there have been numerous large-scale SHM research projects on bridges in Europe, we are not aware of any long-term instrumentation projects in Europe that are as extensive as the ones being undertaken in Asia. There are companies in Europe such as VCE Holding in Vienna, Austria that specialize in monitoring civil engineering infrastructure. It was recently reported that they have done measurements on over 1,100 bridges in Europe.[8] To paraphrase a quote from a recent keynote lecture on bridge structural health monitoring by a representative of this company, "Monitored bridges and buildings in Europe and Asia are considered intelligent structures while monitored bridges and buildings in the U.S. are considered suspect."

(5) What are elements that the U.S. Government should consider as it crafts an investment plan, both near-term and longer-term, for promoting the development of SHM/DP technologies, and facilitating their transition to practice for infrastructure health management?

We begin by strongly encouraging the government, through its various funding agencies such as the National Science Foundation, the Federal Highways Administration, Defense Advanced Research Projects Agency, DOE, and the various DOD research offices, to substantially increase its emphasis on investment in SHM/DP technology development with specific attention to field deployment of test systems. Even more importantly, the share of this investment earmarked for development of basic science and engineering concepts, where the time to maturity is in the 5–10 year range, should be brought into balance with the much shorter time horizons associated with industrial times-to-market, typically 6–18 months. We believe the current funding profile that heavily weights the shorter time horizons exacerbates the technical challenges presented above. That is, there is inadequate funding to do exactly the kind of longer-term exploratory field deployments needed to transition the SHM/DP technology into practice. These short industrial times-to-market certainly have their place in infrastructure health management. Through SBIR and STTR small business programs, agencies can fund small studies on more mature technologies (for example, a new kind of sensor already prototyped) where proof-of-concept requirements are in line with these short industry time scales and can solve certain specific problems already identified.

We believe that a sound renewed commitment to investing in fundamental science and engineering, particularly where multiple disciplines are integrated to solve problems at the systems level, can ensure a strong, balanced research investment portfolio that optimizes the return on that investment. The Committee has led by example on this front, setting forth an aggressive vision for a ten-year doubling of the NSF budget. Particularly given such an appropriate infusion of resources, federal funding agencies can easily be tasked with such a mission and put into a position of being encouraged and rewarded for cooperating to pool resources as necessary in the short-term in order to promote these multi-disciplinary field deployments.

We urge that the engineering/technical community work proactively with policymakers to develop, fund, and execute a comprehensive research, development, and transition plan that engages all technology developers with a reasonable balance of academic, industry, national laboratories and government partners.

More specifically, we would like to reiterate our support of the FHWA's Long-Term Bridge Performance Program. Such test beds are absolutely essential to the further development, validation and field deployment of SHM technology as it is applied to bridge monitoring. We further recommend that funds are made available for each state transportation department to support the deployment of at least one large-scale, long-term monitoring system on a bridge that is of most concern. This funding must also provide for long-term management and analysis of the data obtained from such a monitoring system. Ideally, as part of these studies the more advanced structural health monitoring concepts will be directly compared to traditional inspection techniques over a long period of time. Such comparisons are necessary to validate the SHM methods and to show that these methods can provide a higher fidelity of damage detection and quantification than the current visual inspection methods.

[8] H. Wenzel, "SHM at the Civil Infrastructure: Applications, Recent Progress and Future Demands," Keynote lecture, 6th International Workshop on Structural Health Monitoring, Stanford, California, September 11–13, 2007.

We recommend that policy-makers consider the significant amount of technology components being developed at universities, national laboratories and industry that are directly applicable to the bridge health monitoring problem. However, these technologies must be integrated in a systematic manner to best address the SHM problem as it applies to bridge structures as well as to all types of civilian and defense infrastructure. When technologies from all these sources are integrated though multi-disciplinary research teams such as the one formed by LANL and UCSD, solutions to the complex problem of structural health monitoring can be more rapidly advanced and deployed.

Finally, although this document has emphasized the need for more research aimed at transitioning SHM technology from research to practice, we strongly urge policy-makers to continue to promote formal education innovation in this field. U.S. universities have a long history of being the best at training the technical specialists, and there will be always be a need for such specialists. However, for the U.S. to retain its technical advantage in the global economy, we must also be able to educate a new generation of multi-disciplinary engineers that can integrate diverse technologies to solve complex problems of national importance. In addition, technology leaders of the future will also have to be much more multi-disciplinary than in the past. A key aspect of The LANL/UCSD Engineering Institute is its proactive efforts to develop such a new multi-disciplinary degree program that focuses on training the next generation of engineers in SHM/DP and on training the next generation of technology leaders. It is our position that such formal multi-disciplinary education programs (not just multi-disciplinary research) need to be promoted as a national educational priority.

Thank you again for this opportunity to submit testimony to the Committee, and we hope that we can serve as a resource to the Committee as it considers these and related issues of critical importance to our nation's infrastructure. The faculty, students, and staff of the LANL/UCSD Engineering Institute looks forward to continued interactions with policy-makers, Federal and State Government agencies, and private industry that will further promote and deploy SHM technology on all types of aerospace, civil, and mechanical infrastructure.

STATEMENT OF LARRY W. FREVERT
PRESIDENT
AMERICAN PUBLIC WORKS ASSOCIATION

Mr. Chairman and Members of the House Committee on Science & Technology, thank you for the opportunity to submit testimony for the hearing, *Bridge Safety: Next Steps to Protect the Nation's Critical Infrastructure.* My name is Larry Frevert, President of the American Public Works Association (APWA). I submit this statement today on behalf of the more than 29,000 public works professionals who are members of APWA, including our nearly 2,000 public agency members.

APWA is an organization dedicated to providing public works infrastructure and services to millions of people in rural and urban communities, both small and large. Working in the public interest, our members design, build, operate and maintain our vast transportation network, as well as other key infrastructure assets essential to our nation's economy and way of life.

We join with others in expressing our deepest sympathy to everyone affected by the I–35W bridge collapse in Minneapolis on August 1. We remain saddened by this tragedy and continue to extend our support to local, State and federal officials working on recovery and rebuilding.

The tragic failure of the I–35W bridge is a stark reminder of the importance of public infrastructure to the daily lives of all people and to the welfare and safety of every community. But this essential public asset is aging and deteriorating. It is suffering the effects of chronic under-investment and is in critical need of funding for maintenance, repair and improvement.

Our nation's highway bridges are no exception. The average span currently is more than 40 years old. More than one in every four is rated structurally deficient or functionally obsolete and in need of repair, improvement or replacement. Of the more than 594,000 publicly-owned bridges on which we depend for personal mobility and movement of freight, more than 158,000 are rated deficient, with more than 77,700 classified as structurally deficient and more than 80,600 as functionally obsolete.

Local governments own in excess of 300,000 bridges, more than half of publicly-owned bridges in the U.S. Of the total local inventory nationwide, 29 percent is rated structurally deficient or functionally obsolete.

Standards have been in place since the early 1970s requiring safety inspections every two years for all bridges greater than 20 feet in length on all public roads. Some bridges may be subject to more frequent inspections, and some structures in very good condition may receive an exemption from the two-year cycle and be inspected once every four years. These inspections, carried out by qualified inspectors, collect data on the condition and composition of bridges.

Structurally deficient bridges are characterized by deteriorated conditions of significant bridge elements and reduced load-carrying capacity. Functional obsolescence results from changing traffic demands on the structure and is a function of the geometrics of the bridge not meeting current design standards. Neither designation indicates a bridge is unsafe. But they do indicate a need for repair, improvement or replacement.

We cannot ignore the under-investment in bridge maintenance, rehabilitation and replacement. It is a major contributing factor undermining efforts to adequately address deficiencies. Nationwide, the backlog of bridge investment needs is now estimated to total $65.2 billion.

As a nation, we are failing to meet the needs of a transportation system increasingly overburdened by rising travel, a growing population and more freight. Additional traffic volumes and heavier loads are placing ever greater stress on bridges often designed for lighter loads. The U.S. Department of Transportation reports that the funding backlog could be invested immediately in a cost-beneficial fashion to replace or otherwise address currently existing bridge deficiencies.

Local governments' ability to fund necessary bridge improvements has eroded significantly over the years. They have limited financial means to adequately address deficiencies and typically do not have the capacity to do major repairs or capital work on the magnitude of a bridge replacement without funding support.

Sharp increases in the costs of construction materials and supplies in the past few years are compounding the funding challenge for local governments. In Washington State for example, escalating material and supply costs and one of the largest construction programs in the Nation have had a severe impact on delivering local agency projects. It is not unusual to take 10 years or more from the time funding can be secured and replacement done. And with the recent industry cost index increases, the gap is growing and will continue to grow.

Immediate action to increase investment is crucial to accelerating local bridge repair and replacement programs. Most bridges on local roads were either built to older standards or are so old they are in urgent need of repair or replacement. It is not uncommon that bridges have gone for years, even decades, without the appropriate action to repair or replace, due to lack of funds. This is particularly true in more rural areas.

In many cases, locally-owned bridges were often designed to carry traffic volumes and loads less than present conditions demand. As congestion increases on the Interstate System and state highways, local roads become diversion routes, supporting ever increasing levels of usage. Freight volumes, too, have increased faster than general-purpose traffic, adding demands on all parts of the system. Automobile technology allowing for greater speeds has made many bridge geometrics substandard.

Deficient bridges are rated, prioritized and repaired or replaced as funding is available. When funding is insufficient, deferred maintenance, increased inspections, weight limits and closures are often the only options.

APWA has been and will continue to be an advocate for the development of public policies which ensure the safe and efficient management and operation of our public infrastructure. As Congress considers the needs of our bridge system, we urge you to consider the following recommendations.

APWA supports a determined, comprehensive national effort to increase investment to eliminate the bridge funding backlog needed to repair, rehabilitate and replace all publicly owned bridges—including local bridges—as part of a zero bridge deficiencies goal. Such an effort, however, should not stop there. It needs sustained and sustainable funding to ensure ongoing system preservation and maintenance at a level necessary to prevent future deficiencies of all publicly-owned bridges.

APWA also supports updating bridge inspection standards and strengthening data collection and reporting procedures; evaluating active bridge monitoring systems; and strengthening inspector qualifications and training and inspection technologies, research and procedures for all publicly-owned bridges, including those on our local system. We believe that a program to strengthen research, technology, procedures and standards must be supported by full federal funding necessary to carry out and sustain it.

In conclusion, our nation's bridge system is aging, deteriorating and suffering the effects of decades of under-investment. The result is the unacceptably high levels of deficiencies we see today. APWA believes that working together in partnership with local, State, federal and private sector partners, we can and must take immediate action to address our bridge needs. But it will take funding and leadership. Increased investment to repair or replace deficient bridges is vital to achieve a safer and more efficient transportation network. A strengthened inspection program can help ensure that we make wise investments to maintain and preserve all bridges.

Mr. Chairman, we thank you for holding this hearing and are especially grateful to you and Committee Members for the opportunity to submit this statement. APWA and our members stand ready to assist you and the Committee as we move forward to address our nation's bridge needs.

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