NORTHWESTERN UNIVERSITY
Infrastructure Technology Institute

Year 4 Annual Progress Report
Part A – Corporate-Style Annual Report

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1801 Maple
Evanston, Illinois 60201
(847) 491-8165
Fax (847) 467-2056
dschulz@northwestern.edu
www.iti.northwestern.edu

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Corporate-Style Annual Report

Introduction

Founded in 1992, the Infrastructure Technology Institute of Northwestern University is an upper tier university transportation center funded under the Transportation Equity Act for the 21st Century (TEA-21). On November 10, 1999, the Research and Special Programs Administration (RSPA) of the US Department of Transportation approved the Institute's six-year strategic plan and awarded funding for the Northwestern fiscal year September 1, 1999-August 31, 2000. RSPA had previously granted the Institute an extension for closeout of its previous six-year funding under the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) to March 31, 2000.

Since the Institute continued to expend ISTEA funds well into the first quarter of calendar 2000, the Institute prepared and submitted in Spring 2001 a report documenting progress during calendar 2000 as its Year One funding progress report, and prepared and submitted similar reports on calendar 2001 and 2002 as respectively its Year Two and Year Three progress reports. This report documents progress from January 1, 2003 to December 31, 2004 as the Institute's Year Four funding progress report.

Center Theme

The theme of the Infrastructure Technology Institute is improving the technology and expertise available to address the problems of the nation's transportation infrastructure.

Management Structure and Center Staff

Center Director As the head of an interdepartmental center within Northwestern's McCormick School of Engineering and Applied Science, the Director of the Institute is appointed by and reports to the Dean of the McCormick School. The Director is responsible for the day-to-day management and administration of the activities of the Institute, including but not limited to developing, implementing and monitoring the Institute's annual budget; interacting with federal officials responsible for administering the Institute's grant funding; and carrying out all other aspects of the Institute's program. The Director is currently 100% funded by the Institute. The Center Business Manager assists the Director.

The Director is also responsible for overseeing the Institute's program of research and development projects, including but not limited to monitoring current research opportunities and needs, establishing and maintaining liaison with transportation infrastructure practitioners who are potential partners in research projects, helping to build research project teams to respond to those

needs and opportunities, managing the research project selection process, and administering research projects once they are awarded.

The Director also is responsible for managing the Institute's technology transfer process including overseeing the Institute's library services program and other technology transfer programs, monitoring commercialization activities of research projects and providing assistance as necessary, and establishing and maintaining liaison with transportation infrastructure practitioners who are targets of technology transfer.

The Director is also responsible for establishing and maintaining a public information program for the Institute, including but not limited to the preparation and dissemination of publications and the conduct of conferences and workshops. Finally, the Director is responsible for securing additional sources of support, including but not limited to research contracts, research partnerships, and grant support.

Center Faculty and Staff In addition to the Director, the Institute's only other direct full-time administrative employee is a Center Business Manager, Ms. Elizabeth Brasher. The Business Administrator is responsible for all aspects of the Institute's administration including budgeting, financial monitoring, purchasing, travel arrangements, computer system maintenance, interaction with other University departments, and other responsibilities as assigned by the Director.

In response to concerns raised by RSPA, Institute hired a new program assistant, Ms. Nancy Seeger, as an assistant to Ms. Brasher, with primary responsibilities the preparation of reports and other documents for federal reporting purposes, together with working with Institute staff on document development and preparation for research, education, technology transfer, and management and policy studies activities. Initially, this position will be part-time, allowing the Institute to gauge workload.

The Institute also employs a three-person team of research engineers, including Mr. David Prine, Chief Research Engineer, Mr. Dan Marron and Mr. Dan Hogan, Research Engineers. The team also includes two half-time research engineers, Mr. David Kosnik and Mr. Mathew Kotowsky. This team is totally supported by outside income and Institute research project support.

The Institute does not directly employ any faculty. Project-related research funding supports all faculty, research staff, and graduate students employed on Institute-supported research projects. The Institute also supports the full-time services on the payroll of the University Library of the Infrastructure Knowledge Manager, Ms. Ruth Allee and an assistant, for which a search is currently being conducted.

Program Activities

Education The Institute's primary desired educational program outcome is to achieve a multi-disciplinary Transportation Infrastructure Management specialization in the Master's of Project Management (MPM) program in the Department of Civil Engineering. This program is evolving from and building upon the more generalized Infrastructure Management specialization currently offered in the MPM program.

An additional desired educational program outcome is to use the resources and activities devoted to the Master's program to enrich the available educational opportunities for undergraduate civil and environmental engineering students, and for graduate students at Northwestern in other engineering disciplines, the Transportation Center, the Kellogg Graduate School of Management, and the Medill School of Journalism and other programs. These resources and activities include courses, seminars and symposia, field trips, and other activities associated with the program.

To achieve these objectives, the Institute is working to broaden its direct course offerings. The Institute Director devotes half his time and office resources directly to education activities. He developed and has taught for the last eight years the very popular – 33 students enrolled in Fall 2003 – undergraduate-graduate course, "Civil and Environmental Engineering 338, Public Infrastructure Management." In the spring of 2002, he developed and co-taught with Prof. Joseph Schofer a new course, "CEE 382, Infrastructure Facilities and Systems," which enrolled 24 students in its initial offering and 15 students when re-offered in the spring of 2003, and the intention currently is to make this an annual offering. The Institute Director is developing and will teach an additional undergraduate/graduate course in the Department of Civil and Environmental Engineering.

Possible additional course offerings – a final decision has not been made – include infrastructure planning and engineering, infrastructure organizations, public sector innovation, engineering communications, and development and implementation of large-scale transportation infrastructure projects. It is not currently anticipated that new faculty or staff will be hired and supported by this grant.

In the summer of 2002, the Institute developed and offered a weeklong course in infrastructure facilities and systems aimed at high school juniors and faculty. Post-course evaluations indicated it was very successful, and the Institute offered it again in 2003 when over 35 high school students attended. Based on this success, the Institute intends to make this an annual offering.

In the summer of 2003, the Institute developed and offered a once-a-week ten-week summer course in cooperation with the Country Meadows Montessori School in Gurnee, Illinois. While attendance varied by week, between forty and sixty first to fourth grade students participated in morning classroom discussions and afternoon field trips. The Institute intends to repeat this course in 2004.

The Institute is working to integrate its education program with other disciplines in the University, and with its research, technology transfer and management and policy activities. The Infrastructure Management specialization already provides broad interdisciplinary coverage, as depicted below:

Typical Plan of Study and Alternate Course Selections
Infrastructure Management Specialty
Master's of Project Management

Typical Plan of Study	**Alternate Course Selections**
Financial Issues for Engineers	Public Policy and Private Initiatives
Total Quality Management	Development Finance
Scheduling	Environmental Impact Evaluation
Human Resources Management	Air Photo Interpretation
Accounting Issues for Engineers	Transportation Policy
Engineering Law	Geographic Information Systems
Public Infrastructure Management	Transportation Systems Operations
Non-Profit Management Strategy	Bargaining and Negotiation
Issues in Non-Profit Management	Hazardous Waste Management
Transportation Systems Planning and Management	Uncertainty Analysis
	Transportation Economics
Evaluation and Decision Making for Infrastructure Systems	Construction Estimating
	Construction Management
Construction Contracts and Dispute Resolution	Public Health Engineering
	Computers in Engineering Design, Management, and Decision-Making
Commercial Real Estate Development	

Research The Institute seeks a research selection process which maintains at least the historic breadth and width of Institute-supported research. The objective is to at least maintain, if not expand, the number of technology areas actively being researched (breadth), while continuing to increase both the number of innovations and the amount of technical expertise in the technology areas being researched (depth).

The Institute currently solicits research proposals and accepts unsolicited proposals from Northwestern faculty. The Institute Director and a Research Advisory Panel comprised of three outside experts, including academics, researchers, and/or transportation infrastructure practitioners, review the

proposals and make a recommendation regarding funding to the Institute Executive Committee for each proposal. This review is based on a careful consideration of the research progress to date, with emphasis on the quality of the work, its applicability to meeting infrastructure needs, its degree of successful transfer to practice, and its ability to attract deployment partners.

Their recommendations are based on the salience of the unmet transportation infrastructure need proposed to be addressed by the research, the likelihood of achieving a commercializable end-product from the research and the likely market for it, the relationship to other ongoing research, the experience and qualifications of the researchers, the strength of the proposed technology commercialization and transfer plan, the sufficiency of the practitioner-involvement strategy, the proposed budget -- both annual and multi-year -- related to the Institute's overall research budget, and the success of prior related research in terms of end-products, technology commercialization and transfer, development of potentially-commercializable products, and budget and schedule adherence.

The Executive Committee is the Institute's governing body responsible for making policy and funding decisions. Membership currently includes the chairman of the Department of Civil and Environmental Engineering, the Associate Dean of the McCormick School of Engineering, and the heads of the Master's in Project Management program and the Center for Advanced Cement-Based Materials. The committee reviews the recommendations of the Research Advisory Panel and authorizes funding for projects the Committee deems worthy.

The Institute's desired research performance program outcome is to have each principal investigator publish at least one peer-reviewed research report and present one paper annually based on Institute-supported research.

The Institute's recent research efforts have emphasized nondestructive testing and evaluation of transportation infrastructure facilities – principally bridges – improved transportation infrastructure materials including weldable high-strength steel, better incorporation of recently-developed principles in concrete construction codes, and enhanced ability to determine strength of recently-poured concrete, among others.

As detailed in the discussion of success stories below, Institute researchers have made a series of successful breakthrough deployments in continuous remote monitoring of transportation infrastructure facilities. The Institute is exploiting these advances in continuous remote monitoring while continuing selective work in transportation infrastructure materials research.

One of the key aspects of the Institute's success to date is its demonstrated ability to work closely with infrastructure agencies as true partners in the development and deployment of innovative technologies. To that end, Institute

researchers work directly with the partner agencies, which provide support (and match) to the Institute's activities in three ways: (1) partner agencies provide on-site personnel and equipment to support Institute researchers undertaking field trials and demonstrations; (2) partners provide in-kind support through engineering and other services conducted off site in direct support of the field work undertaken by the Institute researchers; and (3) partners on occasion contract directly with Institute researchers to provide technical assistance in the deployment of advanced technologies in the field.

Performance of Institute-supported research projects is monitored and evaluated in three ways. First, even though there can be implied long-term research support commitments to research topics, Institute funding is provided in annual increments. A careful peer-review evaluation of research performance is conducted annually as part of the Institute's research re-funding decision-making process.

Second, since 1993 the Institute has conducted monthly research luncheon meetings on the second Monday of every month. At these meetings the principal investigator of each active research project is required to make a presentation on recent progress and upcoming activities. Such presentations range in scope from brief reviews to lengthy and sometimes quite elaborate slide presentations, technical briefings, and even outside speakers dealing with the project in question. These presentations frequently generate discussion – often very lively -- among the other researchers present.

Third, the Institute Director is in continual contact with each of the principal investigators to informally monitor project progress, chart short and long-term plans for the work, and problem solve.

This three-part monitoring process provides continuing, thoughtful and productive review of the work and its results, without being overly burdensome in terms of paperwork and reporting requirements.

The Institute is also in contact with transportation infrastructure practitioners and researchers to develop additional research opportunities.

Technology Transfer The Institute's desired technology transfer program outcomes are to: (1) double the number of visitors to the Institute Website, (2) double the number of peer-reviewed papers on the Website, (3) conduct a summer transportation infrastructure institute for high school juniors and conduct other K-12 transportation infrastructure education initiatives, (4) conduct two meetings, one seminar, and one remote learning course annually, reaching 200 professionals, (5) provide frequently updated reports on Institute progress and news on the Institute Website, and (6) achieve an average of one successful research product deployment per funded project.

The Institute has successfully rebuilt its Website www.iti.northwestern.edu.

The Institute continues to build on the successful Midwest Bridge Maintenance and Inspection Technology Sharing Consortium by inviting additional state and local governments, universities, and private consultants to participate in the two meetings of the group each year, in addition to Web-based and other information exchanges.

Policy and Management Studies The Institute Director continues to maintain an active speaking calendar on transportation infrastructure technology, policy, management, and related issues.

In 2003, the Institute embarked on an effort to improve mitigation of impacts on the transportation system of terrorist and other disruptions. This effort is being conducted in cooperation with Chicago area planning, transportation, and emergency response agencies.

Vision

In its strategic plan, the Institute established an ambitious vision for the six-year period:

- Develop a transportation infrastructure engineering **educational program** at the Master's level while enriching the undergraduate civil engineering curriculum at Northwestern and providing significant professional development opportunities to transportation infrastructure practitioners,

- Continue its successful transportation infrastructure **research programs** in nondestructive testing and evaluation of transportation infrastructure and materials,

- Build on its success in **moving the innovative transportation infrastructure technologies it develops into practice**,

- Contribute to advances in transportation infrastructure **policy and management**, particularly the vexing problem of the increasing paralysis of the transportation infrastructure industry in pursuing large complex projects,

- Grow the number of public and private sector transportation infrastructure **industry partners** with whom it works on technology issues, broaden existing partnerships, and develop new partnerships to include human resource and management and policy dimensions, and

- Generally enhance its position as a recognized **center of excellence** in transportation infrastructure technology.

The Institute is pleased and proud to report a number of important successes on these goals during 2003.

Success Stories: Education

… achieve a multi-disciplinary Transportation Infrastructure Management specialization in the Master's of Project Management (MPM) program in the Department of Civil Engineering [italicized inserts throughout this report are quoted from the Institute's University Transportation Center Strategic Plan: 1999-2005]

> **Success Story: Public Infrastructure Management Course.** The Institute once again offered its popular (33 students) Public Infrastructure Management course. Lecture notes were posted on Northwestern's "Blackboard" electronic teaching site, as were student responses to weekly e-mail assignments, items from the trade and popular media in the class's weekly "Infrastructure in the News" discussion, results of the full-day student charrette, and the final student term papers. The all-electronic format again proved to be extremely popular with students, as indicated in the results of the post course evaluation.
>
> **Success Story: Infrastructure Facilities and Systems Course**. In spring quarter 2003, the Institute director for the second time taught, with CEE Chair and Professor Joseph Schofer, a course in infrastructure facilities and systems. 15 students enrolled in the course, in which a weekly lecture was followed by a field trip later in the week to an infrastructure facility or project. Trips included a journey to the Illinois Department of Transportation district office and communications center, a trip on a CTA rapid transit train, a guided tour of the newly-rebuilt Midway Airport, the Millennium Park construction project in downtown Chicago, a ride on a Pace bus with newly-installed GPS-based bus locator system and tour of Pace operation garage, a visit to a project management firm office and tour of an office building construction project, a trip to the Illinois Railway Museum in Union, Illinois, a tour of the construction site of the 11th Street Pedestrian Bridge in downtown Chicago, and a boat trip on the Chicago River to view bridges and architecture from the water. Students were required to participate in team design projects, and three student teams developed outstanding projects. Post-course evaluations indicated the course was very popular and it has been assigned a permanent course number. The Institute intends to offer it again in 2004 and subsequent years.

… use the resources and activities devoted to the Master's program to enrich the available educational opportunities for undergraduate civil and environmental

engineering students, and for graduate students at Northwestern in other engineering disciplines, the Transportation Center, the Kellogg Graduate School of Management, and the Medill School of Journalism and other programs.

Success Story: Summer High School Infrastructure Institute. In the summer of 2002, the Institute developed and offered a weeklong summer infrastructure institute on the Evanston campus. Educational and fun, each morning began with a lecture about elements of urban infrastructure presented by the Institute director. Each afternoon, students and teachers enrolled in the institute embarked on a supervised field trip to prominent facilities. Based on the success of the initial program, the summer institute was offered again in late June and early July 2003. Field trips involving over 35 students and teachers included Midway Airport, a chartered the Chicago Transit Authority train, the Illinois Railway Museum, the construction site of the 11th Street Pedestrian Bridge in downtown Chicago, and a boat trip on the Chicago River. On the CTA trip, summer high school institute participants were joined by students and teachers from the Institute's lower elementary infrastructure program.

Students ride the CTA rails in the 2003 high school summer institute.

The goal of the summer institute was to give students and teachers the opportunity to learn more about Chicago and urban infrastructure, while interacting with their peers and colleagues. While the Infrastructure Technology Institute hoped to pique the interest of at least a few of the participating students to pursue an education and career in civil engineering or a related infrastructure field, the main purpose was to give both teachers and students a richer and deeper understanding of how infrastructure works and the important role it plays in our society. Based on a post course evaluation, the summer institute will be offered again in 2004, with tentative dates June 28 though July 2.

Success Story: Summer Infrastructure Program for Lower Elementary Students. Lower elementary students have proven particularly difficult to reach when it comes to teaching them about the role and importance of infrastructure in American society. As part of its K-12 educational goal, the Institute partnered with the Country Meadows Montessori School to structure an ten-week, once-a-week program of morning classroom sessions and afternoon field trips dealing with various infrastructure facilities and systems.

The program consisted of:

> ***Class #1 – What Is Infrastructure?*** *What is a city? What facilities did people need in order to live in cities? What determines where and how much infrastructure is needed? A mapreading primer. A Chicago and Lake County infrastructure primer; discussion. Build a model city with infrastructure – draw a picture or your neighborhood, model the infrastructure connecting to your house in a sand box, play Sim City, read various maps and make your own map*
>
> ***Class #2 – Roads*** *– History, function, technology, governance, condition, current issues; discussion. Bus trip to a Lake County road construction project*
>
> ***Class #3 – Transit – Commuter Rail & Bus*** *– Modes of public transit; Metra, Pace, CTA: Past, present, & future; how to use public transit including reading a transit schedule, getting fare media and paying your fare, where to board a bus, how to know when your destination is approaching, signaling to get off; discussion. Ride a Pace bus to the Waukegan Metra commuter rail station for a round trip to Lake Forest*
>
> ***Class #4 – Transit – Rapid Transit –****CTA charter train trip being conducted for summer high school student/teacher infrastructure institute.*
>
> ***Class #5 – Railroads*** *– Trip to Illinois Railway Museum, Union, Illinois, museum video, other railroad videos, and discussion on bus.*
>
> ***Class #6 – Bridges –*** *Types and technologies. Build a bridge – Exercises from "Engineering the City," West Point Bridge Designer.*

Class #7 – Airports – *History, technical design, future development, current Chicago airport situation. Trip to Waukegan Regional Airport*

Class #8 – Utilities – *Systems, history, technologies, current issues. Visit and presentation by representative of "Julie," utility location service. Classroom exercises on locating utilities in your neighborhood.*

Class #9 – Waterways –*Trip to Chicago and guided tour boat trip on the Chicago River. On the bus, discussion and videos of waterways, Chicago, etc.*

Class #10 – Team Exercises *– Students were assigned to one of six multi-age teams, and asked to respond to assignments including a serious highway crash, emergency infrastructure assistance to embattled Monrovia, and designs for an airport, theme park, neighborhood, and rail passenger station. Each team was required to provide a presentation of its results.*

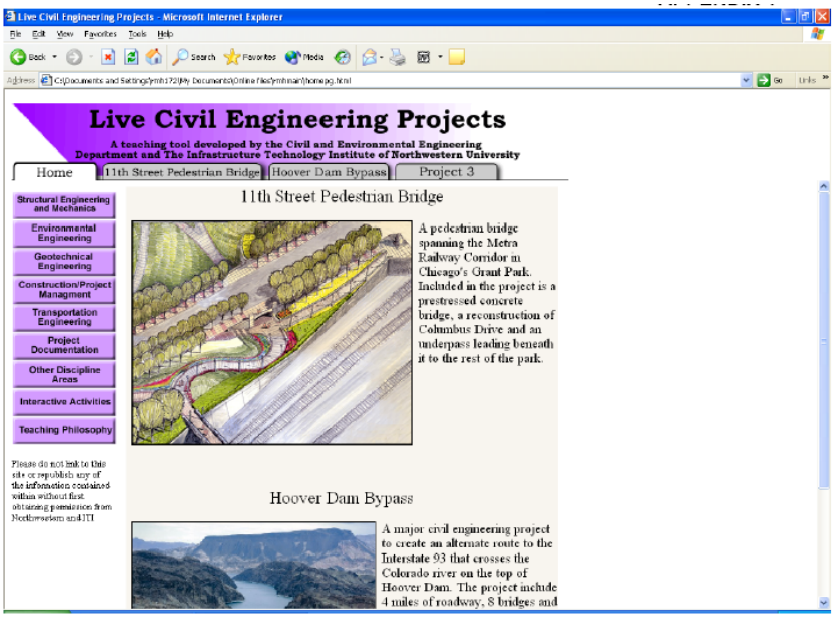
Institute Director Dave Schulz communicates to obviously-interested audience on the lower elementary CTA trip

The Institute staff, Infrastructure Knowledge Services, and the Country Meadows faculty are currently developing a CD-ROM to document the lessons learned and provide guidance to other schools and professional organizations who may be interested in developing similar or related programs.

Based on the success of the 2003 program, the Institute intends to re-offer a refined version of the program in 2004.

Success Story: Integrating Web Cam Images into Internet-Based Teaching. The project deals with the development of multimedia supported case-study material for undergraduate civil engineering courses, using the Infrastructure Construction and Condition Monitoring Laboratory (ICCML) of the Infrastructure Technology Institute, its web site and remotely operated web-cameras as novel teaching toos to enhance undergraduate education.

Teaching material (courseware) has been developed using the case study method and new technologies. The courseware is incorporated into a highly structured and expandable web site and deals with an in-depth analysis and presentation of the 11th Street Pedestrian Bridge, a project of the City of Chicago that has been recently completed at the south-west end of Grant Park. Real time view of the operations during construction has been made possible through a remotely-operated web camera that overlooked the construction site.



Internet-Based Teaching Web Site

Success Story: **Student of the Year**. The Institute was proud to name John WIrtz its 2003 UTC Student of the Year. John received his award at a ceremony sponsored by the Research and Special Programs Administration of US DOT at the annual meetings of the Transportation Research Board.

Success Story: Solar Powered Race Car. Institute Research Engineer Dan Hogan has over twenty-five years of experience as a prototype specialist and a welding researcher. Mr. Hogan provides consultations to the faculty and students who are designing the 2003 solar powered race

car. Mr. Hogan was able to outline the steps needed to fabricate and weld this complex space frame and meet the requirement that total distortion be no more than one millimeter. Mr. Hogan supervised the students who fabricated the individual components and Mr. Hogan welded the space frame. The frame is made of aircraft quality Chrome-Molly tubing. Mr. Hogan assisted faculty members and other staff in portions of the analysis and design. The finished frame weights forty-five pounds and can resist a 5-G side impact.

Dan Hogan welding solar race car frame

…enroll and graduate twenty students each year in the Infrastructure Management specialization in the Master's of Project Management program.

Success Story: Infrastructure Management Students. Eight students currently enrolled in the Master's in Project Management program are specializing in infrastructure management, an increase of one from the Year Three report.

…have a student profile enrolled in its curriculum which meets or exceeds the University-wide proportions of minorities and women enrolled in graduate programs.

The eight students currently enrolled include three white males, four minority males, and one minority female.

Success Stories: Research

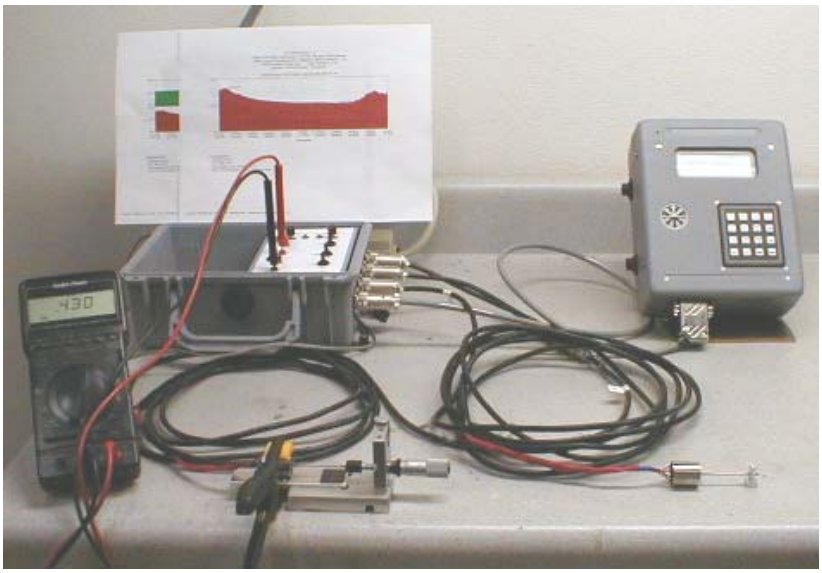
…at least maintain, if not expand, the number of technology areas actively being researched (breadth), while continuing to increase both the number of innovations and the amount of technical expertise in the technology areas being researched (depth).

have each principal investigator publish at least one peer-reviewed research report and present one paper annually based on Institute-supported research.

The Institute has prepared a report summarizing progress on all research projects funded under its TEA-21 funding during 2003. Rather than include that 62-page report either directly within this document, or as an appendix, it is posted on the Institute Web site:

http://www.iti.northwestern.edu/institute/research_report/2003_annual.pdf

Success Story: First-Ever Commercial Instrument for Autonomous Crack Monitoring: During the fall of 2003, researchers on the autonomous crack monitoring project installed and began a two-year test program of the first commercial instrument developed specifically for autonomous crack monitoring. GeoSonics of Warrendale, Pennsylvania, has produced the beta test model for validation under this project as GeoSonics also pursues additional validation.



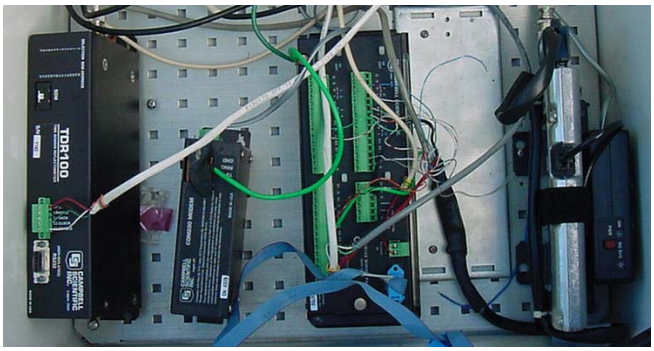
First-Ever Commercial Instrument for Autonomous Crack Monitoring

This parallel deployment scheme was utilized by Prof. Dowding under this project and GeoSonics to enable GeoSonics to maintain clear ownership of any independently developed hardware or software. The system of parallel codeployment has allowed significant synergism as GeoSonics and project researchers can trade experience without GeoSonics fear of issues of ownership of intellectual property.

Both systems have been installed in the test house, which has been loaned to the project by Vulcan Materials Company, another co-deployment partner. The test house is a significant research asset as it is close to Northwestern and it subjected to blasting vibrations. Construction of such a test structure and artificially subjecting it to vibration would be a prohibitively expensive proposition. Response of the GeoSonics system will be compared to that of the project-developed system.

Success Story: Design & Installation of Inexpensive Radio Communication for Florida Sink Hole Time-Domain Reflectometry (TDR) Demonstration Site

In the summer of 2003, continuous communication was established between the Northwestern University data polling computer and the previously-installed TDR-tiltmeter site on state road 66 near Sebring, Florida. This site has been chosen as a permanent demonstration site for both TDR instrumentation and autonomous monitoring of site data. The site was a pioneer in the autonomous monitoring and Internet-based display of data which led to the launch of the Computer Data Systems business.



Exterior and Interior of Equipment Installation, Sebring, FL

Communication was accomplished by 900 Mz radio connection to bridge site from a station hard wired to land line telephone. A radio based system was necessary in this location because of poor cellular connection. Poor

cellular phone communication is commonplace in the United States, because of both poor coverage at remote sites and the analog rather than digital nature of US cellular communication systems. Digital systems are necessary for reliable communication of data, since date requires far higher packet transfer success rates than does voice communication.

Engineers from the Institute upgraded the communications system at the TDR site in June of 2003. The original installation used a cellular telephone for transmitting data to our web server. The cellular signal proved to be unreliable. The nearest land line telephone connection to the site was over a quarter of a mile away. Extending the line would have been prohibitively expensive. ITI engineers developed a wireless solution using point to point spread spectrum data radios. A modem and data radio were installed on a pole off site where telephone service was available. Another data radio was installed at the main instrumentation site to complete the link. Both sites are completely powered by solar panels. This method of communications has proven to be very reliable and FLDOT is planning to install a similar system at a TDR site in the median of a divided highway in early 2004.

Success Story: Upgrading Nine-Year Old Remote Monitoring System on Michigan Street Bridge

The Michigan Street Bridge is a rolling bascule type moveable bridge located in downtown Sturgeon Bay Wisconsin. This 1930 vintage structure is one of only two active bridges providing access to the Northern Door County peninsula. The bridge serves as a vital physical and economic link to the city. Wisconsin Department of Transportation (WisDOT) inspections from 1994 to the present have documented the ongoing deterioration of the structure.

Rack and Pinion Support Structure,

Michigan Street Bridge, Sturgeon Bay, WI

The Institute has been continuously monitoring the condition of the bridge for WisDOT since 1995. The original monitoring system has worked well, but depended entirely on an engineer or technician periodically downloading the data. Recent advances in sensors and data acquisition technology combined with an increase in the number of remotely monitored sites maintained by the Institute prompted a proposal to WisDOT to upgrade the Michigan Street Bridge monitoring system in 2002.

This system with further 2003 upgrades is now operating with autonomous data acquisition. These upgrades include a new on site PC in order to take advantage of new data acquisition software. The most important sensor additions were the motor current probes and new strain gages on the underside of the racks of the rack and pinion drive system. These new sensors will be more indicative of overall changes in the structure. Since late July, the system has been automatically gathering data and sending it to the ITI web server for archiving and display. The Institute is now providing user-specified notification (email, pager, fax, etc) and complex data reduction techniques to the Michigan Street website.

Success Stories: Technology Transfer

… (1) double the number of visitors to the Institute Web site, (2) double the number of peer-reviewed papers on the Web site, (3) conduct a transportation infrastructure essay contest for pre-college students, involving 100 student entrants and/or other K-12 transportation infrastructure education initiatives, (4) conduct two meetings, one seminar, and one remote learning course annually, reaching 200 professionals, (5) develop a monthly Web site-based Institute newsletter, and (6) achieve an average of one successful research product deployment per funded project.

Success Story: Infrastructure Knowledge Services Program. The Infrastructure Knowledge Services Program (IKSP), managed and operated by the University Library and supported by the Institute, continued to improve the Institute web site in 2003, enhancing and expanding publications pages. In addition to managing and maintaining the Institute web site, IKSP designed and developed:

1) the web site supporting the symposium “Structural Engineering: Future Trends”, which was held on October 4, 2003 at Northwestern University;

2) web pages supporting and documenting the 2003 Summer Infrastructure Institute for high school students and teachers

http://www.iti.northwestern.edu/education/high_school_institute/2003/summer2003.html

3) web pages supporting the first nine-week summer infrastructure class for elementary school students

http://www.iti.northwestern.edu/education/elementary_school/index.htm

CD-ROMs containing presentations, course materials, field trip images, and video clips from the two summer classes are in development for distribution to class participants and interested parties. Work was also begun in developing a tool for teaching infrastructure to elementary school students. IKSP provided support to the civil engineering classes "Infrastructure Facilities and Systems" and "Public Infrastructure Management", identifying and making available to the students reference and course materials, and digital images of field trips, via the university's course management web site. IKSP responded to inquiries that were sent to the Institute from practitioners, students, and the public at large, monitored two listservs, and continued to perform infrastructure-related collection development within Northwestern University's library.

Success Story: **Midwest Bridge Inspection and Maintenance Consortium.** An Institute-supported organization of state bridge inspection and maintenance engineers, the consortium consists of members from California, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, New York, Ohio, Tennessee, Virginia, Wisconsin, and West Virginia.

The consortium held two successful meetings during 2003, a May meeting in Kansas City with over 50 attendees, and a December meeting in Nashville with 56.

The consortium has evolved to offer presentations and discussions on themed agendas with topics such as bridge management systems, inspection methodologies, repair methods, emergency response, among others. The most valuable benefit of the semiannual meetings is the opportunity for bridge practitioners to interact with one another, both during the meeting sessions, and informally during breaks and after the meetings. In addition, the consortium, which is managed by the Kentucky Transportation Center -- a state-university cooperative research venture -- has its own technology-sharing Web site.

Success Story: Launch of Civil Data Systems

For the last three years, recently-graduated NU student David Kosnik has worked with Prof. Charles Dowding on the time-domain refloctometry and

autonomous crack monitoring research projects. For the last twenty-four months, Dave and recent University of Illinois Graduate Matt Kotowsky have developed a family of applications to collect, process, archive, and display data from infrastructure remote-monitoring sites over the Internet. This innovative technology will allow infrastructure owners, consultants and contractors, and neighbors to obtain both real-time data on infrastructure facilities, but will also allow them to easily design customized data reports including graphs and charts, to optimize the use of the data.

Messrs. Kosnik and Kotowsky have decided to take this technology and use it to launch a company, Civil Data Systems (CDS):

http://www.civildata.com/demo.html

CDS offers infrastructure owners custom-designed services in data collection, processing, archiving, and display, relieving public agency staffs, who too often has neither the time not the technical training for this sort of information processing. In doing so, CDS will facilitate the more rapid and widespread adoption of remote monitoring as a standard part of the infrastructure engineer's "toolbox," since information processing is a major barrier to large-scale remote monitoring.

The Infrastructure Technology Institute is pleased to be helpful to these two young entrepreneurs in their business launch, through an innovative labor-sharing agreement whereby they each work half-time through the Institute as research engineers, and spend the other half of their time on their new business. The Institute is also providing CDS with office, clerical, equipment, and business planning support, in cooperation with Northwestern's Illinois Technology Enterprise Center.

Success Stories: Policy and Management

Success Story: Impacting the National Infrastructure Debate. In addition to his regular speaking schedule on infrastructure, Institute Director Dave Schulz found himself in demand from ABC News, National Public Radio, and other media outlets in the aftermath of the August 2003 East Coast power blackout. He was invited to write an op-ed piece for Newsday which appeared on August 18, 2003:

Whenever a bridge or dam collapses, a pipeline or water main fails, or the power grid "cascades," people ask, "How can this have happened?" Investigations are conducted, hearings held, people are fired or even criminally charged, while the survivors vow, "It will never happen again." But inevitably, it will happen again. Soon the power failure of Aug. 14 will be largely forgotten. Most Americans will go back to ignoring our physical infrastructure, as we have for a quarter century.

And unfortunately, the problems go beyond disasters to failures on some key missions. We suffer the consequences daily: traffic congestion, energy shortages, water pollution, and a less productive and competitive economy. In its 2001 infrastructure report card, the American Society of Civil Engineers found:

- *One-third of major roads in poor or mediocre shape;*
- *Some 29 percent of bridges deficient or functionally obsolete;*
- *Some 75 percent of school buildings inadequate;*
- *Annual investment shortfalls of $11 billion for drinking water and $12 billion for wastewater;*
- *Some 2,100 unsafe dams;*
- *A $38-billion navigable waterway-project backlog;*
- *More than 10,000 megawatts of new electric capacity needed annually until 2008, compared to the 7,000 added per year in*
- *the 1990s;*
- *And a total five-year infrastructure investment need of $1.3 trillion.*
- *It also reported, chillingly, "The nation's energy transmission infrastructure relies on older technology, raising questions of long-term reliability."*

How has the most powerful nation on Earth allowed the physical facilities on which it depends to come to such a sorry state? The sad answer: Too many Americans don't know or care about infrastructure. We simply don't understand or appreciate the essential enabling roles that roads, bridges, transit lines, railroads, airports, water and sewer systems, dams and waterways, and energy systems play in our economy and quality of life.

Plus, our ever-shortening political horizon - often not even the next election but the next poll - makes the long-range vision necessary for making needed investment almost unobtainable. The controversy over proposed wind-farming off Cape Cod dramatizes that NIMBYism (Not In My Backyard) is morphing into BANANAism (Build Almost Nothing Anywhere Near Anyone), which will ultimately head toward NOPEism (Not On Planet Earth). Overly complicated environmental reviews and other paperwork have killed projects, strained budgets and schedules of those that survive, and fueled litigiousness, further driving up costs and delays.

In effect, we've handed veto power over vital improvements - for roads, pipelines, power generating plants, transmission lines, airport expansions and others - to small minorities of opponents who can afford to hire enough lawyers long enough.

We in the business deserve blame, too. We didn't fairly mitigate the negative impacts of some projects, or adequately compensate those unavoidably impacted. We've been slow to adopt new technologies. With the rest of society, we haven't been able to halt or even slow suburban sprawl, which increased the demand for all infrastructure, while making building it more difficult. And we've failed to convince elected leaders and the public of the urgent need for more resources and more backbone to make needed investments.

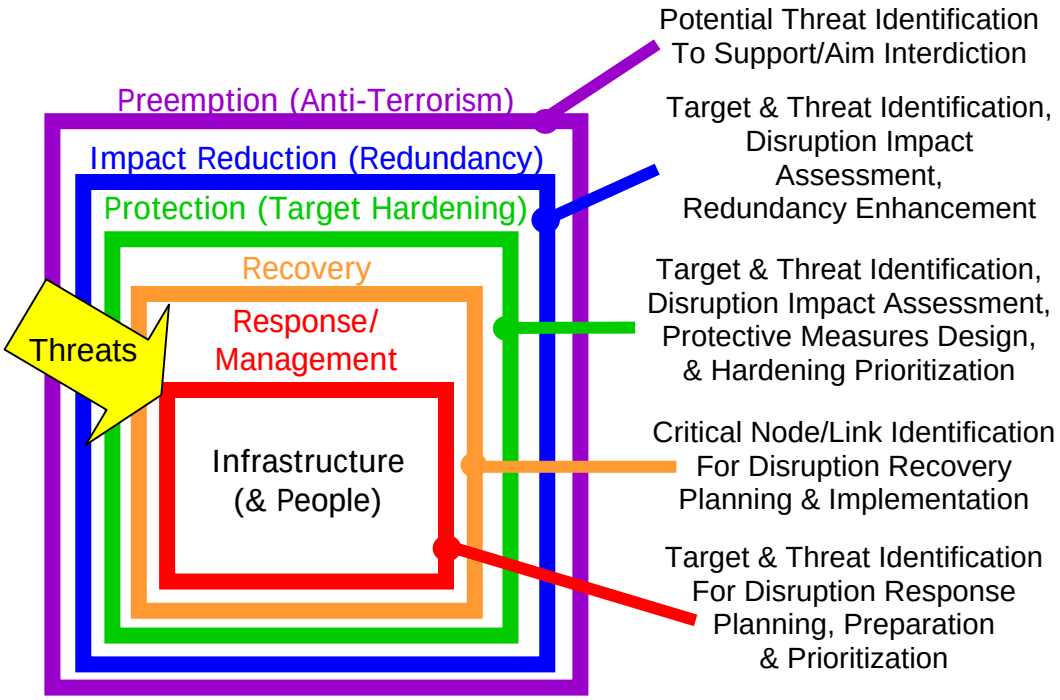
But if we draw the right lessons from Aug. 14 and other infrastructure failures, we can turn this dire situation around. Here's a Top 10 list of things we can do:

1. *Teach kids and ourselves about infrastructure's history and importance.*
2. *Educate infrastructure professionals to effectively use technologies of accelerating complexity.*
3. *Mitigate unavoidable negative impacts.*
4. *Use sustainable approaches where feasible.*
5. *Develop and deploy more innovative technologies.*
6. *Reach out beyond engineers to employ experts in finance, environment, urban planning, public relations, political science, management and law for powerful transdisciplinary teams.*
7. *Draw other interests into project development beside just NIMBYs. Plan infrastructure, realistically assessing needs, identifying projects and priorities, and sticking with them during the next budget crisis.*
8. *Streamline environmental and other reviews while preserving oversight and environmental protection.*
9. *Slow or halt sprawl, developing land in more infrastructure-efficient ways.*
10. *Dig deep to find the political will and the resources to build things again, not just replacing what we have but expanding to accommodate the growing economy and population.*

In his "Path between the Seas: The Creation of the Panama Canal, 1870-1914," David McCullough called the Panama Canal "a work of civilization." Infrastructure - public and private - is the most visible evidence of civilization, indispensable to its prosperity, essential to its very survival. Americans have always defined ourselves by infrastructure triumphs - plank roads, canals, railroads, elevated trains and subways, telephones

and electricity, highways, interstates and airports. By restoring infrastructure vision and capacities, we can, as President Theodore Roosevelt exhorted the Panama Canal- builders, "Make the dirt fly!" once again. And hopefully keep the lights on.

Success Story: Mitigating the Impacts of Disruptions of the Transportation System. Since September 11 there has been greatly heightened concern for the security of America's vital infrastructure systems. Efforts have been undertaken to identify possible measures for preventing infrastructure disruptions and dealing with them if they occur. Funds have been appropriated (not enough) to begin to attack the problem. And perhaps most importantly, planning for disruption management and prevention has increased dramatically, as has coordination among responsible agencies. Planning to mitigate the impact of terrorism-caused disruptions can be conceived of as occurring on five levels: incident response and management, recovery, protection, impact reduction, and preemption.



A Conception of Infrastructure Disruption Mitigation Planning

While the current concerns with disruption of infrastructure systems are spurred by threats of terrorism, engineers and others involved in planning and operation of transportation and other systems know that

transportation systems are routinely disrupted by traffic accidents, law enforcement actions, fires and hazardous materials situations, transportation equipment and facility failures, severe weather, and other acts of God.

This project is based on three observations. First, because of fragmentation of responsibility and authority, no one at a disruption site has transportation impact mitigation as her/his primary responsibility. Second, because of the same institutional fragmentation, system managers find it difficult to react quickly and aggressively enough to limit the scope and duration of disruption impacts. And third, when they do react, there is no pre-planned response akin to those used by fire and police agencies.

Building on these observations, the project is proceeding on three working hypotheses: First, prior agreement on transferring responsibility for mitigating transportation impacts of disruptions to a transportation agency, ideally a regional traffic control agency, once it is appreciated that the disruption exceed a defined threshold scale and duration would facilitate disruption impact mitigation. And second, pre-planning disruption mitigation actions and prior interorganizational agreements based on careful planning and coordination would further facilitate disruption mitigation response.

To date, a team has been assembled, a comprehensive state-of-the-art report has been started, preliminary meetings have begun with transportation agencies and emergency providers, and funding discussions have been ongoing with the Metropolitan Planning Organization for northeastern Illinois, the Chicago Area Transportation Study, and the University of Illinois-Chicago.

Success Stories: Industry Partners

Success Story: Miller Park Movable Roof Bearing Investigation. In 2003 engineers from the Institute conducted additional acoustic emission (AE) tests on components of the segmental moveable roof at the Miller Park baseball stadium, Milwaukee, Wisconsin, building on the work undertaken in 2002 which helped support a redesign of the roof segment pivot bearings. After the damaged pivot bearings were replaced with the new design over the winter of 2002/2003, three more tests were run on the moveable roof and its associated equipment. The roof segments are moved by electric locomotives, called “bogies”, attached to the outfield end of the stadium roof segments. These bogies have been emitting strange noises during use. The engineers working for the Miller Park authority were unable to identify the source or mechanism generating

these noises. The Institute team was invited to return and apply acoustic emission techniques to localize the noise source(s).

Acoustic Emission System Mounted on Roof Segment
Miller Park, Milwaukee, WI

Three roof segments were tested during two separate sessions. The need to monitor a large piece of machinery which rolls, rotates, and translates presented a unique AE challenge. The solution was to affix the entire AE system and one ITI engineer to the catwalk of the moving roof segment. A custom rotating interface was fabricated by Institute engineers to allow AE measurements on the rotating axle. They were able to successfully determine that the bearing/ housing area on either side of the idler wheel axle was the source of the noise. The bogies are scheduled to be completely replaced in order to address this and several other deficiencies. Their third visit to Miller Park was to record baseline acoustic emission readings on the newly installed pivot bearings. The baseline tests detected no AE, a marked improvement over the original bearings.

Conclusion: Center of Excellence

In conclusion, the Institute continued to make substantial strides in 2003 towards its goal of becoming a nationally recognized center of excellence for infrastructure technology. A year of research successes was highlighted by ongoing direct involvement in a problem with a unique segmented movable roof for a new stadium. Institute researchers continued to successfully deploy their results in a growing number of locations across the country, and at the same time enhanced their stature as leaders in a number of important infrastructure technology areas. The Institute's rebuilt Web site was rapidly evolving to take advantage of streaming video, Internet-based televideoconferencing, and other innovations. The Institute-supported Midwest Bridge Maintenance and

Inspection Technology Sharing Consortium continued to grow. And the Institute's management and policy studies efforts enjoyed great success as they examined and brought to public attention a number of important public policy issues including the interrelationship of sprawl and infrastructure problems, the growing difficulty of building large infrastructure projects in the United States, and development of improved means for mitigating the impacts of disruptions of the transportation system. Building on this success, the Institute looks forward to continued growth and achievement in 2004.

Part B – Research Projects

New Projects

A458, Safety Concrete – A New Impact-Absorbing Concrete for Protecting Buildings, Structures, & People, Prof Hamlin Jennings & Prof. Jeffrey Thomas, $101,524[1]

A461, Use of a Remote Web-Accessible Camera to Improve Undergraduate Education in Civil Engineering, Prof. Charles Dowding & Prof. Roberta Massabo, $55,901[1]

A468, Bridge Asset Management Based on Life-Cycle Cost Considerations, Prof. Raymond J. Krizek, $63,210[1]

Continuing Projects

A452, Life Cycle Management of Steel Bridges Based on Nondestructive Testing and Failure Analysis, Prof. Brian Moran and Prof. Jan Achenbach, No Year Four funding

A459, Ultrasonic Technique for In-situ Monitoring of the Setting, Hardening, and Strength Gain of Concrete, Prof. Surendra Shah, $146,875[1]

A460, Improved Condition Monitoring for Bridge Management, David Prine, $682,384[1]

A462, The Infrastructure Construction and Condition Monitoring Laboratory as a Novel Teaching Tool to Improve Undergraduate Education in Civil Engineering, Prof. Roberta Massabo, $89,301[1]

A463, Improved Condition Monitoring of Bridges: Nondestructive Evaluation of Foundations, Prof. Richard Finno, $174,149[1]

A464, Allowable Deformations of Gas Mains Adjacent to Deep Excavations, Prof. Richard Finno, $2,101,179[1]

A465, Commercialization of TDR Measurement of Soil Deformation in Support of Thrust in Remote Monitoring for Bridge Management, Prof. Charles Dowding, $242,386[1]

A466, Introducing Size Effect into Design Practice and Codes for Concrete Infrastructure, Prof. Zdenek Bazant, $88,113[1]

A467, Commercialization of Instrument for Micro-Inch Measurement of Crack Width in Support of Thrust in Remote Monitoring for Bridge Management, Prof. Charles Dowding, $333,651[1]

Note: [1] Budgets shown are Year Four funding including match.

Completed Projects

A428, Analysis of the Performance of the Rehabilitation of the Chicago-State Subway Station and Its Effects on Adjacent Structures, Prof. Richard Finno

A433, Evaluation of Capacity of Micropiles Embedded in Rock, Prof. Richard Finno

A454, Further Commercialization of NUCu Steels, Prof. Morris Fine and Dr. Semyon Vaynman