Traffic Laboratory

This fall, the Institute's ITS Laboratory enters a new phase of operations— with new capabilities and a new location in the University's Civil Engineering Building. The new traffic laboratory will focus on the specific requirements of traffic flow research, including the development of advanced data-gathering and signal-processing systems and support for the computer infrastructure needed for signal processing and traffic-flow modeling.

Along with its new location and new director, John Hourdos, the traffic laboratory will benefit from increased autonomy as an independent research program with its own steering committee. Hourdos's recent work with Professor Panos Michalopoulos on video-based traffic pattern monitoring resulted in the development of a powerful new data-gathering tool. Lab manager Ted Morris, who has worked closely with researchers and students for more than six years, will continue to manage the day-to-day operations of the facility. Professor Gary Davis of the Department of Civil Engineering will serve as principal investigator of the laboratory's ongoing research.

As an independent program, the traffic laboratory will be able to more actively pursue funding opportunities based on the needs of University of Minnesota researchers in a variety of academic departments and also work closely with clients outside the University, such as the Minnesota Department of Transportation.

Supporting education in traffic modeling and management will be one of the lab's core missions. Senior systems engineer Chen-Fu Liao will continue to develop and support the online simulation systems that have become a key element of the ITS Lab's operations in recent years. Liao works closely with faculty to create learning tools that help advanced students experiment and understand traffic patterns in complex road networks.

As part of the move to its new facilities, the traffic laboratory is exploring a range of potential enhancements to its
capacities in order to meet the changing needs of transportation researchers, Morris said. As more ITS projects are implemented nationwide, the new traffic laboratory will offer researchers and students a cutting-edge environment for experimentation and learning.

**Intelligent Vehicles Laboratory**

The Institute’s Intelligent Vehicles (IV) Laboratory focuses on developing and testing innovative, human-centered technologies that improve the operational safety, mobility, and productivity of vehicles. These human-centered technologies integrate sensors, actuators, computer processors, and custom human interfaces to provide drivers with needed information under difficult driving conditions (e.g., low visibility, severe weather, and narrow and congested roadways). Initially, these driver-assistive systems have been tested on specialty vehicles, including snowplows, patrol cars, ambulances, heavy vehicles, and transit vehicles. Ultimately, these systems will also be used on passenger vehicles, providing drivers with warnings and assistance with collision-avoidance and lane-keeping tasks.

The University of Minnesota is recognized as a leader in developing and testing driver-assistive systems and is one of a small number of universities nationwide conducting this work. The IV Laboratory’s core staff consists of engineering professionals who work closely with an interdisciplinary team of specialists, including cognitive psychologists specializing in human factors from the ITS Institute’s HumanFIRST Program. The IV Laboratory staff has developed expertise in wireless communications, embedded computing, visibility measurement and quantification, geospatial databases, virtual environments, image processing, driver-assistive technologies, control systems, and sensors.

IV Laboratory research seeks to increase driver safety in difficult driving conditions through the use of vehicle-guidance and collision-avoidance technologies. Several vehicles serve as experimental testbeds, including the SAFETRUCK (an International 9400 tractor-trailer), the SAFEPLLOW (an International 2540 crew-cab snowplow), a state highway patrol car, and the TechnoBus (a Metro Transit bus). Using these vehicles, IV Laboratory researchers are developing, testing, and integrating advanced technologies including

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**New civil engineering professor focuses on traffic management**

Henry Liu joined the Department of Civil Engineering as an assistant professor in 2005, bringing a strong focus on advanced traffic management techniques and ITS applications. Liu’s research interests complement the department’s growing capabilities in traffic analysis and management; he will also play a central role in the Institute’s new traffic laboratory.

One of Liu’s research interests is the design of effective traffic control systems for evacuating large areas in the event of natural or man-made disasters. Difficulties experienced during the recent hurricane evacuations in Louisiana and Texas serve as unpleasant reminders of the need for better evacuation systems. These extreme situations feature traffic behavior that is very different from the conventional operations for which road networks are designed.

Liu’s approach to real-time traffic control during evacuations incorporates information about current traffic conditions into an adaptive control strategy.

Liu has already attracted funding for new research to be carried out in cooperation with the traffic laboratory following its move from its current location in the Transportation and Safety Building to the Civil Engineering Building in fall 2006. Simulation and modeling systems housed in the lab will serve as a key resource for Liu and his graduate students as they seek to develop new control strategies. Liu is also working with Chen-Fu Liao, the traffic lab’s senior systems engineer, to develop online tools for teaching and interactive learning.
centimeter-level differential global positioning systems (DGPS); high-accuracy digital-mapping systems; range sensors, including radar and laser-based sensors; a windshield head-up display (HUD), a virtual mirror, and other graphical displays; and haptic and tactile feedback.

The IV Laboratory's lane-assist technology is unique in that it uses DGPS and does not require hardware in the roadway surface. The technology is transferable between various transportation modes and works in all low-visibility situations, including snow, fog, smoke, heavy rain, and darkness. In addition, these systems use human-centered technologies to enhance driving ability and reduce driver error due to distractions, fatigue, and other factors related to difficult driving situations.

Other difficult driving conditions are encountered by drivers on a daily basis. For instance, the vast majority of vehicle crashes occurring at rural, unsignalized intersections are the result of drivers incorrectly gauging the size of a gap between oncoming vehicles—not running stop signs.

The IV Lab has developed a sophisticated rural intersection data-collection system used to study how drivers waiting at a low-volume minor road enter or cross a high-speed, high-volume expressway. The data collected at the intersection is being used to model driver behavior to determine where the gap-acceptance decision process fails and leads to a crash, and to then design countermeasures to reduce the number of these crashes.

Additional research topics include the design and testing of custom human interfaces, collision-avoidance sensors and algorithms, and wireless communication among vehicles and with the infrastructure. The IV Laboratory’s partnership with the Minnesota Department of Transportation provides access to roads and other infrastructure, including the Minnesota Road Research Project (MnROAD) test track, which consists of a freeway and a low-volume road pavement test track with 40 different road material test sections, 4,500 electronic sensors, a weigh-in-motion scale, a weather station, and DGPS correction signals. The IV Laboratory

Intelligent Vehicles Lab enhances driver-assistive system with infrared vision

The Intelligent Vehicles Lab has deployed its driver-assistive system in a total of seven vehicles to date. The system is designed to help drivers operate in reduced-visibility conditions (such as severe snowstorms) by providing an electronic visual display of obstacles and road boundaries via a transparent head-up display (HUD) similar to that used by military pilots. Recent work by research associate Pi-Ming Cheng and IV Lab director Craig Shankwitz aims to improve these sensing and display systems by incorporating images from an infrared camera into the HUD.

According to the researchers, the system has proven particularly effective for snowplow drivers, who must sometimes operate in white-out conditions caused by blowing and drifting snow, which makes it difficult to see land boundaries, cars, or other obstacles. As deployed, the system uses high-accuracy digital maps combined with onboard radar sensors to create an accurate picture of what’s going on outside the vehicle.

Although radar has proven effective in finding exactly where obstacles are in relation to the HUD-equipped vehicle, objects detected by radar can only be displayed as square “targets,” making it difficult for the user to determine what is being tracked. Infrared sensors, by contrast, are better at showing what objects look like but are unable to determine exact locations.

As developed by the IV Lab, images from an infrared camera are processed by machine-vision algorithms to extract features of interest—moving objects or other potential obstacles. Visual information about these features, such as their shapes, is then combined with information from a radar sensor to create a more useful display for the driver. Combining radar and infrared sensors offers definite advantages for driver-assistive systems. However, persuading the two very different types of sensors to cooperate is a considerable challenge. The images produced by the infrared camera must be mathematically processed to match the resolution and apparent perspective of the HUD and the existing radar system. Computer-vision techniques are also required to extract features of interest—such as vehicles and persons—from the camera data. Finally, the display system must provide relevant information to the driver in a reliable and intuitive format.

The integration of infrared and radar data has been linked to improvements in the basic software architecture of the IV Lab’s driver-assistive system. These changes will make it easier for the development team to integrate data from different types of sensors and improve the overall performance of the system.
also has relationships with a number of other organizations and government agencies, including the U.S. Department of Transportation’s Research and Innovative Technology Administration, Federal Highway Administration, and Federal Transit Administration; Twin Cities’ Metro Transit; Minnesota’s Local Road Research Board; and various counties. These partnerships provide additional support for implementing research that will influence transportation safety in the United States and around the world.

**Human Factors Interdisciplinary Research in Simulation and Transportation**

The mission of the Human Factors Interdisciplinary Research in Simulation and Transportation (HumanFIRST) Program is to apply human factors principles in order to understand driver behavior and support the design and evaluation of usable intelligent transportation systems. As implied by its name, the program’s research strategy is based on a driver-centered approach, considering the “human first” within the transportation system.

The HumanFIRST Program has a core staff of transportation research specialists made up of psychologists and engineers who provide a consistently available base of expertise. This core group is linked to a broad interdisciplinary network of experts in basic and applied sciences throughout the University to provide a flexible and comprehensive research capacity. This network is supported by affiliations with additional University research units, which allows the program

**Intersection research to help drivers gauge the gap**

Intersections make up only a small part of the U.S. highway network, yet intersection crashes account for more than 40 percent of all vehicle crashes annually. Specifically, many crashes at unsignalized rural intersections are attributable to errors made by drivers entering the main highway. To address this problem, researchers from the HumanFIRST Program, in conjunction with the Institute’s Intelligent Vehicles Laboratory, are working on an innovative approach to decrease the occurrence of such crashes using advanced technologies that minimize driver error.

Although some rural intersections employ traffic lights to indicate when drivers can “go,” most use stop signs instead as the only means of traffic control. In this case, drivers have to decide for themselves when it is safe to proceed. Researchers are now studying intersection decision support (IDS) systems that are specifically developed to handle stop-controlled intersections where the driver on the minor road has the stop sign and the driver on the major road continues through the intersection. The idea is to provide stopped drivers with better information about vehicles approaching the intersection, which leads to better decision making, fewer driver mistakes, and ultimately, fewer crashes.

At the heart of this study is a virtual-reality, wrap-around driving simulator that enables researchers to test multiple IDS interface configurations in a safe yet relatively realistic environment. By simulating a wide range of traffic and weather conditions during both day and night, the scientists can get test subjects to generally behave as they would if driving on a real road. This in turn yields much more credible and reliable data.

In a recent simulator test, researchers created an exact replica of a rural Minnesota intersection deemed to be particularly dangerous. Because different age groups have crashes at intersections for different reasons, these scientists studied two groups: drivers aged 20 to 40 years old and those aged 55 to 75. During a series of experiments, test subjects “drove” up to the intersection as the simulated traffic passed them, leaving different-sized gaps. A dynamic sign provided the driver with information about the size of the gap, and from that information, the test subject determined if it was safe to pull out into the intersection or not.

In this first round of testing, the team analyzed the usability of four different sign prototypes and now has a better idea of which designs work best. From here, researchers will narrow the options to two or three, tweak the designs as needed, and head back to the simulator to test them again. Although real-world field testing is still a few years away, these simulated experiments go a long way in helping this team develop effective methods that will one day greatly improve intersection safety.
ITS Institute Labs and Facilities

to create responsive interdisciplinary teams to investigate a range of complex human factors research issues in transportation safety. The program also has close relationships with the Minnesota Departments of Transportation and Public Safety, private industry, traffic engineering consultants, and other related entities. These connections provide support for implementing research that will influence transportation policy in response to real-world problems both regionally and nationally. In addition, to ensure that research takes into account developments on the world stage, the program’s work is supported by international collaborations with experts in relevant disciplines.

Research in the HumanFIRST Program seeks to propose, design, and evaluate innovative methods to improve transportation safety based on a scientific understanding of driver performance and the psychological processes associated with traffic crashes. This research considers how a driver will accept and use a proposed system, while also considering the possibility of its producing undesirable driver responses and adaptation (e.g., distraction, complacency, fatigue, risk taking) that could undermine the system goal of improved safety. Recent research topics include:

- driver distraction from in-vehicle tasks and cell phones
- rural and urban driver attitudes and crash risk
- interventions for crash reduction at rural intersections
- bus rapid transit using dedicated narrow shoulders
- intelligent driver-support systems such as vision-enhancement, collision-avoidance, hazard-awareness, and lane-keeping systems for passenger and specialty-purpose vehicles
- alcohol impairment
- attention-deficit/hyperactivity disorder and novice drivers
- in-vehicle use of advanced traveler information systems

The facility includes equipment for basic research on driver psychological functioning including a vision tester, DOT-certified alcohol Breathalyzer, mobile psychophysiology recording system, mobile eye-tracking system, video editing and behavior analysis suite, and a comprehensive

Solar/Wind Integrated Renewable Light Pole

Recent advances in sensing, communication, and computing technologies have produced a wide range of intelligent transportation systems (ITS) and related devices that could directly improve traffic safety and efficiency in rural areas. As beneficial as these new ITS technologies are, however, the lack of an easily accessible power source and the high cost of bringing electric power to remote rural areas has made deployment of such systems economically unjustifiable to most transportation agencies.

A group of NATSRL researchers, led by Taek Kwon of the electrical and computer engineering department, has developed a prototype renewable power station using a hybrid technology that integrates a small wind turbine and a photovoltaic (PV) solar panel. Unlike conventional PV-only based technologies, this new system generates electricity under all weather conditions, sunny or not. In winter, northern regions tend to have stronger winds and shorter, cloudier days. By supplementing the solar power with wind, this system solves the problem of significantly reduced daylight hours, which previously impeded the performance of the PV panels.

The prototype power station, which is being tested at the Mn/DOT District 1 maintenance area in Duluth, has been successfully operating a street light using only the natural solar and wind resources since the summer of 2005. The solar- and wind-generated electric power is stored in a battery bank and is sufficient to operate the lighting system for approximately 10 days without charging. Kwon’s team is further testing this technology for use with remote variable message signs (VMS) and traffic signals.

Taek Kwon. Inset: The solar/wind integrated light pole.
psychometric test battery validated for traffic psychology.

Much of the research of the HumanFIRST Program uses a state-of-the-art driving simulator (supplied by AutoSIM and OKTAL) engineered specifically for human factors research in surface transportation. This Virtual Environment for Surface Transportation Research (VESTR) is a versatile and realistic simulation environment linked to a full-cab SC2 vehicle donated by Saturn using software that can create virtual environments that precisely reproduce any geospecific location. In addition, specialized visual-effect software can produce realistic weather and lighting—including light and shadow that correspond with season and time of day—as well as vehicle headlights with nighttime glare and water reflections.

The visual environment is generated with high-resolution images (2.5 arcmin per pixel) over a wide field of view (210-degree forward, 50-degree rear, 2 by 20-degree side mirror images). This immersive driving experience is enhanced by realistic motion generated by a three-axis motion base and both high- and low-frequency vibration units, including a surround-sound system. With multiple sound systems, configurable touch panel displays (including head-up displays), haptic feedback through the seat and accelerator pedal, and a head-free eye-tracker that can detect in real time what a driver is looking at, this simulator supports the investigation of a wide range of interface options for ITS development, design, and assessment. These features make VESTR one of the premier driving simulators in North America and Europe.

To support the validity of HumanFIRST research, the program has access to a variety of closed test tracks and road network field sites for on-road studies with instrumented vehicles.

**Northland Advanced Transportation Systems Research Laboratories**

The Northland Advanced Transportation Systems Research Laboratories (NATSRL) is located at the University of Minnesota Duluth. Its mission is to study comprehensive winter transportation systems and the transportation needs of cities in small urban areas. To accomplish this, NATSRL collaborates with the Minnesota Department of Transportation, city and county engineers, and other agencies on research that covers a wide range of topics, such as optical and electronic traffic and road sensors, transportation data management, and benchmarking of transportation infrastructure.

NATSRL’s current laboratories are the Advanced Sensor Research Laboratory, the Transportation Data Research Laboratory, and the Transportation Engineering Research Laboratory. The Advanced Sensor Research Laboratory tests advanced sensing technologies for pavement and road conditions (speed, weather impact, and traffic density), researches the development of new techniques to detect incidents and abnormal traffic conditions, and analyzes real-world and real-time measurements of road, weather, and traffic information. The Transportation Data Research Laboratory has developed a statewide traffic data archival and analysis system that is used by Mn/DOT for long-range planning and the development of strategic traffic management plans, and continues research in the improvement of data integrity retrieved from the road sensors. The Transportation Engineering Research Laboratory is developing, in conjunction with Mn/DOT, an automated inventory management system for transportation infrastructure and the design of efficient management practices through benchmarking state DOT procedures.

Other NATSRL projects include development of a traffic counter for low-volume roads and student development of software tools to manage large volumes of transportation-related data.

In addition, NATSRL partners with Mn/DOT District 1 each year to provide a day-long formal presentation of ongoing research efforts.