Field Notes
The newsletter of the Infrastructure Technology Institute at Northwestern University

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ADMINISTRATIVE STAFF

Joseph L. Schofer
Executive Director

Elizabeth M. Brasheer
Assistant Director

Melissa J. Mattenson
Manager of Publications & Communications

Colleen M. Hull
Business Manager

Stacy Hester
Accounting Assistant

WRITING & EDITING

Joseph Schofer, Melissa Mattenson, Mathew Kotowsky, David Kosnik, Dan Marron

DESIGN, LAYOUT & PHOTOGRAPHY

Melissa Mattenson

THE RESEARCH ENGINEERING GROUP

Daniel R. Marron
Chief Research Engineer

Mathew P. Kotowsky
Research Engineer

David E. Kosnik
Research Engineer

David J. Corr
Clinical Associate Professor of Structural Engineering

J. Ken Fuller
Research Assistant

Olivia M. Nelson
Research Assistant

The Infrastructure Technology Institute is a National University Transportation Center supported under a grant from the US Department of Transportation's Research and Innovative Technology Administration (RITA).

The Infrastructure Technology Institute
2133 Sheridan Road
Evanston, Illinois 60208

Tel: 847-467-2049
Fax: 847-467-2056

iti@northwestern.edu
www.iti.northwestern.edu

If you are interested in working with ITI, please contact Chief Research Engineer Daniel Marron:

Tel: 847-467-1779
E-mail: dmarron@northwestern.edu

Above: Research Engineers David Kosnik and Mathew Kotowsky discuss wiring electronics to monitor a bridge in Hurley, Wisconsin

Back Cover: Members of the ITI REG at a field site in Chicago.

While freight is carried by private companies, there is a broad public interest in the performance of freight transportation and the condition of the infrastructure that supports it, because efficient freight movement is critical to the US economy and our international competitiveness.

The freight system and its infrastructure are extraordinarily diverse, including – in order of decreasing annual ton-miles carried – railroads, trucks and highways, pipelines, inland waterways, and air transport. The public sector is an important partner for all of these freight modes. US and state departments of transportation are responsible for the road network that not only carries truck freight but also connects to intermodal terminals and ports serving railroads and barge transport. The US Army Corps of Engineers builds and maintains the inland waterways system, and the Federal Aviation Administration operates the air traffic control system, while state and local authorities own and operate airports. There are strong federal roles in supporting research and development, setting standards, and regulating the safety of freight transportation.

The truck and rail industries have become highly collaborative, particularly for container freight, since rail can be more efficient (though not always faster) than trucks for long distance shipping. Labor, energy, emissions, and crash costs can be lower when containers are shifted to rail for the line haul portion of trips.

The flexibility of some commodities to be moved either by truck or rail is important to the public because there can be advantages to shifting some truck flows to rail, not only because of the aforementioned efficiencies of rail, but also because of the relatively high costs to the infrastructure of carrying heavy trucks: the marginal cost of infrastructure damage of an 80,000 pound truck can be more than ten times the cost of carrying a light vehicle.¹

The Virginia Department of Transportation has been studying the diversion of trucks to railroads in the I-81 corridor in order to reduce structural damage to pavements and bridges, crash costs, and roadway congestion. The Heartland Corridor project linking the Port of Norfolk and the Midwest (partly supported under SAFETEA-LU) is increasing vertical clearance under bridges and in tunnels to permit double stack container rail service. Chicago’s Project CREATE, the Alameda Corridor in Los Angeles, the Reno Trench, and the Kansas City Flyover each focus on alleviating rail congestion and its impacts on the road network. These public-private collaborations illustrate the public interest in private infrastructure, the basis for directing some public funds into private facilities both to protect the highway system and its operations and to achieve a more efficient, integrated freight transportation system.

Ensuring the integrity of freight infrastructure is important to the nation as well as private facility owners. The value of critical freight infrastructure components is substantial no matter who owns them. Failures of the publicly-owned waterways infrastructure, for example, can have large impacts, as illustrated in the interruptions to international trade when the Port of New Orleans was closed because of Hurricane Katrina in 2005. Highway bottlenecks motivate the use of other modes, perhaps achieved through infrastructure investments that promote long term reallocation of freight flows among modes.

Strong public–private collaborations to ensure the integrity of the national freight system are important for several reasons:

- They can support systematic planning to achieve the most efficient networks and operations – high highway connections to intermodal terminals, facilities to support economic development, desirable diversion of trucks to rail, and infrastructure investments that mitigate the impacts of freight operations on communities.
- They can help us prepare for service interruptions, guiding rapid response, measuring diversions, and organizing rapid service restoration. They can promote joint investments in materials, designs and technologies to benefit all modes.
- They can guide the deployment of public and private resources for the benefit of the nation. Chicago’s project CREATE, a much-discussed topic at the Third Annual William O. Lipinski Symposium, described on page 6, is pooling public and private money to produce such benefits.

Protecting the capacity and reliability of the US freight system in all of its elements requires resources, information, technologies, and a shared public and private commitment to act together.

Money is always an issue. Public money will flow only when there is an understanding of the needs for and benefits of investments in the freight system. It is easier for the private sector to understand needs and benefits, but private money can come only when industry returns on investment exceed the cost of capital.

Information on infrastructure performance and condition – both trend and real time measures – is essential for spotting needs and directing investments. Advances in structural health monitoring, a specialty of ITI, will help meet this need. But there is a broader need to ensure federal and state data programs to provide the perspective on freight system performance that is essential for good decision-making. The Transportation Research Board (TRB) policy study “Strategies for Improved Passenger and Freight Travel Data,” now underway, as well as the May 19-20, 2010 TRB Workshop “Toward Better Freight Transportation Data: A Research Road Map,” can be expected to set key directions for national data programs.

Research and innovation are needed to ensure the performance and condition of our freight infrastructure. As reported at the November 2009 RITA-TRB Spotlight Conference on Developing a Research Agenda for Transportation Infrastructure Preservation and Renewal, described later in this newsletter, there are important barriers to innovation arising from outdated standards, an aging workforce, and not-invented-here attitudes. There are important shared needs for infrastructure research that cut across highways, railroads, and rail transit.

A public-private commitment to support the freight infrastructure can begin with the efforts of AASHTO, the US Chamber of Commerce, two Congressionally-mandated policy studies on transportation finance, and others that together document the needs. The challenge remains to convince the public and our leadership that freight moves America and infrastructure carries the freight.
THE ANNUAL WILLIAM O. LIPINSKI SYMPOSIUM ON TRANSPORTATION POLICY

Moving the Goods – Freight in the Chicago Region was the focus of the Third Annual William O. Lipinski Symposium on Transportation Policy, sponsored by ITI on November 2, 2009.

Chicago is critically important as a national freight hub, particularly for rail and especially intermodal freight. Keynote speaker U.S. Secretary of Transportation Ray LaHood emphasized this point in his opening remarks: “Chicago as our rail hub – it is an American priority, a non-partisan priority.” He observed that the safety and energy efficiency of railroads mean that resolving Chicago’s freight issues supports the Department’s Transportation Livability Initiative – a federal initiative to help communities across America grow in ways that ensure a better quality of life.

One-third of the nation’s rail and truck cargo passes through the region, and it has been a dominant freight center for nearly a century. This pre-eminence as a hub brings the region a high level of national and international connectivity for goods movement, supporting local industries, markets, and jobs. At the same time, this role brings challenges, in the form of congestion on all modes, delays as freight is interchanged among railroads and between rail and truck, and consequent problems of safety and air pollution. Thus, freight issues in the Chicago area are of both local and national concern.

While Chicago faces numerous freight issues and challenges, there have been many improvements, and more are on the way. Michael Burton, CEO of C&K Trucking, pointed out that Chicago has been a “black hole” for intermodal freight. The city effectively imposes a two-day penalty on through-containers, and there are 11,500 trucks moving containers and trailers in and out of Chicago rail yards each day. However, operational improvements that have decreased rail yard dwell times; equipment and technology upgrades, plus better blocking and scheduling of freight trains, have improved service quality over the last several years.

The Canadian National Railway purchase of the Elgin, Joliet & Eastern Railway, while controversial, is also likely to improve regional freight operations by shifting some freight movements to the edge of the city, relieving some central city congestion on the railroads and at grade crossings. Daniel Elliot, Chairman of the U.S. Surface Transportation Board (STB), reminded participants that this acquisition comes at the expense of some increased grade crossing congestion in certain suburbs – by as many as 23 trains per day in some places. These impacts are being monitored by the STB, which will publish performance reports monthly and quarterly on its Web site. Chairman Elliot stressed that it will be important for the railroad and public agencies to work together to mitigate and manage these impacts.

Participants at the symposium spent much time discussing CREATE, The Chicago Region Environmental And Transportation Efficiency Program, which is intended to provide substantial congestion relief when its various components are completed. It will separate rail and highway traffic, as well as rail freight and rail passenger services. CREATE is a collaboration between the Class I railroads serving Chicago and federal, state, and local governments.

Joseph Szabo, Federal Railroad Administrator, said that CREATE will “establish a national model for rail integration” as it upgrades corridors, grade crossings, and signals, and streamlines other operations. US Representative Daniel Lipinski (D-IL) reported that it has been difficult to get the message of the value of CREATE across to the public, but the social, economic, and environmental benefits of the project will be significant. Six projects are already underway under the CREATE umbrella, and the Illinois State Capital Bill promises another $300 million for the project. Rep. Lipinski reminded participants that it is important to build support for CREATE at all levels.

Railroad consultant Norman Carlson emphasized the need to educate the public and policy makers about the importance of freight to the economy of the nation and the region, and to use that as a basis for growing support for CREATE.

E. Hunter Harrison, then-Chairman of Canadian National Railway, also talked about congestion in the Chicago region. He suggested that additional railroad mergers may provide a cheaper way to clear up congestion, increase capacity, and promote coordination and cooperation in the Chicago region.

Several speakers addressed the need for a national transportation policy to guide planning, investments, and the development of a financing strategy. Professor Hani Mahmassani, Director of Northwestern’s Transportation Center, pointed out that the European Union is ahead of the United States in this respect. There, the priority is to move more traffic by rail, reducing truck dominance to achieve social and environmental benefits.

A national plan would provide the basis for coordination and collaboration across federal transportation agencies, the 50 states, and the private sector to deliver a more integrated and sustainable freight system that ensures our economic competitiveness. Administrator Szabo reported that the Federal Railroad Administration is currently developing such a plan, which integrates passenger, freight, and intermodal rail transportation, and connects to the safety, livability, competitiveness, and sustainability initiatives of the federal government.

Speakers on the concluding panel addressed the national balance between truck and rail. Both James LaBelle of the civic interest group Chicago Metropolis 2020 and Paul Nowicki, vice president of the BNSF Railroad, discussed the introduction of road pricing as a source of much needed funding for the highway network, as well as to provide incentives to shift more long-haul freight to rail. Beyond the environmental and energy benefits, such a shift would reduce the burden on aging highway infrastructure.

As they focused on freight, speakers and the 250 participants at the Lipinski Symposium addressed the needs of both private and public freight transportation infrastructure – the CREATE project to relieve both rail and road bottlenecks,
rail network integration through mergers and acquisitions, and the importance of maintaining and renewing aging freight infrastructure to protect capacity and reliability of services, ensuring the economic vitality of the region and the nation.

THE DAVID F. SCHULZ AWARD FOR OUTSTANDING PUBLIC SERVICE IN TRANSPORTATION AND INFRASTRUCTURE

The David F. Schulz Award for Outstanding Public Service in Transportation and Infrastructure is presented every year at the William O. Lipinski Symposium on Transportation Policy. This award commemorates the lifelong commitment of David F. Schulz (1949-2007) to transportation infrastructure. The founding Executive Director of Northwestern University’s Infrastructure Technology Institute, Schulz was an articulate spokesman and advocate for transportation throughout his career as a public servant, elected official, university leader and teacher.

The Schulz Award honors individuals or groups for technical or policy innovations of transportation or infrastructure, or for public policy leadership in calling attention to problems in transportation or infrastructure.

The 2009 award was presented to key collaborators from five different agencies who worked to create the new I-35W St. Anthony Falls bridge in downtown Minneapolis. This bridge replaces the structure which collapsed on August 1, 2007.

This infrastructure disaster took 13 lives, and over 140 injuries. Destruction of this key link – carrying over 140,000 vehicles each day – was a major disruption for the city, region, and state, imposing traffic delays and congestion affecting both passenger travel and the logistics operations in the upper Midwest. With incremental transportation costs estimated to be at least $400,000 per day, quick restoration of this major Mississippi River crossing was a priority, but rebuilding a bridge of this scale, in the middle of a major city, is a long and complex task.

The new St. Anthony Falls Bridge was opened for traffic 414 days after the old bridge was lost. And the result is spectacular – a work of art and technology that is designed to last 100 years.

- It features a segmental concrete box girder design that facilitated rapid and high quality construction and that benefits from high performance concrete.

- This was a design-build contract in which Minnesota DOT implemented extraordinary measures to facilitate efficient communication between the owner, the stakeholders, the regulatory agencies, and the design-build team.

- Despite the speed of the effort, aesthetics were a key part of the proposal evaluation process, and that is apparent from the result.

- Incentive payments to reward timely, and early, completion were offered – and earned – tied to the cost of diverted traffic.

- Every step was compressed, worked progressed day and night, quality control was stepped up, and a landmark collaboration among all parties delivered a landmark bridge, pulling off an amazing infrastructure success.

This project is a model for rapid infrastructure restoration that recognizes the high costs of infrastructure disruption and responds with creativity, commitment and coordination. It is a model of what can be done when the right resources are brought together. ITI Director Joseph Schofer presented the award to the team, and Jo Ann and Bobby Schulz (David Schulz’s widow and son) attended the presentation.

THE ST. ANTHONY FALLS BRIDGE TEAM:

The Minnesota Department of Transportation, represented by John Chiglo

Figg Engineering, the designer, represented by Linda Figg

The Federal Highway Administration, represented by Romeo Garcia

Flatiron-Manson Joint Venture, the contractor, represented by Peter Sanderson

The City of Minneapolis, represented by Jon Wertjes
DEVELOPING A RESEARCH AGENDA FOR TRANSPORTATION INFRASTRUCTURE PRESERVATION AND RENEWAL
Research is one of the keys to solving the crisis in America’s infrastructure. This was the focus of the fourth annual Spotlight Conference sponsored by the Research and Innovative Technology Administration (RITA) of the U.S. Department of Transportation and organized by the Transportation Research Board (TRB) of the National Academies. Held November 12-13, 2009 in Washington D.C., the conference brought public and private infrastructure owners and managers together with researchers to discuss infrastructure preservation problems and needs and define a research agenda for the future. The planning committee was chaired by ITI Director Joseph Schofer. TRB management was provided by Thomas Palmerlee, Associate Director of the Technical Activities Division.

“Many elements of the nation’s surface transportation infrastructure are deteriorating as a consequence of aging and growing stresses,” Schofer said to conference participants. “Under these circumstances, it is particularly important to develop and deploy the best methods and technologies to support effective management of transportation infrastructure…The road map we develop together should serve as a guide for both research investors and producers in the deployment of resources and talent to assure the condition, performance, safety and security of the nation’s transportation system in the years ahead.”

US Secretary of Transportation Ray LaHood kicked off the two-day conference by saying that the Obama administration is committed to revitalizing the nation’s infrastructure. To accomplish this, forward-looking, innovative transportation ideas and policies are necessary. “It’s a new day at DOT,” LaHood said, emphasizing the importance of maintaining assets and making them safe, efficient and sustainable. Keynote presentations were given by three infrastructure owner-managers. Michael Miles, Deputy Director for Maintenance and Operations at the California Department of Transportation (CalTrans) spoke about spending funds wisely so that all needs, not just some, can be fulfilled. He also explained that CalTrans is moving towards preventative maintenance to extend the life of structures for significantly less cost. Robert Prince, Vice President of AECOM Transportation and former General Manager of the Massachusetts Bay Transportation Authority, stressed the need to build support for transportation infrastructure preservation. “We are all in the same boat, and we need to tell our story better because the public doesn’t understand. We need to help them understand,” he said. The last speaker of the morning, David Connell, Vice President-Engineering of Union Pacific Railroad, emphasized the importance of research in driving further safety and efficiency improvements, as it would “set our future.”

Conference participants then worked in four breakout sessions to define a comprehensive research agenda for infrastructure preservation and renewal. The focal areas were Inventory and Condition Assessment, Innovative Materials for Preservation, Restoration, and Reconstruction, Strategies for Rapid Repair and Rehabilitation, and Methods to Support Infrastructure Preservation and Renewal. A key resource for this process was more than thirty poster presentations describing research activities and achievements. ITI and Northwestern University were well represented at the poster session. The ITI Research Engineering Group (REG) – David Kosnik, Daniel Marron, Mathew Kotowsky, and David Corr – presented five posters, and Civil Engineering graduate students Nathan Tregger and Zoi Metaxa presented their research with ITI researcher Professor Surendra Shah. The REG posters were co-authored by ITI researchers Professors Charles Dowding, Richard Finno, and Pablo Durango-Cohen.

The conference ended with presentations from each of the discussion groups and the development of research priorities by all participants. In addition to the lengthy research agenda, a series of six crosscutting themes was discussed throughout the conference. TRB prepared and issued the infrastructure preservation and renewal research agenda at the end of December. It was widely distributed at the 89th Annual Meeting of the Transportation Research Board in January, 2010, and Schofer and other members of the planning committee are working with TRB and RITA to distribute the agenda even more broadly.

In the breakout sessions the REG presented several significant case studies of recent projects, including acoustic emission monitoring of two steel bridges, continuous remote monitoring of in-service historic utility tunnels, continuous remote monitoring of uplift bearings on a large truss bridge, and the use of wireless sensor networks to monitor crack growth on bridges.
1. METHODS FOR RAPID TESTING OF NEW MATERIALS AND DESIGNS
Implementation of new materials and methods is commonly slowed by uncertainties about long-term effective and efficient performance. Validated and reliable accelerated testing techniques will help overcome uncertainty about such innovations. Accelerated testing techniques must be sensitive to the effects of environmental, utilization, and aging factors on component and system condition and performance. These techniques should target new and recycled materials, innovative designs, and construction methods.

2. RESPONSIVE AND FLEXIBLE STANDARDS AND SPECIFICATIONS FOR NEW, ADVANCED, AND RECYCLED MATERIALS, DESIGNS AND SYSTEMS
An important barrier to innovation and implementation is reliance on standards and specifications grounded in traditional materials and methods. A new concept may be rejected because there is no specification to support it, rather than because of inherent limitations. Updated and performance-based standards and specifications will help to advance innovation in infrastructure preservation and renewal.

3. UPDATED INSPECTION STANDARDS AND POLICIES
The value of advanced sensor and monitoring technologies is limited by outdated inspection procedures. Modern and more flexible inspection standards and policies are needed to make effective use of new sensors and automated continuous monitoring capabilities, to manage inspection based on risk and condition, and to cover new materials and additional components of the transportation system.

4. VALUATION METHODS TO SUPPORT INFRASTRUCTURE MANAGEMENT PROCESSES
Reliable and credible information on the values of infrastructure options is needed to support more informed investment and management decisions. Research is needed to develop objective, quantitative, and monetary methods and models to estimate life cycle values for (a) automated monitoring technologies and methods; (b) preservation and renewal actions; and (c) keeping transportation facilities and systems in a state of good repair.

5. TRAINING AND EDUCATION
Limitations of knowledge and skills about new materials and methods slow innovation in infrastructure renewal and preservation, creating a critical need to invest in transportation infrastructure education and training in universities, private entities, and public agencies. While training is not a research function, knowledge transmission is an integral part of the research process, both in academic institutions which have this dual mission, and research organizations that have a mandate to move products into practice. The training challenge is exacerbated by the need to renew the transportation infrastructure workforce at both the professional and technical levels, and it is accelerated by the rate of development of new technologies.

6. CONTINUED DEVELOPMENT OF INFRASTRUCTURE CONDITION AND PERFORMANCE SENSORS
While there has been much progress on new, automated sensors and remote monitoring technologies, a variety of enhancements are needed. In particular, sensors are needed to monitor a broader range of transportation system components extending beyond pavements and bridges. Advanced technologies that can monitor hidden and inaccessible components represent special needs. New sensors are also needed that can be easily deployed with minimum disruption to operations, are hardened for long life, and are responsive to new materials and designs.

CROSSCUTTING THEMES
A number of research and development needs arose in several areas addressed by the conference. The first five of these crosscutting needs directly address key barriers to implementing new concepts, and thus investments in these topics are likely to produce broad and important impacts on the field. The sixth, advancing technologies for condition and performance monitoring, aims to improve the quality and cost-effectiveness of information for infrastructure management decisions.

POSTERS PRESENTED BY ITI STAFF AND PRINCIPAL INVESTIGATORS

CONTINUOUS REMOTE CONDITION MONITORING OF AN IN-SERVICE HISTORIC UTILITY TUNNEL
David Kosnik, Mathew Kotowsky, Daniel Marron, Richard Finno, and Charles Dowding

CONTINUOUS REMOTE STRUCTURAL HEALTH MONITORING FOR LIFE EXTENSION OF AN UPLIFT BEARING ASSEMBLY ON THE I-65 JOHN F. KENNEDY BRIDGE IN LOUISVILLE, KENTUCKY
David Kosnik, Mathew Kotowsky, Daniel Marron, and Theodore Hopwood

ASSESSMENT OF STEEL BRIDGE DETAILS WITH ACOUSTIC EMISSION MONITORING
David Kosnik and Daniel Marron

WIRELESS SENSOR NETWORKS TO MONITOR CRACK GROWTH ON BRIDGES
Mathew Kotowsky, James Kenneth Fuller, and Charles Dowding

EXPLOITING ADVANCED INSPECTION TECHNOLOGIES TO SUPPORT CONDITION ASSESSMENT, FORECASTING, AND DECISION MAKING
Pablo Luis Durango-Cohen and David Corr
THE 52ND MEETING OF THE ACOUSTIC EMISSION WORKING GROUP
The Infrastructure Technology Institute hosted the 52nd meeting of the Acoustic Emission Working Group (AEWG) October 19-21, 2009, in Sturgeon Bay, Wisconsin. AEWG is an international organization dedicated to advancement of the theory and practice of acoustic emission (AE) testing. AE refers to the phenomenon by which materials under stress emit noises – sometimes audible, as with the “tin cry” known to metalworkers, but more often inaudible ultrasonic frequencies – and to the non-destructive evaluation technique based upon analysis of these noises. ITI is a leader in application of AE techniques to large civil structures, especially steel bridges. While a wide variety of AE applications were featured at the 2009 meeting, civil infrastructure was a special area of focus. Sturgeon Bay was selected as the meeting site in part because it allowed participants to tour steel bridges.

In keeping with AEWG’s custom, the first day of the meeting consisted of a series of hour-long primer sessions intended to introduce novices to basic AE concepts while refreshing and expanding the knowledge of veteran AE workers. The morning featured lectures on AE instrumentation and basic analysis as well as feature-based analysis by Rick Nordstrom of Portland State University and Tomoki Shiotani of Kyoto University, respectively. Jihui Li of Inova Fairfax (Virginia) Hospital closed the morning with an overview of biomedical applications of AE. The entire afternoon was dedicated to civil infrastructure applications. ITI research engineers David Kosnik and Daniel Marron presented a summary of the Institute’s work on AE localization and characterization of cracks in steel highway bridges. Kosnik and Marron also discussed AE for localization of mechanical noise sources on large movable structures. The second and third days of the meeting were filled with technical presentations and lively discussion. Presentations ranged from AE sensor design and data analysis techniques to practical applications ranging from materials science to medicine, civil structures, and aerospace.

Immediately following a tour of one of the bridges in downtown Sturgeon Bay, ITI research engineers David Kosnik and Daniel Marron presented their recent work on AE for localization of the source of unsettling “banging” noises observed on a lift bridge. Because sound travels about 17 times faster in steel than in air, it is nearly impossible to locate the source of such noises by ear. Fortunately, AE source location techniques can provide unambiguous results; once the noise source is identified, it is possible to determine the cause.

On Tuesday evening, an awards dinner was held during a boat tour of Sturgeon Bay. Attendees were treated to up-close views of the three bridges over the bay and adjoining ship canal. Masayasu Ohtsu of Kumomoto University was awarded the AEWG Gold Medal for his work on AE analysis of concrete, including investigation of rebar corrosion and corrosion-induced cracking.
Frontiers in ISHM: An Interview with Sridhar Krishnaswamy

Sridhar Krishnaswamy is a professor of mechanical engineering and director of the Center for Quality Engineering and Failure Prevention at Northwestern University. He is also principal investigator for the collaborative NSF-sponsored Partnerships in International Research and Education - Structural Health Management program (PIRE-SHM).
WHAT IS THE MISSION OF PIRE-ISHM?

The mission of the PIRE-ISHM program is to form substantive collaborative interactions with partners from the US and abroad in the general area of Intelligent Structural Health Management (ISHM). The basic idea underlying ISHM is to instrument safety-critical structures with several diagnostic sensors that can provide timely information that can be used to predict structural reliability going forward. Diagnostics is an essential component for ensuring structural reliability, and this has typically relied mostly on visual inspections. In the future, most structures will be instrumented with several sensors that can report on the condition of the structures. A second very important component of ISHM is the ability to use the information from the sensors to assess whether the structure is currently operationally safe. ISHM therefore requires a cross-disciplinary approach bringing together several emerging and some mature sub-fields of science and engineering, including smart structures and materials, structural health monitoring and nondestructive evaluation, damage and failure mechanics, materials science, and probabilistic reliability analysis.

The PIRE-ISHM program is funded by the National Science Foundation for a five-year period. It is led by Northwestern University and it involves the University of Illinois-Chicago as well as universities from China, India, Korea and Hong Kong. Honeywell, GE, and Boeing are among the industry partners.

WHAT CAN WE EXPECT NEXT FROM INTELLIGENT SENSORS?

For ISHM, we need sensors that can provide information about the structural, environmental and material states. Structural and environmental sensors such as strain gauges, load cells, temperature gauges, accelerometers, tilt gauges, etc are fairly well developed. We can expect continued performance improvements in these types of sensors, and, more importantly, we are also likely to see a definite move towards wireless sensors as they are much easier to install than bulky wired sensors. Wireless sensing would also require self-powering through energy-harvesting so that we are not faced with having to change sensor batteries often. Some of these types of wireless sensors are beginning to enter the market, but there is still a lot of work to be done in this area. Going forward, we would also like to see new sensors developed that can provide information about the material state and not just the structural state. Sensors that can provide early indication of fatigue damage, stiffness degradation, incipient corrosion, etc., would all be very valuable diagnostic tools.

IS THERE A CRISIS IN INFRASTRUCTURE?

The large portfolio of aging infrastructure that we have in the US will obviously have to be fixed or replaced over the next couple of decades. While this is a big economic challenge, it also presents a great opportunity to upgrade the infrastructure so that they can be more efficiently managed and maintained in the future. Manual inspection is always going to be more expensive and perhaps more prone to error. On the other hand, structural health monitoring using remote sensing might involve added initial costs during installation, but the case for reduced total cost of ownership using the ISHM approach is very strong.

To give a parallel example, the electrical meters in the town where I live are read by a person from the electric company having to trudge through rain or snow from house to house. Since this is time consuming and expensive to do, the electric company often chooses to read the meters only once every couple of months or so, and they estimate the usage for the months that they do not have an actual meter reading. By contrast, our water meter can be remotely accessed by the city through a wireless radio connection, with significant cost savings for the city. It is easy to imagine that the wireless water meter sensor could also be used to automatically detect water leaks, etc., which is not currently done. Current infrastructure inspection process is more like the electric company’s approach in that most of the time we estimate the structural state based on relatively few manual inspections. This is both inefficient and prone to error. Structural health monitoring using remote sensors can provide information as often as necessary at a fraction of the cost of manual inspection. The resulting savings from the diagnostics process can be utilized towards better prognostics and rehabilitation.

HAVE THERE BEEN PROMINENT FAILURES WHERE STRUCTURAL HEALTH MONITORING COULD HAVE MADE A DIFFERENCE?

In the book ‘Outliers’ by Malcolm Gladwell, there is a chapter on the root causes of airplane crashes. To paraphrase Gladwell’s point, catastrophic failures (especially of systems with built-in redundancy for safety) are often the result of cascading string of errors. The I-35W bridge collapse, I think, is a classic case of that. My understanding is that improper design, combined with unexpected overload, and structural aging (fatigue cracking) were all contributing factors. In hindsight, it is conceivable that if we had sensors to monitor overload and aging, perhaps the catastrophic collapse could have been avoided.

WHAT IS THE INTERNATIONAL COMPONENT OF YOUR PROGRAM?

The PIRE part of the PIRE-ISHM acronym stands for ‘Partnerships for International Research and Education.’ Our partners currently are from China, India, Korea and Hong Kong. As part of the PIRE-ISHM experience, our graduate and undergraduate students go on extended research visits to the partner labs. The graduate students, especially, have continued collaborations with their international counterparts extending through the duration of their studies. The international component of the program serves several purposes. First,
there is a lot of ISHM activity in our partner countries, which is not surprising considering that there is a lot of infrastructure construction going on there as well. There are several bridges, off-shore platforms, television towers, etc., that have been extensively instrumented in these countries which can serve as test beds for new ISHM systems that we develop in this program, and we can learn a lot from our partners in this regard. As an example, one of our PIRE-ISHM faculty affiliates, Professor Pablo Durango-Cohen is currently in discussions with our Hong Kong Polytechnic University partner regarding the possibility of mining a twelve-year long database from the Tsing-Ma bridge in Hong Kong in order to test some of his prognostics algorithms.

A larger purpose of the international component is to provide our students an opportunity to learn how to successfully engage in complex technological endeavors with global partners. No matter what technical or management career paths they choose in the U.S., our students will most certainly have to deal with foreign clients, customers, colleagues or students, and the PIRE-ISHM program gives them an early glimpse of the emerging global work environment. It is also my hope that at least some of the PIRE-ISHM students will see that they do not have to let geography limit their career options. Opportunities for research careers exist not only at GE Niskayuna in New York, but also at GE Global Research in Bangalore or Shanghai. Or, perhaps one or two of our students might team up with their counterparts in India or China to create startup companies that can leverage the strengths of the U.S. and the international partner countries.

ARE NEW INFRASTRUCTURE MATERIALS SUCH AS COMPOSITES EASIER OR MORE DIFFICULT TO MONITOR?

New materials almost always increase the challenge for ISHM. Obviously, the use of new materials implies that there is some gain in terms of function or cost. However, we will need to understand their failure mechanisms and long term degradation behavior, and we will need to identify or develop appropriate inspection tools for monitoring their condition. This keeps those of us involved in ISHM research in business!

SHOULD WE DEPLOY STRUCTURAL HEALTH MONITORING TECHNOLOGY MORE BROADLY TO THE PUBLIC INFRASTRUCTURE?

Ultimately, we would want to deploy ISHM technology across the board for enhanced safety and potentially lower total cost of ownership. There are of course several barriers to overcome, both technical and economic. On the technical side, standardization and codification of ISHM approaches will be required. Standardization can be readily achieved for structures such as airplanes that are built to common specifications in a factory, but it is quite hard to enforce for civil infrastructure, where every structure is somewhat unique and is built on site. Organizations such as the American Society of Civil Engineers (ASCE) will obviously have to codify emerging ISHM methodologies. On the economic side, the barriers for adoption of ISHM primarily relate to the diverging interests of the builder, operator, owner and users of the infrastructure.
ITI is proud to name Jeff Meissner, a senior in Civil & Environmental Engineering in Northwestern’s McCormick School of Engineering and Applied Science, as its Student of the Year.

Beginning in his sophomore year, Jeff made valuable contributions to ITI-sponsored research projects under Professor Charles Dowding. Dowding’s Autonomous Crack Monitoring project evaluates the response of cracks in various structures to vibration and environmental changes. Jeff was involved in the study of a residential structure in Naples, Florida, aimed to reduce litigation costs for road aggregate quarry operators by demonstrating that cracks in nearby homes are affected much more by weather fronts and daily temperature cycles than by blasting vibrations. Some of Jeff’s work was recently presented at the annual meeting of the International Society of Explosives Engineers. Jeff also assists the ITI Research Engineering Group in field installations from time to time.

In his free time, Jeff enjoys both coaching and playing for the university’s club baseball team, and cheering on his Northwestern Wildcats in all their athletic endeavors. In Fall 2010, he plans to attend graduate school in pursuit of a Ph.D in civil engineering.

“I’m very honored that ITI is presenting this award for my effort in ACM. Research in transportation and engineering is so important and undervalued.”

This January, Jeff travelled to Washington, DC to accept this award and a $1000 scholarship at the 13th Annual Council of University Transportation Centers Awards banquet as part of the 89th annual meeting of the Transportation Research Board.
ITI RESEARCH EMBRACED IN HIGH-RISE CONSTRUCTION
In late 2008, construction began on a new high-rise condominium building in the fast-growing South Loop area of Chicago. The site of this planned 53-story reinforced concrete tower is a prime example of the infrastructure congestion typically found in urban centers: the embankment of the East Roosevelt Road bridge is a mere six feet north of the site, and South Indiana Avenue, an abandoned water tunnel, and several underground public utilities lie immediately west of the tower. The City of Chicago’s Board of Underground laid out strict monitoring guidelines to ensure the safety of these nearby critical facilities.

ITI researcher Professor Richard Finno and his team have deployed a network of over 70 vibrating wire strain gages to monitor the loading of the different sections of each basement slab during the innovative “top-down” construction process in which the concrete slabs of the basement levels are constructed as the excavation progresses rather than after excavation is complete. Just before each slab of concrete is poured, engineers attach these gages to the reinforcing steel and immediately begin to take readings. When the slab is poured, the sensors become a permanent part of the structure and provide critical information about how the slabs bear load as the soil beneath them is excavated.

In December 2009, the Chicago Department of Transportation and owners of the largely completed building requested that ITI continue its investigation into the effects of the construction method on surrounding infrastructure with the goal of developing design recommendations for future use of this innovative construction technique. Keeping the sensing system in place for a longer period of time makes more data available to engineers about the long-term performance of “top-down” construction as it relates to the surrounding soil and infrastructure.

Though the building’s basement levels were part of an active construction site at the time of the installation of the equipment, these levels will become the garage where the building’s new occupants will park their cars. As with any long-term structural health monitoring system, especially those that exist in an area to which the public has access, great care must be taken by engineers to protect the equipment from accidental damage and to inconvenience the building’s occupants as little as possible. The efforts of the ITI engineering team to leave the building’s residents with a functional yet inconspicuous monitoring system not only ensure the safety and continued successful operation of the equipment, but also provide a stage on which to showcase the advancements in structural and geotechnical health monitoring pioneered by ITI.

Opposite Page: (Top) ITI Chief Research Engineer Daniel Marron installs a vibrating wire strain gage in a soon-to-be-poured basement slab. (Bottom) The partially completed high rise. 
This Page: One of the five data loggers that composes the structural health monitoring system.