The mission of the Human Factors Interdisciplinary Research in Simulation and Transportation (HumanFIRST) Program is to apply human factors principles 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 well-established base of content 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 to create 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

Research assistant Danny Drew driving in the HumanFIRST simulator while wearing a psychophysiological data recording cap
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
- intelligent driver-support systems such as vision-enhancement, collision-avoidance, hazard-awareness, and lane-keeping systems for passenger and specialty-purpose vehicles
- alcohol impairment including motorcycle safety
- intelligent driver-support systems for novice teen drivers

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 psychometric test battery validated for traffic psychology.

Much of the research of the HumanFIRST Program uses a state-of-the-art driving simulator engineered specifically for human factors research in surface transportation. This versatile simulator consists of a full-cab

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**Technology lends a hand at rural intersections**

Rural expressway intersections pose a significant hazard for Minnesota drivers. At this type of intersection, a small road crosses a larger, multi-lane expressway and the only traffic control device available to drivers is a stop sign. This means drivers at the stop sign must judge gap sizes in fast-moving traffic to ensure the gap they select provides enough time to cross the intersection or enter the traffic flow without causing a crash. This task is difficult for many drivers, particularly when traffic speeds are high.

The ITS Institute developed a dynamic traffic sign that displays information to drivers about gaps in traffic that may make it unsafe for the driver to enter. The HumanFIRST Program then designed and evaluated several dynamic sign displays that could be erected at intersections to aid drivers in making crossing decisions. The goal was to develop a sign that intuitively displayed information about unsafe gaps.

The dynamic sign receives information about approaching traffic from a sensor network located at the intersection that incorporates multiple radar units. The sign depicts a diagram of the intersection, similar to a “divided highway” sign. When an approaching vehicle on the main road is detected within an unsafe gap size, a red box and “do not cross” symbol are displayed for the lanes in which the vehicle is detected. This means it is dangerous for a driver to attempt to enter or cross the intersection because the approaching vehicle is too close and a conflict or crash could occur. When a vehicle is detected by the system but is outside the unsafe gap, a yellow box is displayed on the sign. In this case, the sign warns the driver of approaching traffic, but the decision rests with the driver about whether she or he will use that gap. When no traffic is detected, the sign is blank and it is up to the driver to scan the roadway for approaching traffic and determine if it is safe to enter or cross.

Testing first took place in a driving simulator to assess the effectiveness of the designs and determine the best display to be deployed at the Minnesota test intersection. Further testing at the intersection using an instrumented vehicle supported the results of the simulator study. The results of both studies showed that drivers selected fewer unsafe gaps in traffic when the sign was present. Additionally, no unintended consequences occurred while using the sign.

In the future, a field study will be conducted using Minnesota drivers who live near the test intersection to determine how they behave when using the sign over a longer time period. The hope is that it will improve their ability to avoid unsafe gaps and lead to a reduction in crashes.

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*An instrumented vehicle approaching the test intersection*

**The display showing it would be dangerous to enter the intersection**
Saturn SC2 vehicle and software capable of creating 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 (1.97 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 it one of the premier driving simulators in North America and Europe.

The HumanFirst Program will also have full access to a new bus driving simulator installed the summer of 2009 at the Minnesota Valley Transit Authority garage, where program staff will be able to test and evaluate research and driver training protocols.

Additionally, 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.
Transportation agencies must balance the need for highway construction with public concerns about congestion, delay, and work-zone safety. Full-road closure is one possible way of balancing these conflicting needs. In the Minnesota Traffic Observatory (MTO), researcher John Hourdos, who directs the MTO, and Gary Davis, a professor of civil engineering, evaluated traffic operations and extracted performance measures for partial-closure construction and full-road-closure construction alternatives for a section of Trunk Highway 36 (TH-36) in North St. Paul.

Their study went beyond the usual cost-benefit analysis because it included the cost of the additional time and fuel imposed on road users during the closure. This road use cost (RUC) is usually ignored by planners since, for traditional construction methodologies, the difference between alternatives is small. However, in the case of TH-36, the 20-month difference between a four-month full closure and a 24-month partial closure meant that the RUC was potentially important.

RUC can be calculated in three ways. The first, using algebra and a lot of assumptions, is easy, fast, but often inaccurate, Hourdos says. The second, using travel demand modeling, can also be inaccurate if the models were not specifically calibrated for the relatively small area of the construction project. The third, traffic simulation, can be very accurate but also very time consuming and costly. It also requires data that may not always be available.

“We wanted to see if we could estimate the RUC for the TH-36 project through simulation, and if we could, whether the results would be worth the expense,” says Hourdos. The simulation that he and Davis built aimed at capturing the impact of the TH-36 full closure on the surrounding areas. To achieve this, the model covers approximately one-quarter of the Twin Cities metro area, from I-35W in the west to the Wisconsin border in the east, and from I-94 in the south to I-694 in the north. It is the largest model built to date in Minnesota.

To create the model, the researchers used the AIMSUM traffic microsimulator and entered origin/destination demand data generated by the Metropolitan Council and intersection control information supplied by Mn/DOT and Ramsey County. The model was calibrated with the help of volume and speed data from Mn/DOT’s freeway loop detectors and temporary tube counts collected on the streets of North St. Paul before, during, and after the construction on TH-36.

In the end, the model confirmed that a partial closure would have been more expensive than the full-closure method that was used. The researchers’ goal is to create guidelines that will enable transportation professionals to calculate RUC using a method that meets their specific need in a way that is both cost-effective and accurate.
are critical. In addition to a large projection wall, two innovative pieces of equipment provide researchers with powerful interactive visualization capabilities.

The GIS/MAP table combines the large horizontal working surface of a traditional drafting table with the interactive capabilities of geographic information systems technology. Two ceiling-mounted digital projectors create a seamless image covering the entire conference-table-sized surface, which can be manipulated using a tabletop pointing device to pan and zoom in on specific areas. In contrast to traditional ways of viewing digital maps and models on a desktop monitor, the table allows users to comfortably survey the entirety of a large traffic system and quickly focus in on areas of interest.

The Digital Environment, or DEN, takes a different approach—putting viewers in the center of the action via three-dimensional immersive graphics. Three sides of the cubical structure are formed by large rear-projection screens presenting polarized images from two slightly different sources; a user wearing specially designed glasses sees a different image with each eye, producing a realistic sense of three-dimensional space. A tracking system mounted in the DEN’s ceiling monitors the position of the user’s head and adjusts each projector to provide an accurate perspective.

Intelligent Vehicles Laboratory

The Institute’s Intelligent Vehicles Laboratory (IV Lab) develops and tests innovative, human-centered technologies that improve the operational safety, mobility, and productivity of the transportation network in general, and highway vehicles in particular. These human-centered technologies integrate sensors, actuators, computer processors, and custom human interfaces to provide drivers with needed information under difficult driving conditions such as low visibility, severe weather, and narrow and congested roadways.

Although the IV Lab is focused primarily on vehicles, it also considers the roadway, supporting infrastructure, and electronic wireless communication as part of the transportation network and uses all of these elements in generating solutions to transportation problems.

Driver-assist systems developed by the IV Lab 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. Numerous vehicles utilizing IV Lab driver-assist technologies have been deployed in both Minnesota and Alaska.

The University of Minnesota is recognized as a leader in developing and testing driver-assist systems and is one of a small number of universities nationwide conducting this work. The core staff of the IV Lab 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 staff has developed expertise in wireless communications, embedded computing, visibility measurement and quantification, geospatial databases, virtual environments, image processing, driver-assist technologies, control systems, and sensors.

IV Lab 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: the SAFETRUCK (an International 9400 tractor-trailer), the SAFEPLOW (an
International 2540 crew-cab snowplow), a state highway patrol car, and a Minnesota Valley Transit Authority (MVTA) bus. Using these vehicles, IV Lab researchers are developing, testing, and integrating advanced technologies including 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 Lab lane-assistive 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 technology.

The Intelligent Vehicles Laboratory (IV Lab) is getting ready to put a new spin on public transportation in the Twin Cities. In 2010, a fleet of 10 buses equipped with advanced driver-assist technologies is scheduled to begin offering bus rapid transit (BRT) service on one of the area’s most important commuter routes, the I-35W/Cedar Avenue corridor linking downtown Minneapolis to the southeastern suburbs.

The project is part of Minnesota’s efforts to improve the performance of its transportation system under the U.S. Department of Transportation’s Urban Partnership Agreement (UPA) program. In June 2008, the federal agency selected Minnesota to receive $133.5 million under the program to fund a variety of innovative congestion reduction measures along the corridor. (The University of Minnesota’s portion of this funding is $4.3 million.)

BRT uses transit buses to provide the kind of fast commuter service usually associated with rail transit systems. Because it does not require the construction of rail lines or other specialized facilities, BRT is cost-effective and relatively easy to implement, making it a good option for rapidly improving commuter transit service, says ITS Institute director Max Donath.

The IV Lab has been working with BRT since 2002, when lab director Craig Shankwitz and Donath saw an opportunity to use driver-assist technologies to improve transit service. The result was a successful multiyear collaboration with Metro Transit, the Twin Cities’ primary transit agency.

Keeping track of a bus’s position to within a few centimeters over the entire route is one of the most significant technical challenges of the project. In addition to requiring extremely high accuracy—far beyond the capabilities of the satellite navigation units in new cars—the system must avoid losing track of its position even when the signals from GPS satellites are temporarily interrupted by bridges, buildings, and other obstacles along the route.

To improve the robustness of GPS positioning, IV Lab researchers developed a system that combines laser range sensors (lidar) mounted on the vehicle with radio-frequency identification (RFID) tags located along the road. A lidar sensor monitors the vehicle’s lateral position relative to a curb or barrier, while RFID is used to track longitudinal position along the route. An RFID reader mounted on the bus activates passive RFID tags as the bus passes, causing each tag to transmit its exact linear position along the route. An onboard computer combines the data from the RFID and lidar sensors and updates its internal estimate of the vehicle’s position whenever it determines that the position provided by the GPS system is not up to date.

In keeping with the ITS Institute’s “human-centered technology” approach, the driver-assist system of the new BRT vehicles surrounds bus operators with a suite of tools designed to make their jobs easier and safer. The driver interface, the product of collaboration between IV Lab engineers and human factors researchers from the HumanFIRST Program, employs both visual and haptic (touch-based) modes to allow the driver to understand safety-critical information quickly and intuitively.

For the commuters who rely on BRT service to get them to and from work every day, the biggest benefits of the new technologies will be improved schedule adherence and a better overall riding experience. By making it possible for bus operators to use shoulder lanes under a wider range of conditions, buses equipped with the IV Lab’s driver-assist technologies will be able to avoid delays associated with traffic congestion and provide a service with many of the scheduling advantages of light-rail transit systems.

High-tech buses tackle Twin Cities congestion

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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 example, 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. This test intersection is located at the junction of U.S. 52 and Goodhue County Road 9 near Cannon Falls, Minnesota. The data collected at the intersection were used to model driver behavior to determine where the human gap-acceptance decision process fails and leads to a crash, and then used to design effective countermeasures.

Because safety systems can produce improvements only if they are deployed, the IV Lab works with a variety of states to collect data and evaluate system performance. Four vehicles with driver-assist technology have been deployed in Alaska, where high snowfall rates and dry, blowing snow routinely cause whiteout conditions and zero visibility. Because of its success with the IV Lab, the state of Alaska has ordered three new driver-assist systems and two upgrade kits for its systems that operate in Valdez. The kits will provide new computation capability not provided by the current computers.

The Minnesota Mobile Intersection Surveillance System (MMISS) has collected driver behavior at rural expressway through-stop intersections in Wisconsin, Iowa, Michigan, North Carolina, Georgia, Nevada, and California. Data collection in a broad array of states will ensure a nationally deployable intersection safety system designed to save lives among rural drivers. This technology is also being deployed at a rural expressway intersection (U.S. 53 and County 77 in Minong, Wis.) through the USDOT’s Rural Safety Improvement Program (RSIP). This represents yet another out-of-state-deployment of IV Lab technology.

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 Lab’s partnership with Mn/DOT 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 Lab also has relationships with a number of other organizations and government agencies—among them, the USDOT’s Research and Innovative Technology Administration, Federal Highway Administration, and Federal Transit Administration; Twin Cities’ Metro Transit; the Minnesota Valley Transit Authority; 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.

**Northland Advanced Transportation Systems Research Laboratories**

The Northland Advanced Transportation Systems Research Laboratories (NATSRL), founded in 2000, form an advanced research program located at the University of Minnesota Duluth. Its mission is to develop innovative ITS technologies that can make surface transportation systems in northern areas safe, efficient, reliable, and environmentally sound.

Since its inception, NATSRL has been
According to the National Highway Traffic Safety Administration, drowsy drivers cause about 100,000 crashes every year, resulting in about 1,500 fatalities as well as 71,000 non-fatal injuries and $12.5 billion in damages.

Researchers at the University of Minnesota Duluth are trying to reduce these numbers. Xun Yu, assistant professor of mechanical and industrial engineering, is developing a low-cost sensor to detect drowsiness by measuring the electrical activity of the driver’s heart. He estimates that the final detection system would cost about $100 per vehicle, making it initially attractive to large companies and commercial fleet operators.

Yu, along with graduate student Shan Hu and undergraduate Ryan Bowlds, is using measurement techniques developed for electrocardiograms (ECG), which record electrical waves generated during heart activity. ECGs usually require electrodes to be placed on the head or chest, something that is not practical for drivers. To overcome this difficulty, the research team is examining two methods of measuring electrocardiac activity in the driver’s hands.

The first method involves wrapping each half of the steering wheel with special fabric that conducts electricity. The fabric acts as an electrode, picking up the electrical impulses of the heart as monitored in the hands and transmitting them to an onboard computer for analysis. This method is effective, but only when the driver is bare-handed and keeps both hands on the steering wheel.

The second method consists of installing piezoelectrical film around the inner circle of the steering wheel. The pumping action of blood flowing through the driver’s hands—which is related to the heart beat—causes the film to vibrate, and the vibration creates an electrical signal that can be analyzed by a computer. This method works for drivers who steer with one hand on the wheel, but like the first method, is effective only when hands remain bare.

In the next phase of their work, the researchers will improve the stability of the sensors, which are sensitive to vehicle vibration. They will also conduct large-scale tests to determine whether the sensors can detect drowsiness for most drivers, including those whose heart-rate patterns have slight variations. And they will decide how best to rouse drowsy drivers, Yu says, possibly by using sound or steering wheel vibration.

Xun Yu and Shan Hu demonstrate their system to detect driver drowsiness.