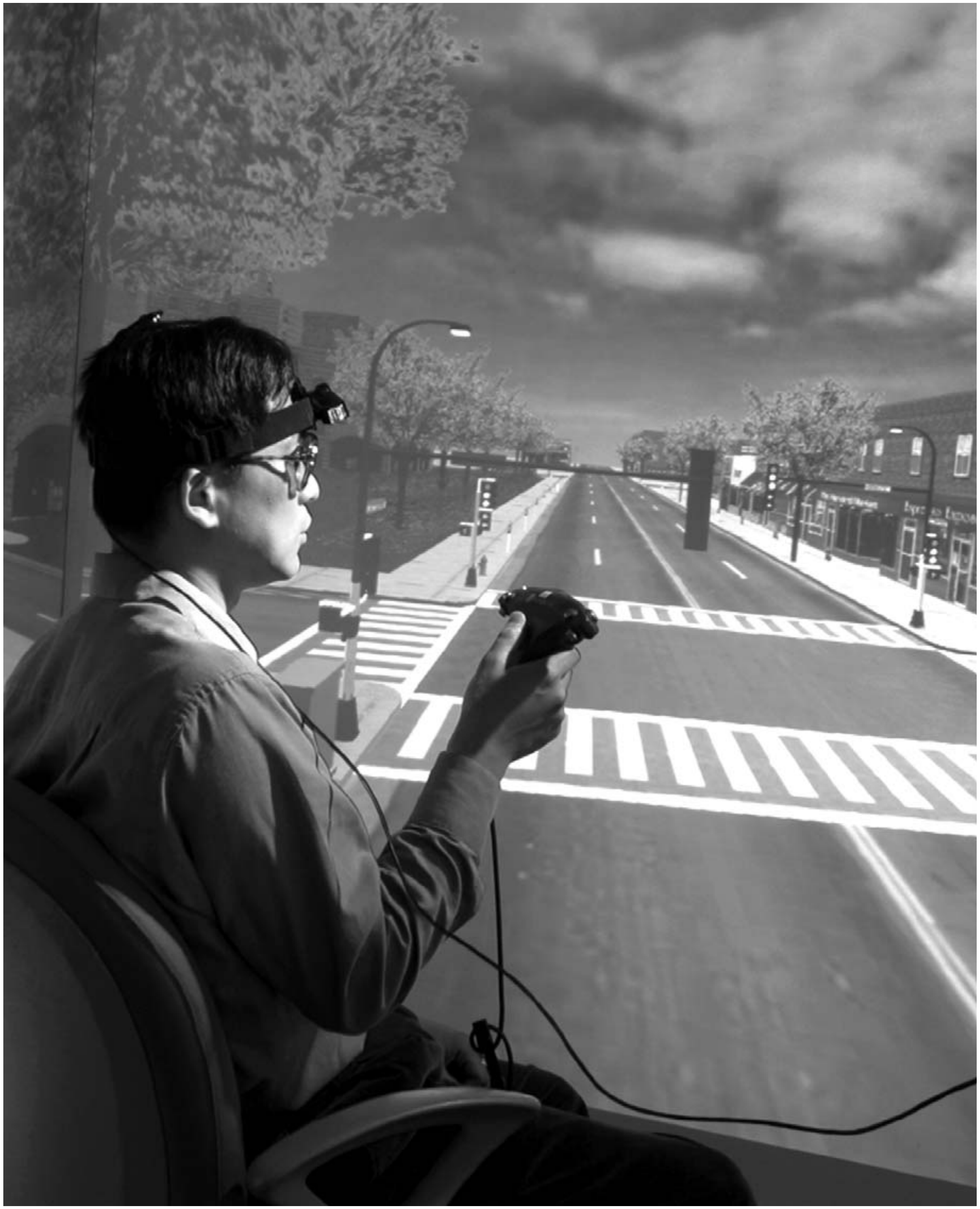


ITS Laboratory

The Intelligent Transportation Systems Laboratory is a dedicated facility supporting ITS research and education. The lab's mission is to develop or provide state-of-the-art resources for researchers, students, and collaborators pursuing research in ITS.

Focused on supporting research in surveillance, monitoring, and management of traffic systems, the ITS Laboratory works in partnership with other University of Minnesota research facilities including the HumanFIRST Program and the Intelligent Vehicles Laboratory to enable a full spectrum of ITS research.

The lab's facilities are used by faculty and students in civil, mechanical, and electrical engineering, computer science, and affiliated disciplines. Additionally, the lab hosts training events.

The ITS Laboratory has developed several generations of data-gathering systems to meet the needs of researchers working on freeway traffic-flow issues. The most recent of these is the Beholder system, a fully independent network of video detectors providing space- and time-continuous coverage of the I-35W/I-94 Commons freeway area in Minneapolis.

The system expands on the pioneering Autoscope™ system, originally developed at the University of Minnesota and now in commercial use. Beholder's portable monitoring stations are currently deployed on the roofs of several high-rise buildings overlooking the freeway, and transmit data back to the lab via a high-speed IEEE 802.16 wireless network.

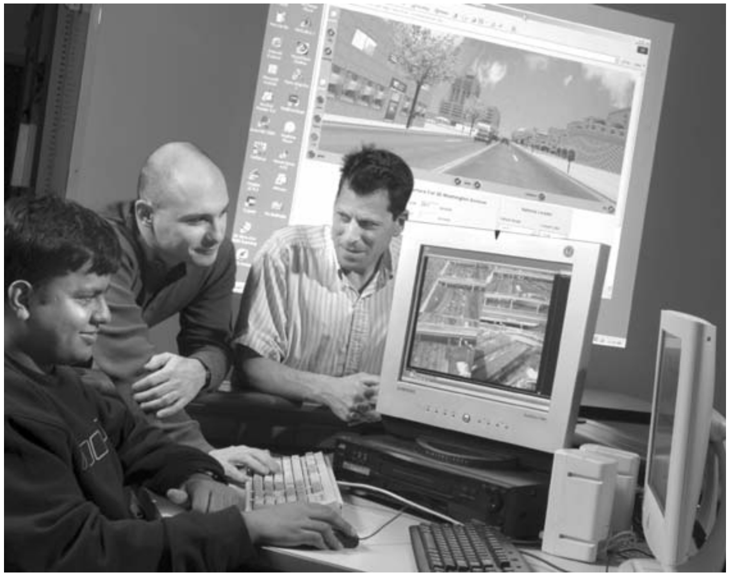
Besides the data provided by the Beholder system, the lab is supplied with eight switchable compressed/streamed Internet video feeds by the Minnesota Department of Transportation (Mn/DOT). Researchers have the ability to switch between any of the approximately 300 Mn/DOT cameras monitoring the metropolitan freeway network.

Several traffic simulation packages are used in the ITS Laboratory, chiefly AIMSUN2 for microscopic flow simulation based on individual vehicles, and the KRONOS 9 package—developed at the ITS Institute—for macroscopic or platoon-based simulations. Other packages such as VisSim are used as needed.

Recent simulation and modeling projects at the ITS Laboratory have focused on improving the efficiency of metered access to urban freeway networks and on developing a dynamic, centrally regulated traffic signal preemption system for emergency vehicles.

Putting the researcher inside the simulation is the goal of the ITS Laboratory's Digital Immersive Environment, or DEN. Three large rear-

The ITS Lab's Digital Immersive Environment, or DEN



From left: graduate student Vishnu Garg, research fellow John Hourdakis, and ITS Lab manager Ted Morris

projection screens surround the user; behind the scenes, a bank of six computers controls a visual environment developed using Open Scene Graph (OSG) and driven by data from an AIMSUN2 traffic simulator.

Each screen displays both left- and right-eye projections simultaneously, and polarized eyeglasses separate the image channels to create a three-dimensional virtual world where the corners of the DEN melt away. Users can navigate and interact with the simulated world using a handheld wand; a high-accuracy tracking system constantly adjusts the perspective of the projected scene according to the position and orientation of the user's head.

The DEN will allow investigators to understand traffic flow within the context of urban design constraints, pedestrian uses, and other factors that have been impossible to visualize using conventional display technologies. It will also complement the vehicle simulation capabilities of the HumanFIRST Program, including the ability to use the same virtual worlds in both environments.

Reducing crashes where they occur most often

Some stretches of highway are more hazardous than others. In the Twin Cities metro area, one of the most crash-prone areas is the "commons" where interstate highways 94 and 35W come together. If traffic researchers could find out why crashes occur here, they might be able to help prevent them.

The ITS Lab's Beholder system is playing an integral role in helping two University researchers do just that.

Professor Panos Michalopoulos and research fellow John Hourdakis of the Civil Engineering department are working to develop a crash avoidance/prevention system for crash-prone freeway locations. Their first step is to learn the reasons for and mechanics of crashes by recording them and extracting raw traffic-detector measurements. The Beholder system is providing them with real-time video and traffic measurements, allowing them to observe and verify the incident represented in the recorded measurements.

Conditions that are being analyzed include traffic pressure, speed, volume, occupancy, quality of flow, weather, pavement conditions, and other factors before, during, and after a crash occurs.

The advantage of using the Beholder system, Hourdakis explains, "lies in the detail and resolution of the collected measurements. There is no other site in the world that [reliably] collects such information." For a stretch of highway that is approximately a mile long, Beholder provides continuous individual vehicle speeds and headways around the clock. Having such detailed measurements for a specific location is essential for the success of the study, Hourdakis adds.

So far, the researchers have collected data on approximately 50 crashes and 50 near-misses. From this, Hourdakis says they've gained a good understanding of the nature of crash mechanisms and are now analyzing the measurements in order to detect specific patterns signaling the crash-prone conditions. As the project progresses, they will attempt to enhance the Beholder system with algorithms that will automatically detect these conditions. If successful, their research will seek ways to either alert drivers during such conditions, such as through an automated crash-prevention system, or communicate to a traffic management center that such crash precursor conditions exist and recommend mitigative procedures.

Portable monitoring stations transmit freeway traffic data to the ITS Lab.

The program's research strategy is based on a driver-centered approach, considering the "human first" within the transportation system.

Human Factors Interdisciplinary Research in Simulation and Transportation

The Human Factors Interdisciplinary Research in Simulation and Transportation (HumanFIRST) Program's mission is to apply human factors research to the design and evaluation of usable intelligent transportation systems to improve traffic safety and mobility. 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 cognitive psychologists and software engineers linked to a broader interdisciplinary network of other psychologists, engineers, computer scientists, and public health and safety practitioners. This network is supported by affiliations with additional University research units and industry, which allows the program to create responsive interdisciplinary teams to investigate a broad range of complex human factors research issues. These affiliations include formal appointments as visiting scientists and visiting professors from Nissan Research Center, the University of Calgary, and the University of Groningen (the Netherlands).

Moreover, the HumanFIRST Program has close relationships with the Minnesota Department of Transportation and the Department of Public Safety, as well as with traffic engineering consultants. These connections provide additional support for implementing research that will influence transportation policy in response to real-world problems both regionally and nationally.

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 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.

Current research topics include driver distraction from in-vehicle tasks, cell phones, and alcohol; bus rapid transit using dedicated narrow shoulders; intelligent driver-support systems such as vision-enhancement for specialty purpose vehicles (State Patrol vehicles, snowplows); infrastructure-based driver support systems for intersection safety; driver training for young drivers with attention-deficit disorders; alcohol impairment of cognitive and emotive behavior in driving; effects of sleep deprivation on driving; and new methods for increasing driver situation awareness regarding traffic hazards.

HumanFIRST Program staff. Back row: Curt Olson, Mike Manser, Rick Odgers, Mick Rakauskas, program director Nicholas Ward, Nobuyuki Kuge, and Amit Chohan. Front: Peter Easterlund (kneeling), Ben Chihak, Ma Zhu, and Praveen Balachandran (kneeling)

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 Virtual Environment for Surface Transportation Research (VESTR), provided by AutoSim, is an extremely versatile and realistic simulation environment that can be used for a variety of theory- and application-based research. This simulator is involved in a series of methodological tests to validate simulators and tune each simulator to correspond with actual driving conditions.

Among the features that make VESTR one of the most advanced academic simulators in North America are a 2002 SC2 full-vehicle cab (donated by Saturn) that provides realistic operation of the controls and instrumentation, including force-feedback steering and the feel of power-assisted braking; high-fidelity simulation for all sensory channels; a visual scene projected to a high-resolution, five-channel, 210-degree forward field of view, with rear and side mirror views provided by a rear screen and LCD monitors; software (provided by OKTAL) that can generate any type of road environment, including precise reproductions of geospecific locations, and produce a range of realistic weather and lighting effects; and auditory and tactile feedback provided by a three-dimensional surround-sound system, car body vibration, and a three-axis electric motion system. It also has the capacity to simulate and configure any type of display interface using versatile graphics software that can interact with data from the simulator.

To support the use of VESTR, the program has access to a variety of additional research facilities and locations such as closed test tracks and road network field sites for on-road studies with instrumented vehicles. To support these research activities, the HumanFIRST Program has state-of-the-art measurement tools, including a mobile psychophysiology recording system, an eye-tracking system, a vision-testing system, certified breathalyzers, and comprehensive psychomotor test batteries validated for driver assessment.

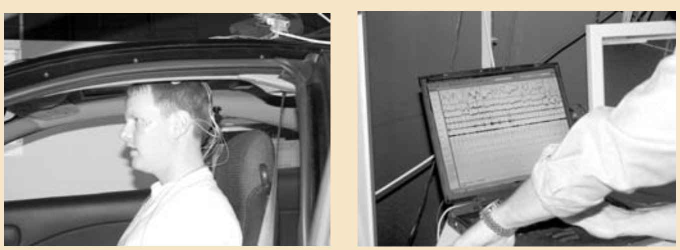
Capturing the driving experience

For human factors researchers, one of the most significant challenges in working with human test subjects is obtaining reliable data about the subjects' experience during the test. Post-test questionnaires and interviews are commonly used to obtain this data, but such tools are limited in that they require test subjects to remember and report their thoughts and reactions after the test is over.

The HumanFIRST Program has recently purchased specialized equipment to enable researchers to monitor subjects' psychophysiological reactions in real time during in-vehicle testing. The portable system can be used both in vehicle simulators and on the road while driving. Using small electrodes attached to the test subject, the system collects data on muscle (EMG) and brain (EEG) activity, as well as heart rate (EKG) and eye movement (EOG).

The expertise required to operate the system has been developed through partnerships with Professor Christopher Patrick of the University of Minnesota's Department of Psychology and visiting scientist Dr. Dick de Waard from the University of Groningen, the Netherlands.

Initial uses for the system will include investigation of alcohol impairment of driver cognitive and emotional performance in a simulated environment. Future projects include using psychophysiological data to measure mental effort and stress related to distraction, fatigue, and other performance impairments.



Electrodes are attached to a test subject in the driving simulator (left), while data are collected on muscle and brain activity, heart rate, and eye movement (right).

Intelligent Vehicles Laboratory

The Institute's Intelligent Vehicles 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, including 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 able to warn drivers and assist them with collision-avoidance and lane-keeping tasks on passenger vehicles.

The IV Laboratory's core staff is made up of engineering and computer science professionals. They work closely with an interdisciplinary team of specialists, including cognitive psychologists specializing in human factors from the ITS Institute's HumanFIRST Program and experts in visibility, geospatial databases, road-weather and other traveler information systems, virtual environments, image processing, and traffic-signal operations.

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 SAFEPLOW, an International 2540 crew-cab snowplow; a state highway patrol car; and the recently added TechnoBus, a Metro Transit bus. Using these vehicles, IV Laboratory researchers are leading the way in developing, testing, and integrating advanced technologies such as 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), virtual mirror, and other graphical displays; and haptic and tactile feedback.

The IV Laboratory's 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.

Current research topics include the design and testing of custom human interfaces, collision-avoidance sensors and algorithms, intersection-surveillance sensors, and wireless communication among vehicles and with the infrastructure.

View of the head-up display showing the location of other vehicles and lane boundaries

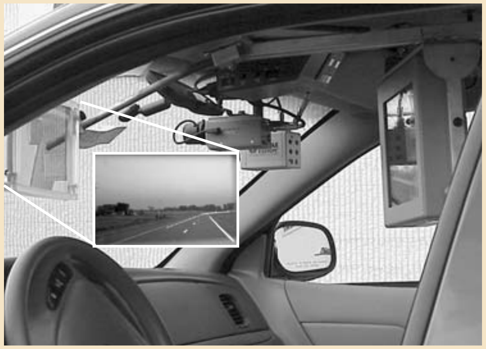
The IV Laboratory's technology is unique in that it uses DGPS and does not require hardware in the roadway surface.

The IV Laboratory's partnership with the Minnesota Department of Transportation provides access to roads and other infrastructure, including the Minnesota Road Research Project (Mn/ROAD) 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 also has relationships with a number of other organizations and government agencies, including the U.S. Department of Transportation's Research and Special Programs Administration, Federal Highway Administration, and Federal Transit Administration; Twin Cities' Metro Transit; and Minnesota's Local Road Research Board. These partnerships provide additional support for implementing research that will influence transportation safety in the United States and around the world.

IV Lab staff aboard the TechnoBus. From left: Bryan Newstrom, Lee Alexander, Alec Gorjestani, program director Craig Shankwitz, Curt Olson, Pi-Ming Cheng, and Walter Trach

Finding clear solutions for driving in low visibility

One significant research component of the IV Laboratory is the Intelligent Vehicle Initiative Field Operational Test Program, funded by the USDOT through the Minnesota Department of Transportation. Over the course of this recently-completed three-year program, IV Lab engineers, in cooperation with researchers from the Institute's HumanFIRST Program and the University of Minnesota Duluth's Department of Electrical and Computer Engineering, developed, tested, and evaluated a variety of vehicle-guidance and collision-avoidance technologies designed to help drivers navigate in low-visibility situations including snow, fog, and darkness.



The inside of a State Patrol car showing equipment used for the HUD. Inset: Road view on the HUD.

In the study's first year, researchers conducted a series of human factors studies of visual, tactile, and audible lane-departure and collision-avoidance warnings. Simulator and closed-course testing was completed in the second year. Following these tests, four snowplows, an ambulance, and a State Patrol car were released for the field operational test. All of the equipment designed to assist the driver, including the head-up display (HUD), driver's seat (which provides the tactile warning), audio warnings, sensors, and computers, was installed in each vehicle. Data acquisition equipment was installed to record driver-response to the system during operational testing.

The driver-assistive system was tested on the Highway 7 corridor for two years. Unfortunately, during this time, snowfall amounts were low, and opportunities to use the system under conditions for which it was designed were limited. As a result, only a small amount of data exists that can be used to quantify performance and economic benefits of the system. In order to better compare the benefits associated with this driver-assistive system, a second set of closed-course tests was designed and executed at the Mn/ROAD pavement research facility. During these tests, driver performance and stress levels were measured under low-visibility conditions both while driving with the system on and with the system off. Comparing test results for both conditions should allow conclusions to be drawn regarding the benefits of these driver-assistive systems. Preliminary analysis and feedback from drivers was positive, and plans are moving forward to re-deploy the technology on vehicles operating in areas with low-visibility conditions.

For complete project information, visit www.its.umn.edu/research/ivifieldtest/index.html.

Sensing changes on the road

NATSRL's Advanced Sensor Research Laboratory (ASRL) is currently investigating three disparate sensor technologies: one each for meterological applications, real-time road surface snow and ice detection, and non-intrusive vehicle identification and speed measurement.

An IRID System sensor mounted on a bridge structure at NATSRL's I-35 research facility

Initial work is underway at ASRL's off-campus facility, where the necessary infrastructure is now in place to support the calibration and installation of a multi-purpose meteorological sensor suite, controlled experimentation with the Infrared Road Ice Detection (IRID) System, and development of inductive loop detector circuitry to aid analysis of inductive changes and their resultant vehicle-specific signature characteristics. Specifically, the Biral Model 730 sensor will allow the lab to collect weather data such as air temperature, visibility, fog density, precipitation intensity, rain rate, and snowfall rate. It will be used in conjunction with a Coastal Roadway Weather Information Sensor, which will measure air temperature, relative humidity, dew point, wind speed, and wind direction. After integration with a Zeno 3200 programmable logic controller, the sensors will allow the lab to generate real-time weather information for that specific location.

The IRID System incurred substantial damage from a suspected lightning strike, but repairs have been completed, and the system was installed at the lab in March. The IR sensors on the unit will be used in conjunction with polarizing filters to examine spectral reflectance in the near-IR region for water, ice, and various de-icing solutions as well as contaminants often found on the roadway.

Finally, the inductive loop detectors (ILD) used to mark the passage of vehicles are operational. Researchers are modifying existing circuitry and developing new circuitry to facilitate increased sampling rates and acquire more informative vehicle signatures. Development of algorithms to calculate vehicle speed by analyzing magnetic field profiles and their subsequent analog responses would then provide a low-cost practical solution for speed detection using existing single ILD infrastructure.

Northland Advanced Transportation Systems Research Laboratories

The mission of the Northland Advanced Transportation Systems Research Laboratories (NATSRL), located at the University of Minnesota Duluth, is to study comprehensive winter transportation systems and the transportation needs of cities in small urban areas. Research covers a wide range of topics, including optical and electronic traffic and road sensors, transportation data management, and benchmarking of transportation infrastructure. NATSRL is collaborating with the Minnesota Department of Transportation, city and county engineers, and other agencies to address transportation-related needs, especially those specific to northern areas and climates.

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's goals include development and testing of advanced sensing technologies for pavement and road conditions (speed, weather impact, and traffic density); development of new techniques to detect incidents and abnormal traffic conditions; and real-world analysis 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 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, with a specific project in snowplow fleet management.

Other NATSRL research includes projects on traffic data automation for Mn/DOT's traffic monitoring program, an automatic visibility measurement system based on video imaging, and the utilization of satellite images for detecting traffic conditions.

NATSRL staff, from left to right: Carol Wolosz, program director James Riehl, Stanley Burns, Donald Crouch, Taek Kwon, David Keranen, and Jeanne Hartwick