Intelligent Infrastructure Systems

How smarter buildings, self-monitored environmental systems, and better managed transportation flows will make for a safer, more efficient world.

A trillion dollars spent. That staggering expenditure, which any math major could tell you is a thousand billion, is, says Purdue’s Fred Mannering, what America spends a year on infrastructure—the construction, maintenance, and rehabilitation of the foundations that house and keep this country running.

It’s that trillion-dollar overhead that has Mannering, head of civil engineering and co-chair of the Intelligent Infrastructure Systems (IIS) signature area, so adamant about making infrastructure smarter. And why shouldn’t he be? We’ve witnessed the havoc of disasters, both natural and man-made, upon daily lives. And we too often know the perfect vision of hindsight during cleanup time. IIS seeks to proactively make security, self-monitoring, and emergency response plans part of the forethought of environmental, transportation, and structural systems.

“You can look, for example, at the failure of the World Trade Center during the September 11th terrorist attacks,” Mannering says. “If the World Trade Center had been monitored, a sensor system could have determined that a collapse, after the plane attacks, was imminent. Many more lives could have been saved.”

Intelligent Structural Systems, a subhead under IIS, incorporates the ideas behind self-diagnosing and even self-healing structures. In addition to wiring buildings for their own self-examinations, two other subheadings—Intelligent
Environmental Systems and Intelligent Transportation and Logistic Systems—will look to bolster those infrastructures. Chemical and biological sensors, for example, could ensure the safety of drinking water. When coupled with wireless technology, optimally placed sensors could immediately detect accidental and intentional releases of hazardous contaminants. Likewise, a smart transportation and logistics system will increase security while deftly managing day-to-day flows for both passenger and freight traffic.

With research experts pulled from practically every academic corner of the Schools of Engineering, including aeronautics and astronautics, chemical engineering, civil engineering, electrical and computer engineering, industrial engineering, mechanical engineering, and nuclear engineering, Purdue is positioning itself as a frontrunner in the IIS field.

“Work in these areas is interdisciplinary by its very nature, involving expertise found in many departments in the School of Science, as well as engineering,” says Jim Krogmeier, co-chair of the IIS signature area and a professor of electrical and computer engineering. “My own work involves the
application of information technology—particularly wireless communications and sensor signal processing—to the problems of IIS. This effort began with a small collaboration with civil engineers working in the transportation area and has grown with the support of the Joint Transportation Research Program and other agencies.”

On the environmental front, Q. Yan Chen, a professor in mechanical engineering, is looking to improve indoor air quality. Since the average American spends 90 percent of his or her time indoors, Chen knows that a nasty winter indoors, with various influenzas flying about a workplace and even the allergies and asthmas of the warmer months, can be quite costly to a company. With backing from industry and the National Institute of Health, Chen has constructed an environmental chamber in Purdue’s Herrick Laboratories to measure airflow patterns and the distribution of contaminant concentrations, air velocity, temperature, relative humidity, and air turbulence parameters. Chen’s findings will—in ten years’ time—likely revolutionize the circulation of airflow throughout business centers.

Back on the structural side, the Bowen Laboratory for Large-Scale Civil Engineering Research is providing a new research home for the interdisciplinary teams that will increase the IQs of next-generation buildings. “With 55,000 square feet of space, 14 faculty offices, three conference rooms, and space for 40 graduate students, this facility will be one of the largest and most advanced structural and materials testing facilities in the world,” says Mannering.

**Heating Up:** Q. Yan Chen (foreground), a professor in mechanical engineering, has constructed an environmental chamber in Purdue’s Herrick Laboratories. Shown here with Ph.D. student Jinsong Zhang, Chen believes most business centers will be circulating airflow from the floor up in ten years.
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“The Bowen Lab will allow us to take a national leadership role in emerging new areas in structural analysis and materials such as composite systems, auto-adaptive media, seismic response and behavior, structural modeling and system performance, experimental mechanics, nondestructive testing, advanced sensor development and application, multi-scale modeling, and the application of advances in nanotechnology for structural evaluation and monitoring.”

With its world-class facilities and call for the world’s elite researchers, Purdue is clearly committed to intelligent infrastructures. And the smart money, even a trillion dollars of it, says Purdue and the Schools of Engineering are a pretty good bet.

**View from Above:** Fred Mannering, the head of civil engineering, surveys the completion of the Bowen Laboratory for Large-Scale Civil Engineering Research. The facility, which opened officially in the fall of 2003, is one of the largest and most advanced structural and materials testing facilities in the world.

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*Processing Signals:* Electrical and computer engineering researchers lend a technical hand in the Joint Transportation Research Program. Tien-Chien Chen (left), a Ph.D. candidate, and Professor Jim Krogmeier apply wireless communications and sensor signal processing to the problems of traffic control.

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Taking a Signal from Nature

One evening in his West Lafayette home, Doug Adams, an assistant professor of mechanical engineering, spied outside his living room window that a rather large spider had spun a web in hopes of catching flying insects. At that instant, a Japanese beetle had become ensnared in the web and was struggling to free itself. Adams watched as the spider, which he later discovered was of the orb web variety, interrogated its web to detect and locate the beetle. The spider was able to find the beetle by plucking the web like a guitar string to transmit and sense waves that traveled outward towards the beetle and back again.

In their research, Adams and Shankar Sundararaman, a graduate student in mechanical engineering, have developed and successively applied a diagnostic technique similar to the spiders for interrogating heterogeneous structural systems like advanced military composite armor, rocket motor casings, and thermal protection systems in defense applications. By transmitting and then sensing propagating elastic waves, which are scattered by defects like cracks and delaminations through the material, Adams and Sundararaman have demonstrated that damage can be accurately detected and located. Their technique is based on beam-forming technology, which was originally developed in the communications industry to “look” in certain directions for signals that are corrupted by jamming interference from other directions.

“This technique is one of several that we are applying in tandem to interrogate complicated heterogeneous structures,” Adams says.