University of Idaho

NIATT

ANNUAL REPORT

National Institute for Advanced Transportation Technology

PREPARED FOR UNIVERSITY TRANSPORTATION CENTERS PROGRAM

RESEARCH AND INNOVATIVE TECHNOLOGY ADMINISTRATION

U.S. DEPARTMENT OF TRANSPORTATION

FUNDING PERIOD JULY 1, 2004 THROUGH JUNE 30, 2005 - FY05

UTC 1987 2004

Cover photo: Traffic Control Laboratory II provides remote access to simulate traffic signal systems using state-of-the-art equipment and software.

Theme: Advanced Transportation Technology

MISSION

Our mission is to work with industry, government, and research institutions to develop, evaluate, and market technologies that will improve the design and operation of transportation vehicles and systems.

VISION

NIATT is a Center of Excellence for research and development of transportation technologies for the state of Idaho, the Pacific Northwest and Intermountain regions, and the United States.

- We educate and train university students and the professional engineering community in vehicle, infrastructure, and traffic control technologies.
- We assist the Idaho Transportation Department and other governmental agencies in meeting their responsibilities for the design, construction, and operation of transportation facilities.
- We work with industries and research institutions to develop and evaluate new transportation technologies and to bring these technologies to the marketplace.
- We seek collaborative research and development projects with the Idaho Transportation Department and other organizations.
- We work with university faculty to develop transportation research agendas and obtain funding for transportation research projects.
- We seek to educate the public about new transportation technologies.

Because of our geographic location, NIATT is able to serve a unique segment of the population. A number of other UTCs focus on transportation issues impacting metropolitan areas. NIATT, along with the regional University Transportation Center TransNow, serves the Pacific Northwest, where population centers are significantly smaller than in other parts of the country. With that in mind, NIATT's Center for Traffic Operations and Control chose to direct its research toward local government agencies and practicing engineers in medium to small cities with populations less than 150,000.

Much of the work completed by our Center for Clean Vehicle Technology relates to the area's environmental concerns of preserving national parks and other pristine areas, while continuing to provide for recreational uses of those same areas. We invest our research dollars in projects involved with alternative fuels and the next generation of vehicles in an attempt to protect and enhance communities and the natural environment affected by transportation.

At UI's Engineering Expo in May 2005, Cami Johnson, a senior Biological and Agricultural Engineering student, attracts attention to the Biobug with a miniature remote-controlled VW.

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This *Annual Report* highlights the activities and accomplishments NIATT has achieved over the past year of funding as a University Transportation Center.

To access this report on the Internet, please visit NIATT at http://www.webs1.uidaho.edu/niatt

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Michael Kyte, NIATT Director

We will be considering how we can collaborate more effectively within the Northwest in both education and research, and how our efforts can be aligned with both state and federal departments of transportation.

Director's Message

This is a time of transition for the transportation industry in the United States. We now have a reauthorized surface transportation program that spells out federal initiatives and funding for the next four years. The program includes a significant increase in university research funding, more emphasis on safety and operations, and a renewed consideration for energy and environmental issues.

Within our region, there is a renewed interest in collaboration among Northwest universities and state departments of transportation. All four states in our region now have a university transportation center, each with a significant level of funding. In fact, the level of UTC funding in our region exceeds the amount of State Planning and Research funding by a factor of nearly three to one. More importantly, the level of earmarking to university programs, at the expense of FHWA's research program, puts a new responsibility on our universities to make sure that our programs are aligned with federal research priorities. We will be considering how we can collaborate more effectively within the Northwest in both education and research, and how our efforts can be aligned with both state and federal departments of transportation.

At the state level, we have actively worked with the Idaho Transportation Department to redefine its research program. ITD has now hired a full time research manager, Matt Moore, and is in the process of setting up a research advisory policy committee, generating a strategic research plan, and finding ways to more effectively implement the results of the research that they fund. We have learned important lessons from this process about how we can be more timely and relevant in our research work. More changes are on the horizon as ITD continues to implement its new research program.

At the local level, we have taken a more active role in defining our own future and in working with the university and our local community. We have initiated a process to develop a new strategic plan, including a set of in-depth discussions with our research affiliate faculty and with the university's administration. We held a successful two day planning effort in May 2005 in which we engaged over 30 university researchers, students, and staff on future directions for our transportation research and education program. These discussions also included six transportation experts from around the U.S., who provided important feedback to us on our program and possible future directions that we might take. We are also planning a conference on sustainable transportation to be held on the University of Idaho campus in September 2005 in which we will engage the campus and local communities in five critical transportation problems.

These issues represent both opportunities and challenges for those of us who are a part of NIATT, a chance to reassess our program and to identify how we should invest our time and money this coming year and in the following years.

I would like to extend my sincere thanks to Don Blackketter for providing his leadership during my year's sabbatical leave in 2004. It was a tremendous opportunity for me to work on traffic signal timing projects in Boise, Idaho, and at the University of Tennessee in Knoxville, and to work with the Idaho Transportation Department in redefining their research program. Don not only kept NIATT going, but he worked on several important new issues that will help to shape our future, including the planning for a new Sustainable Energy Laboratory Building.

I invite you to review the pages of this annual report, where you will find out more about the projects in which we have been engaged during the past year. Here you will read about the students, faculty, and staff who are the essence of what we do and who we are. My thanks to each of you who continue to be a part of transportation research and education at the University of Idaho.

Michael Kyte

Michael Kyte, Director
National Institute for Advanced Transportation Technology

- **We are bringing new professionals into the transportation workforce.**
- **We have made a significant contribution to traffic signal control technology through the development of our Controller Interface Device**
- **We have developed vehicle technology to promote a cleaner environment and reduce our dependence on foreign oil.**
- **We have provided our students with the opportunity to test their engineering designs and research results in a variety of student competitions.**
- **We have invested in our future by developing new laboratories and hiring new faculty.**

Management Structure and Principal Center Staff

The National Institute for Advanced Transportation Technology (NIATT) is one of six research institutes on the University of Idaho campus. Institute status was granted to NIATT in July 1998 in recognition of its university-wide, multidisciplinary activities. The institute, originally known as NCATT, was established in 1991 under the Intermodal Surface Transportation Efficiency Act (ISTEA).

NATIONAL INSTITUTE FOR ADVANCED TRANSPORTATION TECHNOLOGY

- Center for Trafffic Operations and Control
- Center for Clean Vehicle Technology
- Center for Transportation Infrastructure
- Idaho Technology Transfer (T2) Center

Although the University Transportation Centers (UTC) program primarily supports the work of NIATT's Center for Traffic Operations and Control and the Center for Clean Vehicle Technology, the UTC funding has a positive impact on the entire institute and our ability to deliver transportation technology. UTC funds are supplemented from a variety of sources, including the Idaho Transportation Department (ITD), Idaho Department of Water Resources, the U.S. Departments of Energy and Defense, and the Federal Highway Administration. The research in the Center for Transportation Infrastructure is supported mainly by the cooperative agreement between NIATT and ITD. The Idaho T2 Center receives major funding from the Federal Highway Administration's Local Technical Assistance Program.

Management staff

Michael Kyte
Director, NIATT
Professor, Civil Engineering

Donald Blackketter
Director, Center for Clean Vehicle Technology
Professor, Mechanical Engineering

Judy B. LaLonde
Assistant to the Director, NIATT

Deborah Foster
Financial Technician, NIATT

Steven C. Taylor
ITS Integration Analyst, NIATT

Douglas Moore
Director
Idaho Technology Transfer (T2) Center

Bruce Drewes
Training and Research Manager
Idaho Technology Transfer (T2) Center

Ruthie Fisher
Administrative Assistant II
Idaho Technology Transfer (T2) Center

Irma Sixtos
Administrative Assistant I
Idaho Technology Transfer (T2) Center

NIATT Affiliate Faculty

Ahmed Abdel-Rahim
Assistant Professor, Civil Engineering

Fouad Bayomy
Professor, Civil Engineering

Steven Beyerlein
Professor, Mechanical Engineering

Donald Blackketter
Chair, Mechanical Engineering

Karen DenBraven
Professor, Mechanical Engineering

Michael Dixon
Assistant Professor, Civil Engineering

Brian He
Biological and Agricultural Engineering

Brian Johnson
Professor, Electrical and Computer Engineering

James Kingery
Associate Professor, Range Resources

Axel Krings
Associate Professor, Computer Science

Stanley M. Miller
Professor, Geological Engineering

James R. Nelson
Professor, Agricultural Economics/Rural Sociology

Richard J. Nielsen
Associate Professor, Civil Engineering

Edwin Odom
Professor, Mechanical Engineering

NIATT is located in the University of Idaho's Engineering Physics Building.

Paul Oman
Professor, Computer Science

Charles Peterson
Acting Dean, College of Engineering

Karl Rink
Assistant Professor, Mechanical Engineering

Edwin R. Schmeckpeper
Associate Professor, Civil Engineering

Judi Steciak
Associate Professor, Mechanical Engineering

Jon Van Gerpen
Chair, Biological and Agricultural Engineering

Richard Wall
Associate Professor, Electrical and Computer Engineering

Section 1: NIATT Begins Update of New Strategic Plan

Over 30 University of Idaho researchers, students, and staff, together with an external Peer Review Panel, met for two days in May 2005 to develop the core of NIATT's new strategic plan. The new plan will guide UTC program investments and the kinds of projects undertaken by NIATT researchers during the next five years.

A set of 35 interviews conducted by director Michael Kyte during the winter and spring 2005 identified strengths and weaknesses, as well as opportunities and threats faced by NIATT. The material gathered during these interviews provided valuable input for workshop participants.

Boise-area transportation management consultant Fred Kitchener facilitated the workshop, guiding participants as they considered the following questions:

- Who are our clients?
- What is our expertise?
- What is the proper balance between basic research, applied research, technology transfer, and research synthesis?
- How can we better communicate with our clients?
- How should we measure success?
- What opportunities exist in research, education, and training?
- How should we prioritize these opportunities into a strategic direction?
- How can we more effectively deliver the results of our research?
- How can we both acquire new funding and diversify our existing funding sources?
- Looking forward, what changes to our organization structure are required to properly focus our efforts?

Facilitator Fred Kitchener records input during Strategic Planning brainstorming session.

During the second day of the workshop, the Peer Review Panel provided feedback based on what they heard during the first day's discussions and brainstorming. The panel offered the following recommendations to be considered during the development of the new strategic plan:

- Recognize and document your core values
- Prepare short and concise mission and vision statements
- Develop clear research focus areas
- Evaluate NIATT's scope and structure
- Improve the communication and marketing of NIATT to its core audiences
- Complete and utilize the strategic plan

The Peer Review Panel included six transportation experts from around the U.S.:

- Amy Stearns, University Program Specialist, Research and Innovative Technology Administration, U.S. Department of Transportation
- Genevieve Guiliano, Director, METRANS Transportation Center, University of Southern California
- Dock Burke, Director, Southwest Region University Transportation Center, Texas A & M University
- Matthew Moore, Research Manager, Idaho Transportation Department
- Rhonda Brooks, Research Manager, Washington Department of Transportation
- Fred Kitchener, Principal, McFarland Management

Research Opportunities

- **Clean vehicles and alternative fuels**
- **Infrastructure**
- **Policy**
- **Safety**
- **Security**
- **Traffic operations and control**

Comments made during brainstorming session:

"We have a remarkable strength in the way we currently combine research with education and technology transfer."

"NIATT's success in the last competition was due in great part because of a staggering number of new students and increase in other numbers in the performance measures. Compared to other UTCs, you grew further and faster from where you were before."

"We need to focus on our vision/plan; get regional input for implementing our plan, and review this with people outside of our organization."

Idaho Transportation Research Manager, Matthew Moore, makes a point during the discussion about research.

NIATT director Kyte identified three immediate activities to continue this process:

- Complete the strategic plan and use it as the basis for NIATT's investments and activities during the next five years.
- Actively participate with the Idaho Transportation Department as it develops and implements its new research program.
- Expand discussion regarding research opportunities and how NIATT might address high priority potentials.

NIATT Integrates Course Work and Experiential Learning with Research

NIATT offers a multidisciplinary program of coursework and experiential learning that reinforces its transportation theme. Three education projects are highlighted in this section.

"Mentorship and Performance Assessment of Design Teams in Transportation-Related Projects." Idaho Engineering Works is a group of graduate mechanical and electrical engineering students that mentor undergraduate students in continuous improvement, peer-to-peer training, customer communications, and personal and professional development as they complete senior engineering design projects. This project funded IEW students as they completed seven transportation-related senior design projects. (See page 12)

"Developing Course Materials for Traffic Signal Design." Transportation engineers typically receive little or no education on how traffic control systems work in the field. This project included experimental studies of the operation of the traffic detector-control system and the development of materials based on these studies that can be used to educate university students and practitioners in the design and operation of this kind of system. (See page 14)

"Traffic Signal Summer Workshop." NIATT conducted its first Traffic Signal Summer Workshop in August 2000. Sixty university students and practitioners have participated in this workshop during the past five years. The fifth annual workshop, conducted in August 2004, provided the opportunity for twelve students to design and use traffic control systems through five days of experiential learning. (See page 16)

"NIATT's Backbone: Our Students." Five of our outstanding transportation engineering students are recognized through awards and scholarships. We also describe how the experience gained by our Advanced Vehicle Concepts Team leads to job offers from the automotive industry. (See page 17)

Mechanical engineering undergraduates display clean snowmobile work at Engineering Expo.

Project: Mentorship and Performance Assessment of Design Teams in Transportation-Related Projects

Principal Investigators: Steven Beyerlein and Edwin Odom

Outcomes: Completion of eleven senior design projects with transportation themes and four refereed pedagogy papers.

Idaho Engineering Works

Established in 1994, Idaho Engineering Works (IEW) is recognized as an innovative model for developing leadership skills in future engineers. IEW emphasizes peer-to-peer training, regular customer communications, ongoing dialog on personal and professional development, and a commitment to excellence. A diverse group of well-trained, collaborative, and reflective graduate students mentor senior mechanical and electrical engineering students as they complete a comprehensive design project. These capstone design projects combine students' course work with practical engineering design methods.

Financial support for these projects comes from UTC funds, other external grants, and private companies. A UTC project, "Mentorship and Performance Assessment of Design Teams in Transportation-Related Projects," provided support for eleven capstone design projects completed during the academic years 2003 and 2004.

- Ultracapacitor System for Future Truck
- Hybrid Electric Drivetrain for Future Truck
- Airbag Pleating and Folding Station
- Airbag Initiator Teststand
- Frame Optimization for Formula SAE Vehicle
- Gear Drive for Formula SAE Vehicle
- Composite Body for Formula SAE Vehicle
- Tuned Intake System for Formula SAE Vehicle
- Direct Injection Two-Stroke Engine for Clean Snowmobile
- Direct Drive System for Clean Snowmobile

The objective of the project was to develop resources to support design resources, hardware solutions, and training experiences. Examples of these resources included:

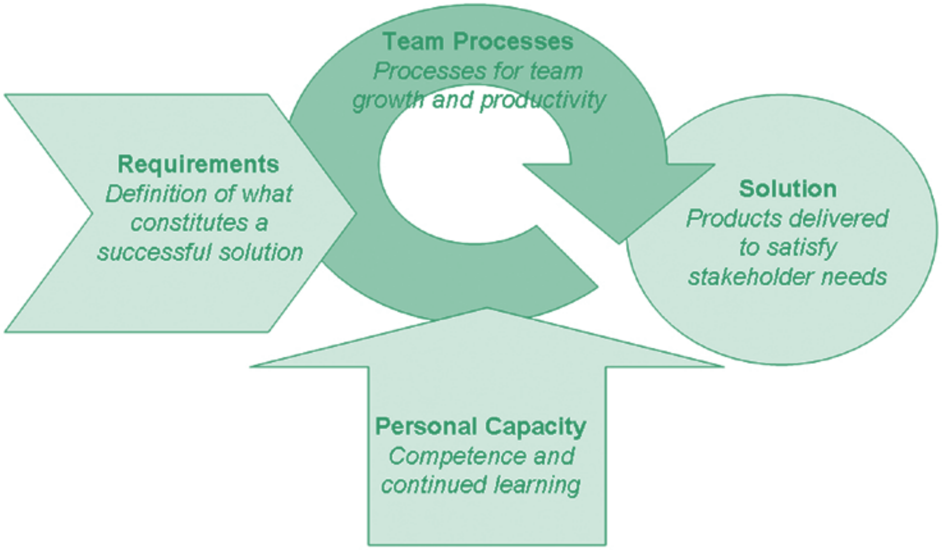
- Design and implementation of an intensive, three-week lean manufacturing short course for graduate mentors and new senior engineering students. Lean manufacturing focuses on eliminating all wastes in manufacturing processes.
- Establishment of a new laboratory, known as Mindworks, that teaches students about just-in-time machine design and manufacturing.
- A capstone design assessment system built around key performance rubrics.

These design projects supported research projects conducted through NIATT's Center for Clean Vehicle Technology.

"Over the last ten years, the IEW has been successful in facilitating delivery of hardware that exceeds expectations of industry customers, shortening time required for large-scale design projects, and developing new manufacturing capabilities within the Mechanical Engineering Department. Many of the projects are vehicle related and are supported by NIATT as well as the College of Engineering."

Steven Beyerlein,
IEWorks Coordinator

Engineering Design Model



Engineering Design Model showing four areas of performance: requirements, team processes, solution, and personal capacity.

Project Outcomes

Two donations and a new funded project were stimulated by this UTC-funded project.

- A $50,000 donation from Schweitzer Engineering Laboratory for the purchase of a four-axis Haas CNC Mill and related tooling.
- A $30,000 donation for the purchase of a Haas CNC lathe and related tooling.
- A $50,000 grant from the National Science Foundation to support collaboration with Washington State University, Seattle University, and Tuskegee University to develop assessment and evaluation instruments for capstone design courses.

The results from this project also contributed to four refereed pedagogy papers. These papers were published during the past two years in the *Proceedings of the Annual Meeting of the American Society for Engineering Education*:

- Role of Axiomatic Design in Teaching Capstone Courses (2005)
- Measuring Added-Value Using a Team Design Skills Growth Survey (2005)
- Development and Use of an Engineering Profile (2005)
- Capstone Design Course and Assessment of ABET EC 2000: A National Survey (2004)

A complete archive of capstone design courses can be reviewed at *http://seniordesign.engr.uidaho.edu*.

PROJECT: DEVELOPMENT OF TRAFFIC SIGNAL OPERATIONS CASE STUDIES

Principal Investigator: Michael Kyte

Outcomes: Web site with educational materials, results of research experiments, and transcript of practitioner interviews.

The Importance of Traffic Signal Systems

The traffic signal controller is one of the most ubiquitous and important components of our nation's transportation system. Two-thirds of all miles driven each year by U.S. motorists are on roadways controlled by traffic signals. In some urban areas, signals at busy intersections control the movement of more than 100,000 vehicles per day. However, most engineers receive little if any education on traffic controllers, how they work, and how one designs a signal timing plan that includes all of the intricacies of the traffic controller-detector system. And despite the importance of the signal timing plan, the design, implementation, and maintenance of most signal timing plans are the responsibility of a technician reporting to an engineer, and the latter often does not understand or appreciate the subtleties of traffic controller operations.

This UTC-funded project takes a first step in helping to alleviate this problem. The primary objective of this work is to develop educational materials on traffic signal operations and timing that can be used to educate university students and practicing traffic engineers about signal timing design parameters.

Understanding How Professionals Work

Transportation engineers who regularly prepare signal timing design plans have acquired a significant amount of practical knowledge of the design process and the factors that are important in this process. These experienced professional are often not able to articulate this process, their extensive knowledge base, and the factors they consider in this process to a new or inexperienced engineer. In addition, as these experienced engineers retire, the profession loses this (often undocumented) experience.

To better understand the process by which experienced transportation engineering professionals think about the signal timing design process, principal investigator Michael Kyte conducted 30 to 45 minute interviews with seven such professionals. The engineers were shown a photograph of an intersection design and were asked to complete a signal timing design, considering a set of questions as they proceeded with their design. As they worked, they were asked to describe orally as much of their thinking as possible. The interviews were digitally recorded and Kyte took notes as the professionals worked. The professionals were also asked to write down their work, including all steps, assumptions, and conclusions. A transcription of these interviews has been completed.

What information do you need in order to design the timing plan for this signalized intersection?

Briefly describe what your final output will be. [or, What is the normal form of the output from this design; what parameters do you include in this design]

What are the timing parameters that you will produce? [how do you determine the parameters? which are computed using design guidelines or standards, and which are produced using analysis tools or models?]

What is the proper sequencing of phases for this intersection? [How do you determine the sequence? What options do you consider?]

What MOEs do you use to measure the performance of the intersection?

What models or tools do you use to produce these MOEs?

Describe the process or steps that you will go through to produce your timing parameters.

What other factors should you consider: pedestrian phasing, other controller settings, volume variations during the day, detector settings/issues?

Figure 1 Questions Posed to Designers

"We have now developed the laboratory infrastructure and knowledge base to allow us to make a major contribution to traffic signal system research and education in the U.S."

Michael Kyte
NIATT Director

In collaboration with Dr. Thomas Urbanik, Professor and Goodrich Chair of Excellence in Transportation at the University of Tennessee, Kyte developed case studies that address a range of technical issues relating to traffic signal systems. These studies illustrate the interrelationship of signal timing parameters and the vehicle detectors that are used in actuated traffic control systems. Each case is based on a learning process defined by educational objectives and includes a set of computations and problems, as well as interpretations and assessment tools for students using these problems.

FHWA Grant for Signal Timing Training

The UTC project completed by Kyte and Urbanik laid the groundwork for a new grant from the Federal Highway Administration to develop signal timing training based on using actual traffic controller units. This new project, known as MOST or Mobile Signal Timing Training, provides the funding to develop a set of laboratory exercises for training professionals in signal timing training. The project, part of FHWA's signal timing roadmap, is an extension of NIATT's Traffic Signal Summer Workshop. The project team includes Kyte and Urbanik, as well as Darcy Bullock (Purdue University), Michael Dixon and Ahmed Abdel-Rahim (University of Idaho), and Jim Pline (Pline Engineering). The project will be completed in 2007.

“It’s good to see the Traffic Signal Summer Camp is still going strong. I attended back in August 2001 and this summer camp really helped me stand out from other applicants when I was searching for my job.”

Scott Arnold, EIT,
Kimley-Horn, Fort Worth,
Texas

“Thank you for your hospitality at the Signal Workshop. It was without a doubt some of the best training I have ever experienced.”

Dan Harelson, District 4 Traffic Engineer, Idaho Transportation Department

Project: Traffic Signal Summer Workshop

Principal Investigators: Michael Kyte

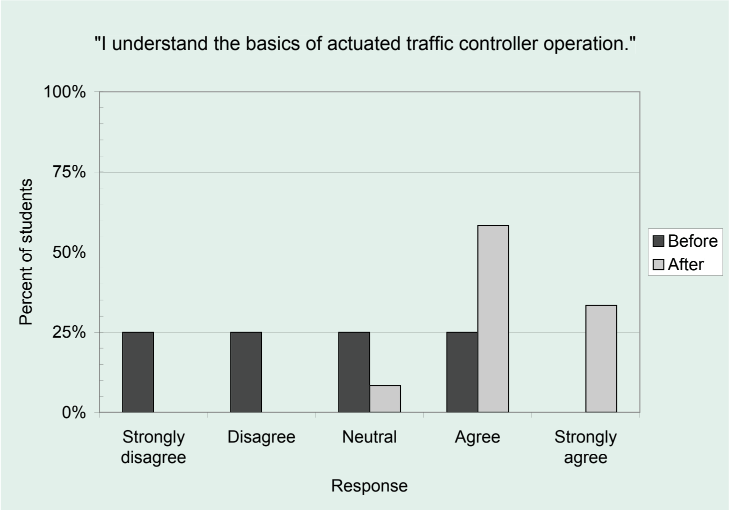
Outcomes: Hands-on education experience for twelve university students and professionals with traffic signal controller technologies

Eight university students and four transportation professionals attended NIATT’s fifth annual Traffic Signal Summer Workshop, held in August 2004 on the University of Idaho campus. The students and professionals worked with nine different instructors to learn about signal design, signal timing, controller operations, and loop detector design.

Traffic Signal Summer Workshop participants display their loop detector system.

“This workshop was oriented to help people understand practical engineering experiences. I came away from this workshop with more than what I expected.”

William Webb,
UI undergraduate student



Results from student assessment of how well they understood the basics of actuated traffic signal operations.

NIATT's Backbone: Our Students

Recognizing Excellence

Five of our outstanding transportation engineering students were recognized for their excellence this past year through awards and scholarships.

Yuri Meresczak was selected as NIATT's Student of the Year for 2004. Yuri received his $1000 award at the 2005 annual meeting of the Transportation Research Board, during the Council of University Transportation Centers banquet. Yuri received his MS degree in Civil Engineering in May 2004 and is now working for Kittelson and Associates in Boise, Idaho.

Amy Stillman and **Guillermo Madrigal** received Coral Sales/ Douglas P. Daniels scholarships during 2004. Amy received her undergraduate degree in civil engineering and is now working for JUB Engineering in Lewiston, Idaho. Guillermo continues his undergraduate studies at the University of Idaho. In the summer of 2004, he received his second FHWA internship and worked as a field inspector on "The Big Dig" in Boston, Massachusetts.

Michael Shaw received the Institute of Transportation Engineers scholarship. Michael is currently working as a NIATT intern with Dr. Richard Nielsen on a bridge design project sponsored by the Idaho Transportation Department.

Geoffrey Walters was awarded the Road Builders' Clinic scholarship. Geoffrey continues his undergraduate studies in civil engineering at the University of Idaho, working toward a BSCE degree.

Educational Experiences Carry Students to Automotive Industry Jobs

The experience gained by members of the Advanced Vehicle Concepts Team (AVCT) has led to job offers from the automotive industry. In May 2004, Jeremy Forbes, BSEE, and Richard Statler, BSME, began working in the automotive industry with jobs that paralleled their work as members of the AVCT. Forbes, a development engineer with Micron Corporation in Franklin, Tennessee, and Statler, a development engineer with Neoplan USA, both attribute their success in getting their jobs to the experience and knowledge gained while working on FutureTruck vehicles. NIATT students and faculty have participated in the FutureTruck competition, sponsored in part by the Department of Energy, since 1998. The competition challenges budding engineers to redesign vehicles to increase energy efficiency and reduce emissions while continuing to meet expectations for performance, utility, safety, affordability and comfort.

Members of 2004 FutureTruck team display the reengineered Ford Explorer. (left to right, back row: Jeremy Forbes, Tom Coburn; Mike Briggs (back seat); Chris Clark (front seat); Jason Georgides; Frank Albrecht, front row: Bill Weidenaar, Ford mentor; Dan Cordon; Greg Johnson; Jeremy Boles; Eric Cegnar.

Jeremy Forbes was the AVCT vice president and team leader for the electrical power and electronic control systems on the 2002 Ford Explorer hybrid electric vehicle project. Jeremy led the effort in designing, building and testing the electric drive system which stored energy with Maxwell ultra-capacitors and delivered power through a three-phase induction machine. System control was managed through a National Instruments PCI eXtensions for Instrumentation software, LabView software and field point modules. National Instruments and LabView donated software and hardware as a result of white papers written by Forbes and submitted to these companies by AVCT. (See p. 31.)

Forbes' work at Micron, a research and development company that works on military contracts and Small Business Innovation Research projects, is involved in the development of a "power neuro system" that will start a 24V military vehicle even when the batteries are totally discharged.

Richard Statler served as the AVCT president and team leader for the mechanical powertrain. His group built a new transfer case that directed the power from the electric motor and combustion engine to the front and rear axles. Recycling several internal components from the original stock unit, Richard and his team developed a lightweight and efficient gear drive that was as quiet as the stock system. By securing sponsorships for the drive chain, aluminum casting, and heat treatment, Richard and his team built the transfer case at a cost below budget.

John Beard, FutureTruck Faculty Advisor at Michigan Technological University where the 2004 competition was held, wrote a letter to UI's Dean of Engineering Chuck Peterson following the 2004 FutureTruck competition, congratulating the team and UI. He wrote: "I had the opportunity to meet Richard Statler, the team leader, and I am 'duly impressed' with his leadership and people skills. He made a good impression on the other advisors, team members and organizers."

"I am so glad I spent the extra time during college to get involved with FutureTruck. Not only did my work on the project put me in contact with my present employer, but I am also using skills I picked up while on the team. I use LabView every day. I just gave a presentation to a colonel in the Army that, before the FutureTruck experience, would have made me very nervous and stressed out."

Jeremy Forbes

SECTION 3: Research

NIATT uses University Transportation Center program funds for research in three areas:

- Traffic control system technologies that are essential to national intelligent transportation infrastructure
- Technologies that support the development of the new generation vehicle
- Capacity building for transportation engineering professionals working in both vehicle and traffic control technology industries

The seven projects described in this section directly support one of these three areas. The projects also support our educational and technology transfer goals. Four of the projects were completed through the Center for Traffic Operations and Control and three through the Center for Clean Vehicle Technology.

UI's snowmobile during the March 2005 acceleration competition (photo used with permission from KRC/MTU).

Center for Traffic Operations and Control

"Plug-and-Play Smart Sensor Traffic Signal Systems." This project challenges traditional assumptions in the design of traffic controller devices. Researchers propose the use of plug-and-play technology, as part of a radical redesign in traffic controllers, displays, and cabinets to reduce traffic signal installation and operations costs. (See page 22).

"Traffic Controller Laboratory Upgrade." This project, in conjunction with the Moscow ITS project, funded an expansion of the laboratory that now includes twenty traffic controllers and supporting equipment. Networks with up to twenty intersections can now be tested using NIATT's hardware-in-the-loop technology. (See page 24).

"A Remote Access Hardware-in-the-Loop Simulation Lab." This project produced new technology that facilitates remote use of NIATT's traffic controller laboratory, allowing users throughout the country to have access to the laboratory's facilities. The new Controller Interconnection Network or CIN is one of the products of this research. (See page 24.)

"Assessing the Security and Survivability of Transportation Control Networks." This project shows that new traffic control system networks, based on Internet protocol addressable devices, can benefit from survivability and security analysis. A test case, the Moscow ITS project, is used to demonstrate the benefits of this type of analysis. (See page 27.)

Center for Clean Vehicle Technology

"Hybrid Heavy Weight Vehicles." Several senior design projects tested various aspects of hybrid hydraulic control systems. (See page 30).

"Design and Construction of a Direct-Injection Two-Stroke Snowmobile." Student and faculty developed a new snowmobile design that reduced noise and emissions and met SAE performance requirements. (See page 33.)

"A Novel Continuous-Flow Reactor Using Reactive Distillation Techniques for Economical Biodiesel Production." This project tested new processes for producing biodiesel fuels. (See page 35).

Project: Plug-and-Play Technology Could Reduce Cost of Traffic Signals

Principal Investigator: Richard Wall

Outcomes:

- A test bed for analyzing distributed sensor network (DSN) applications to traffic signals
- A process for generating Plug and Play (PnP) traffic Signals and sensors;
- An analysis of the performance of a PnP DSN reduced scale model of a signalized intersection
- An advisory committee consisting of university and industry experts in traffic signals
- Interest among Electrical and Computer Engineering undergraduate and graduate students in traffic signal controls
- Two conference papers accepted (IECON05 and TRB 2006)

Richard Wall and graduate student Andrew Huska began their research knowing that the functionality of traffic controllers had not changed significantly over the last 50 years. Even controllers that meet today's Intelligent Transportation System (ITS) standards are constrained to turning on or off single element displays. The information from sensors is reduced to the detection of the presence of a vehicle in a particular space in the road or the request from a pedestrian to be served.

With the goal of reducing traffic signal installation costs and providing additional functionality for traffic signal systems, Wall and Huska constructed a system demonstrating plug-and-play (PnP) distributed sensor technology. To provide an open architecture environment, the researchers adhered to the Smart Transducer Interface Standards (IEEE 1451) set by the National Institute of Standards and Technology. The system included Ethernet communications connecting four nodes controlling a single traffic signal as well as eight countdown pedestrian signals to a simulated traffic controller. A laptop PC simulates a simple traffic semi-actuated traffic controller algorithm and provides network diagnostics.

Demonstration System Uses Unique Traffic Signals

The traffic signals in the demonstration system are unique because each color consists of a 25-LED array in which every LED is individually controlled allowing it to display arrows, balls or any other shape. The signal can be programmed to flash or remain on, and it can report its state back if needed. The vehicle detector is simply a toggle switch attached to a software counter; it can be reset, disabled, and polled for its vehicle count.

The pedestrian walk/wait display operates in standard fashion, but the pedestrian timer is programmed with a start-time directly from the controller rather than "learning" the proper duration (as in current systems). The pedestrian button remembers the event when it is pressed; it can be set, reset, polled, or disabled by the controller. Each approach is controlled by a Smart Transducer Interface Module (an interface) and a Network Capable Application Processor, which are on a separate circuit board mounted underneath the demonstration intersection. In this demonstration the transducer electronic data sheets are stored in a removable memory chip that is separate from the sensor control hardware (Fig. 2).

Capability and Advantages of PnP Technology

Because they can support dynamic signaling and facilitate temporal requirements for traffic control, PnP traffic signals can provide better real-time traffic control than current systems and can result in safer and faster traffic flow. PnP signals can reduce installation and maintenance costs because they use fewer wires and connectors. Electronic descriptions in the smart transducer modules provided by the smart transducers simplify signal and sensor replacement and or upgrades. Network communications minimizes the number of wires required between the traffic controller and signals or sensors. The distributed environment can eliminate the need for load switches, thus significantly reducing the size of the traffic controller cabinet or eliminate it altogether. While the overall system speed was less than originally anticipated, the desired performance is still obtainable using low-cost microprocessors with faster hardware and/or software.

Future research will focus on two critical issues that impede the application of this technology in traffic controls. The first issue is the fail-safe operation of a distributed control environment, now accomplished by conflict monitors or malfunction management units. The second area of research will be to integrate the PnP system into existing advanced traffic controller schemes replacing the signals wires.

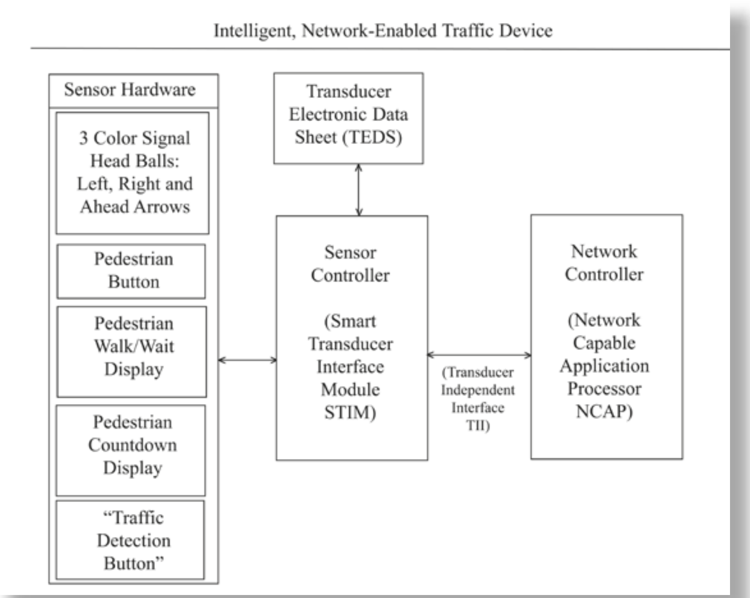


Figure 2. Design for an intelligent traffic network.

Research Team

Management
Richard W. Wall, principal investigator
Brian K. Johnson, co-principal investigator

Technical Advisors
Darcy Bullock (Purdue University)
Michael Kyte
Ahmed Abdel-Rahim
Mike Dixon
Zhen Li, civil engineering graduate student

Senior Design Team
Troy Cuff, computer engineering
Ben Hamlett, electrical engineering
Eresh Suwal, computer engineering

Undergraduate Project Assistant
Tyrel Jensen, electrical engineering

Project: Traffic Controller Laboratory Upgrade

Principal Investigator: Ahmed Abdel-Rahim

Outcomes:

- A laboratory facility that allows for testing of advanced signal control systems either in the laboratory or from a remote location
- A research infrastructure that enhances teaching undergraduate transportation engineering classes at the University of Idaho

Project: A Remote Access Hardware-in-the-Loop Simulation Lab

Principal Investigator: Brian Johnson

Outcomes:

- A modular hardware interface to a traffic controller that facilitates communication with other traffic controllers or a central controller in the NIATT traffic control lab
- Tools for configuring the hardware interface and traffic controllers settings

State-of-the-Art Traffic Lab Provides Remote Access for Traffic Signal Simulations

What began in 2001 as an upgrade for NIATT's Traffic Controller Laboratory became in 2005 the Traffic Controller Lab II, or TC-LABII, an advanced traffic laboratory that provides remote access for users to test traffic signal timing plans using real-time hardware-in-the-loop (HIL) simulation.

Several UTC-funded projects supported the upgrade of the TC-LABII. They support NIATT's strategy to develop the controller interface device as a key enabling technology for traffic engineers in the testing and deployment of traffic controller systems and in the training of traffic engineers in the design of traffic controllers systems. In addition, this work supports a larger ITS integration and deployment project funded by the Federal Highway Administration, the Idaho Transportation Department, the City of Moscow, and several traffic supply companies. This project, known as the Moscow ITS Project, will improve traffic flow and safety in the City of Moscow. The project will implement and test the feasibility of using the National Transportation Communications for ITS Protocol standards in a small city.

TC-LAB II houses 20 CIDs and traffic controllers, an instructor area, and a communications system that allows users to test traffic networks with up to 20 intersections. The lab includes nine dedicated workstations computers running industry-standard simulation software and the CID Software Suite.

A distinguishing feature of TC-LAB II is that users from all over the world can access and make use of its capabilities via the Internet. By providing access to remote users, NIATT gives students and instructors the ability to run hardware-in-the-loop traffic simulations and use other traffic management software from their home locations.

Users can access any of four controllers types: an Econolite ACS/2S-2100; an Econolite 2070; an Eagle EPAC300; and a PEEK 3000. Each network includes five CIDs, connected by a USB hub to a host computer. The computer runs the CID software suite and three types of traffic simulation software (CORSIM, VISSIM and SimTraffic). Four traffic management software tools (Arise, QuicNet, ACTRA and MIST) are also installed on each host computer.

"Our TC-LAB II is something that never existed before—researchers and practitioners from around the nation now have the opportunity to study advanced signal controls from their own computers."

Ahmed Abdel-Rahim,
principal investigator

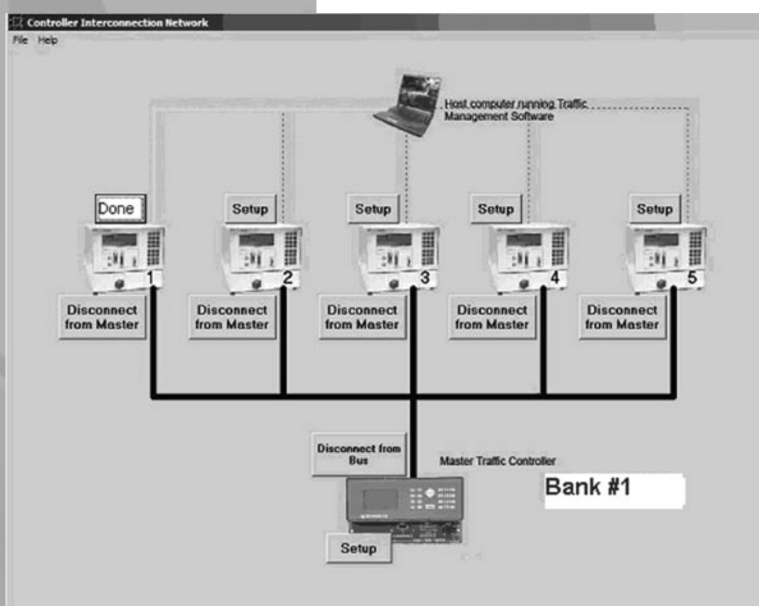
The Controller Interconnection Network

The evolution of Intelligent Transportation Systems (ITS) technologies promises new tools for integrated traffic signal systems, including centralized control systems and the provision for real-time adaptive control. Many states and metropolitan areas have already deployed integrated centralized signal control systems. These systems often consist of a network of traffic controllers and detection and surveillance devices connected to a centralized control center through an extensive communications network.

The developments in communication and computing technologies, however, have not been accompanied by corresponding developments in evaluation and decision-making tools that can take advantage of real-time data to produce more efficient control strategies. This deficiency is primarily due to the inability to model advanced control systems, such as centralized and closed-loop control systems, in a controlled lab environment.

A new system was needed that would enable TC-LABII users the ability to access the tools—remotely—to model advanced traffic control systems. A NIATT research team designed a prototype microprocessor-based hardware device that automates the configuration of an ITS network for various modes of traffic controller operation.

The device, called the Controller Interconnection Network (CIN), is scalable. Up to 20 traffic controllers can be interconnected in a single network or in up to four parallel networks, allowing for multiple tests to be run concurrently. The CIN enables communication between controllers and also provides users an interface to enter controller settings. The CIN allows users to connect and disconnect traffic controllers from a network using a graphical user interface (GUI). This feature eliminates the need for manual connection or disconnection of cables once all of the controllers are connected to the device.



An embedded-controller approach was used for the hardware design because this approach enables easy modification. A GUI displays the status of the network and allows the user to make changes in network configuration.

Beta testing of the TC-LABII is scheduled to begin in the fall of 2005.

The Controller Interconnection Device (CID) GUI.

Project: Assessing the Security and Survivability of Transportation Control Networks

Principal Investigator: Paul Oman

Outcomes:

- A survivability map for the Moscow ITS project that defines resistance, recognition, and recovery mechanisms for every physical and cyber threat identified via stakeholder normal usage scenarios and red-team (offensive) attack scenarios
- A communication infrastructure routing alternatives
- An intersection critical point identification via VISSIM simulations of Moscow's traffic flows under normal and event-driven conditions

Analyzing the Survivability and Security of Traffic Control Networks

The North American transportation system is the backbone of our national and international commerce and literally supports all other critical infrastructures within the United States. However, increasing reliance on computer technology for improved communication and automation of traffic and transportation control networks has created vulnerabilities within those control systems. These vulnerabilities are similar to those seen in electric power control systems. Particularly vulnerable are

- control center and dispatch communications
- computer controlled equipment for access, safety and monitoring
- remotely accessible real-time sensors and controllers regulating transportation flow (e.g., bridges, tunnels, rail crossings, arterial routes, etc.); especially Internet-Protocol addressable and modem-accessible in-the-field devices used to monitor and regulate traffic flows in large urban environments.

Cyber attacks and electronic sabotage targeted against these vulnerabilities have the capability of inducing transportation disruptions over very large geographic areas. Loss of life, property, production, and service may result from those outages. Financial support from the National Institute of Standards and Technology supplemented UTC funds for a two year study of transportation system vulnerabilities.

Research Team

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Patrick Merry

Neil Nguyen

Matthew Phillips

Jeanine Schmidt

Vishakh Nair

Sean Melton

Investigating the Security of ITS Systems

Malicious attacks on computing systems and networks have grown drastically over the last decade and have reached epidemic proportions. In 2002 the Computer Emergency Response Team (CERT) alone reported over 4,000 vulnerabilities resulting in more that 80,000 reported intrusion incidents. Traffic control systems, and the transportation infrastructure in general, were not designed with malicious acts in mind, and neither were the computers and networks controlling them. Given the cyber threats to the control infrastructures, ranging from recreational hackers to foreign government sponsored cyber terrorism, a basic shift in design and operations philosophy is necessary.

Stakeholder Needs	Drivers / Pedestrian	NIATT	City of Moscow	City of Moscow	ITD	FHWA
A traffic signal system that safely and effectively moves people and vehicles through and within the City of Moscow	X	X	X	X	X	X
A traffic signal system that can be integrated with ITD's regional architecture and national ITS standards					X	X
A traffic signal system that is flexible and can be expanded to meet future needs				X	X	X
A traffic signal system that adapts to changing traffic conditions and responds to special events and to pedestrian and bicycle flows	X		X	X	X	
A traffic signal system that can be easily and remotely maintained				X	X	
A communications infrastructure that provides links between signalized intersections, with the central traffic operations centers, and to the city's operations center				X	X	X
A roadway sensor or detection system that monitors traffic signal system performance and changing traffic flow conditions and provides continuous system evaluation and diagnostics		X		X	X	
A data archiving system that collects, aggregates and archives traffic flow and signal timing data		X		X	X	
A surveilance system that provides real-time monitoring of the city traffic signal network		X	X	X	X	X
Highway/rail intersections that use signal preremption and interconnects			X	X	X	
A training facility that provides traffic signal system training and real-time signal timing testing capabilities.		X		X	X	X

Figure 3 Identification of Moscow ITS stakeholders and needs.

It is imperative that we move from "Design for Dependability" to "Design for Survivability." This means that our transportation control infrastructures should be designed and operated so that essential services will survive even in the presence of malicious faults, intrusions, and attacks. The integration of survivability features can be seen as: (1) part of the design specification and process, or (2) as an augmentation to an existing system in order to increase survivability. Examples of both types of survivability design are possible within the Moscow ITS project, including fiber optic cable routing, communications protocols linking traffic controllers, placement and networking of system detection devices and CCTV cameras. This two year study analyzes the Moscow ITS project, with the intent to develop quantitative methods for assessing the security and survivability of complex automated traffic control systems.

Supporting the Moscow ITS Project

One outcome of the project was a vulnerability analysis of security and survivability of the proposed Moscow Intelligent Transportation System, a project to renovate the city of Moscow's traffic signal control system. The Moscow ITS project is a cooperative effort by NIATT, the Idaho Transportation Department, the Federal Highway Administration, and the City of Moscow.

This study looked at both security and survivability analyses of fiber optic cable routing, traffic controller network topologies, communications switchgear linking traffic controllers, computer server placement, and network connections to project stakeholders for access to data and signal control. The analysis also includes the identification of essential components, the development of a stakeholder/component responsibility and access matrix (Fig. 3), the identification of project threats, and the development of a threats/ critical component matrix. Furthermore, the analysis identifies threat mitigation strategies for each threat identified and provides suggestions for improved security and survivability. The analysis has been presented to the Moscow ITS planners for their use in making design decisions in this project.

Researchers propose modeling measurable improvements in the dependability and security of surface transportation control systems operating under conditions induced by extreme events (e.g., oversaturated, damaged, or impacted by accidents, malicious attack, or weather). The modeling system will be verified using real traffic system data from the City of Moscow.

Project Publications

Abdel-Rahim, P. Oman, J. Waite, M. Benke, and A. Krings, "Integrating Network Survivability Analysis in Traffic Systems Design," presented at the IEEE Intelligent Transportation Systems Safety and Security Conference, (March 24-25, Miami, Florida), 2004.

F. Sheldon, T. Potok, A. Loebl, A. Krings and P. Oman, "Management of Secure and Survivable Critical Infrastructures Toward Avoiding Vulnerabilities," presented at the Eighth IEEE International Symposium on High Assurance Systems Engineering, (Mar. 25-26, Tampa, FL), 2004.

P. Oman, A. Krings, D. Conte de Leon, and J. Alves-Foss, "Analyzing the Security and Survivability of Real Time Control Systems," *Proceedings from the Fifth IEEE Systems, Man and Cybernetics Information Assurance Workshop*, (June 10-11, West Point, NY), IEEE Press, 2004, pp. 342-349.

M. Benke, J. Waite, P. Oman and A. Abdel-Rahim, "Survivable Systems Analysis for Real Time Control Systems in Critical Infrastructures," *Proceedings of the International Conference on Security and Management*, (June 21-24, Las Vegas, NV), CSREA Press, 2004, pp. 278-283.

J. Schmidt and V. Nair (with P. Oman and B. Johnson, advising), "A Taxonomy of Security Standards for Real-time Control Systems," *Proceedings of the 36th Annual North American Power Symposium*, University of Idaho, (August 9-10, Moscow, Idaho), 2004, pp. 59-66.

J. Waite, J. Oman, M. Phillips, S. Melton, and V. Nair (with P. Oman and B. Johnson, advising), "A SCADA Testbed for Teaching and Learning," *Proceedings of the 36th Annual North American Power Symposium*, University of Idaho, (August 9-10, Moscow, Idaho), 2004, pp. 447-451.

J. Waite, M. Benke, N. Nguyen, M. Phillips, S. Melton, P. Oman, A. Abdel-Rahim, and B. Johnson, "A Combined Approach to ITS Vulnerability and Survivability Analyses," *Proceedings of the IEEE Intelligent Transportation Systems Council Symposium*, (October 3-6, Washington, DC), 2004.

"It is imperative that we move from "Design for Dependability" to "Design for Survivability." This means that our transportation control infrastructures should be designed and operated so that essential services will survive even in the presence of malicious faults, intrusions, and attacks."

Paul Oman,
principal investigator

The University of Idaho electrical engineering design team of Fred Jessup, Erin Jessup, and Benton O'Neil were honored as having "The Most Innovative Project" at the 2005 Engineering EXPO (a yearly exhibition of student engineering projects at the University of Idaho). University President Tim White met with the students who explained the design during a photo opportunity for the *Moscow Daily News*. For more information please visit the team's website: http://seniordesign.engr.uidaho.edu/2004_2005/loadlevelers/

PROJECT: HYBRID HEAVY WEIGHT VEHICLES

Principal Investigators: Donald Blackketter and Frank Albrecht

Outcomes:

- Demonstrated that an ultracapacitor array can provide a lighter energy source for starting vehicles
- Demonstrated that using an ultracapacitor array can support the use of smaller, longer-lasting batteries that are environmentally advantageous
- Graduate student MS thesis led to publication of a special issue "Hybrid Electric and Fuel Cell Vehicles" in the International Journal of Vehicle Design
- Began process for patenting the ultracapacitor array and initiated new project to commercialize the process

UI Student Engineers Change the Way an Engine Starts

For most vehicles, the lead acid battery plays a crucial role, providing the electrical power necessary to drive the starter motor to turn the engine until fuel ignites and the engine starts. During engine starting, electric current drawn from the battery may reach as high as six hundred amps. After the engine is started, however, the lead-acid battery plays a much less crucial role as the alternator supplies the majority of the electric power to the vehicle. With a typical weight ranging from thirty-five to fifty pounds, a life-span of less than five years, and a number of environmental issues involved with its production and disposal, the lead acid battery may not be the most optimal way to start an engine.

This project supported the work of a senior capstone design team in the Department of Mechanical Engineering to build a system that eliminates the need for large lead acid batteries during engine starting. Using the Ford Explorer (FutureTruck 2004/2005) as a teststand, students designed a double-layer capacitor for engine start-up.

Ultracapacitors Perform Better Than Lead-Acid Batteries

The basis of the design is the ultracapacitor, a double-layer capacitor technology with high current capabilities, a device that is well-suited for the requirement of starting an internal combustion engine. Ultracapacitors are much smaller, weigh far less, last up to ten times as long, and perform better in extreme conditions than batteries found in many of today's vehicles. Though this technology is ideal for starting an engine, its energy storage capability is much less than that of a typical automotive battery. The design developed for this project eliminates this short-coming by using a simple DC/DC converter.

The team designed and built a custom converter that recharges the ultracapacitors at a regulated thirty amps each time that they are discharged (Fig. 4). If the engine is running, the current comes from the vehicle's alternator and if the engine is not running, the current comes directly from the battery. By limiting the charging current to thirty amps, the battery never sees a large discharge current. This means that the system battery that was once required to supply 600-700 amps now only supplies 30 amps.

Capacitors Enable a Longer-Lasting, Lighter Battery

By reducing and regulating the battery load current, a new type of battery (NiMH, Lithium-Ion, or NiCad) can now be used instead of the lead acid battery. A lithium-ion battery with the same energy storage capability of the stock lead acid battery would be much smaller, lighter, and would last much longer than the lead acid battery. Future designs could integrate the system into a single unit of roughly the same shape and size as today's typical automotive battery. This new unit, however, would be twenty-five pounds lighter and would need to be replaced half as often as today's battery.

Figure 4 The system installation in a Ford Explorer consists of a bank of six capacitors weighing 0.42 lbs each, a DC/DC converter and controller and a small battery.

"... perhaps the most ground breaking energy storage system this year was 48.6 volts (for a reasonable $2,400) of Maxwell ultracapacitors used by the University of Idaho. Jeremy Forbes explained to me that while you can only expect a few hundred or a few thousand cycles from lead-acid and NiMH batteries, respectively, ultracaps are expected to be good for 500,000 cycles. The other advantage is a huge savings in weight. 2,500 amps worth of lead acid batteries will weight upwards of 1,400 lbs. compared to a mere 190 lbs. for the 130 ultracaps mounted under the vehicle in a steel box. On top of this, its efficiency in terms of energy in vs energy out is incomparable, approaching something like 99 percent."

Bill Moore, "Goodbye Future-Truck," *EV World* June 26, 2004, "Goodbye FutureTruck"

http://www.evworld.com/modules/win_printdoc.cfm?section=article&docnum=712&doctitle=Goodbye%20FutureTruck

Senior Design Team Demonstrates Technology for Heavy Weight Vehicles

The need for improved fuel economy and lower emissions standards has increased interest in hybrid vehicle research. One new option for heavy-weight hybrid vehicles (such as garbage trucks) is an hydraulic assist system. The main goal of this project was to create a hydraulic launch assist system that could be used on large refuse vehicles to improve fuel economy with a design that is both feasible and affordable.

A senior design team from the department of mechanical engineering developed a control system that optimizes hybrid vehicle efficiency (Fig. 5). Their goal was to increase efficiency of the current hydraulic system on the platform of a 1988 Ford F350, created by a previous project, to reduce component wear and tear on the system, to increase brake life of the vehicle, to improve better noise control, and to improve safety features.

All UI mechanical engineering senior design teams must document their work throughout the year on a website. The site for the “Dumpster Divers” team (http://seniordesign.engr.uidaho.edu/2004_2005/dumpsterdivers/) includes a report documenting three different methods of research used to design the new system:

- The current system was analyzed to provide the team with a better understanding of hydraulic hybrids and to find potential problems with the system.
- The team also modeled the various objectives and goals that would be achieved by this project.
- The current platform was tested for analysis of a hydraulic system.

Hydraulic-assist systems work by capturing energy that is normally wasted during braking. The energy then assists the engine when it works the hardest, during acceleration. By storing and reusing energy, the hybrid is more fuel efficient, which in turn reduces vehicle emissions. For urban driving, the Environmental Protection Agency estimates that hybrid hydraulic delivery trucks could reduce fuel consumption by 25 to 45 percent and tailpipe emissions by 20 to 30 percent. An additional benefit to refuse trucks is significantly less wear on brakes in their daily stop-and-go environment. By adding a redundant braking mechanism, the hydraulics improve safety while recycling energy.

One application of this technology could be improved hydraulic controls. Recognizing the possibilities of such research, Ford Motor Company, Eaton Corp., and the EPA jointly agreed to donate to NIATT a concept 1998 Lincoln Navigator along with two hydraulic systems to be used as a teststand for the project.

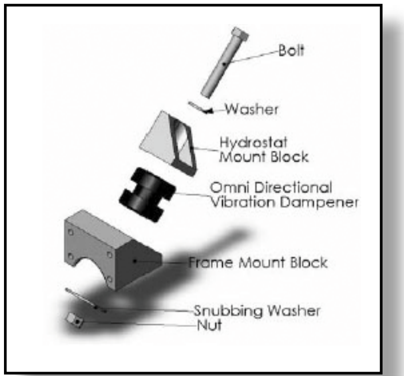


Figure 5 Design of the hydraulic mount system.

Project: Design and Construction of a Direct-Injection Two Stroke Snowmobile for Competition in the 2005 SAE Clean Snowmobile Competition

Brad Devorak describes the development of the UI direct-injection system to a judge during judging of the static display during the CSC competition.

Principal Investigator: Karen Den Braven

Outcomes:

- Ninth place finish in the competition
- A working two-stroke direct-injection snowmobile engine
- Numerous internship and permanent job offers to student team members
- A peer-reviewed SAE publication
- Two ME senior design projects, one EE senior design project, one senior ME laboratory project, and a ME technical elective class
- Several presentations to K-12 groups

Best Available Technology Required in Snowmobiles in National Parks

Because of the University of Idaho's location near several national parks, motivated by the "Northwest lifestyle," NIATT researchers have continued their efforts to develop the "best available technology" for snowmobiles. The Society of Automotive Engineers (SAE) supports such efforts through their International Clean Snowmobile Challenge (CSC). The CSC is an intercollegiate engineering design competition in which students must cost effectively re-engineer an existing snowmobile to reduce emissions and noise levels, while maintaining or improving the performance characteristics of the original snowmobile.

The SAE Clean Snowmobile Challenge began in 2000. A NIATT team has competed each year since 2001, capturing first place in 2002 and 2003. Twelve other universities, including two from Canada, competed in the Challenge, March 14-19, 2005, in Houghton, Michigan. Throughout the six-day competition, sleds were tested for design, noise, exhaust emissions, fuel economy, cold-start ability, acceleration, safety, handling and braking.

The UI sled finished ninth out of 17 entries. However, the team proudly finished first place in the oral presentation and second place in the competitions for acceleration and for static display.

"The team did well because our work is cutting edge and the students are knowledgeable and enthusiastic about what they are doing. The placing in acceleration shows they were able to maintain the performance of a stock snowmobile while reducing pollution emissions and improving fuel economy. The UI direct-injection snowmobile showed the potential of DI technology for use in recreational vehicles—that it is possible to maintain the power-to-weight ratio, light weight and handling characteristics of conventional snowmobiles while meeting snowmobile emissions standards and improving fuel economy."

Karen Den Braven, principal investigator

Designing a Two-Stroke Engine with Greater Fuel Efficiency

The characteristics that make two-stroke engines mechanically simple also cause them to have poor fuel economy, poor low load operation, and high exhaust emissions. These problems are caused by the way the air/fuel mixture is introduced into the engine's combustion chamber. Scavenging is the process of emptying the cylinder of burned gases and replacing them with a fresh mixture (of air). During the scavenging process, the intake and exhaust ports are open at the same time and a portion of the fresh air/fuel charge is lost out the exhaust pipe, or "short-circuited." Toward the end of the scavenging process, there can be a back flow of fresh charge and exhaust gas residuals into the combustion chamber due to the ramming effect of tuned exhaust pipes.

Direct-injection can lessen the effects of charge and exhaust gas mixing, and significantly reduce, if not eliminate, short-circuiting. It can also improve cold start reliability. Although direct-injection is considered the best technology available to reduce emissions from two-stroke engines, many obstacles need to be overcome for a gasoline direct-injection (DI) system to be successful in a snowmobile application. The injectors need to be able to atomize the fuel quickly and completely to ensure unburned hydrocarbon UHC emissions are kept to a minimum. The shape of the combustion chamber needs to be changed significantly in order to have a combustible mixture near the spark plug during ignition. Additionally, the engine should have a multiple spark discharge system to ensure that a spark event occurs when a rich mixture is near the spark plug. Another factor limiting the development of high power-output DI two-stroke engines is the fact that these engines operate at high engine speeds.

Rather than using snowmobiles from previous successful competitions, the UI team developed a new DI snowmobile engine. A battery-less direct-injection system was used to decrease exhaust emissions and improve fuel economy without reducing the power output of the engine. A spiral exhaust silencer was used to reduce exhaust noise. Under-hood noise was reduced by using sound absorbing materials and a sealed hood. Chassis noise was addressed by using a spray-on rubberized material that absorbs vibrations transferred through the chassis. Power transfer and space issues were addressed with the addition of a direct-drive system that eliminated the jackshaft.

The clean snowmobile team members proudly display their sled at the 2005 competition. (Photo used with permission from KRC/MTU)

Project: A Novel Continuous Flow-Reactor Using Reactive Distillation Techniques for Economical Biodiesel Production

Principal Investigator: Brian He

Outcomes:

- Better understanding of process parameters for a new biodiesel reactor technology
- A bench-scale reactive distillation (RD) reactor system was constructed and tested
- A proposal based on the project results was submitted to the USDA National Research Initiatives competitive grants. While it was not funded, it ranked as "high priority" and was in the top 7 percent of the 198 proposals in the category and will be re-submitted in FY06.
- Four presentations were given at regional and national technical conferences and three manuscripts based on this project were submitted to a refereed lournal and are under review

The gas chromatograph in the Biofuels Research Laboratory. Gas chromatography is a fundamental analytical technique that separates mixtures into individual components so that they can be identified and quantified.

NIATT Biodiesel Production Research Continues

Biodiesel from seed oils has attracted increasing interest from researchers and the public. It has been shown to be the best substitute for fossil-based fuels due to its environmental advantages and the fact that it is renewable resource available from vegetable oils. Several studies have shown that biodiesel is a better fuel than fossil-based diesel in terms of engine performance, emissions reduction, lubricity and environmental benefits.

Increasing popularity of biodiesel has generated great demand for its commercial production methods, which in turn calls for a technically and economically sound reactor technology. Most of the existing biodiesel processes requires at least 100 percent excess alcohol for complete transesterification of seed oils into alkyl esters (biodiesel) and glycerol (by-product), which has to be recovered and purified through rectification and distillation for reuse. This project explored the applicability of a homogenous reactive distillation technique for transesterification of seed oils for biodiesel preparation. This novel biodiesel reactor technology was thoroughly studied with a laboratory-scale RD system. Process parameters were examined and optimized.

The RD reactor process was found to be feasible for the continuous production of biodiesel from seed oils. The original objective of making the process more efficient by reducing the alcohol-to-oil molar ratio was realized. A 66 percent reduction in the industrial standard of 6:1 alcohol to oil molar ratio was achieved with good results. It is concluded based on the experimental results that the operating the RD system at 65ºC with a 4:1 molar ratio and a pre-reactor was the optimum point for producing biodiesel from among the parameters examined in this study. Other parameters such as residence time and methanol distribution in the column will be studied in the next phase of this project.

"This research has generated a great interest among the biodiesel research community and industry. The project investigators have been contacted a number of times by other researchers and developers about many times for the possibilities of using this technology in their biodiesel production facilities."

Brian He, principal investigator

SECTION 4: Technology Transfer

One of the most significant outcomes of NIATT's research is the development and transfer of technology products that are useful to others and that meet national, regional, and state priorities. Likewise, the resulting knowledge base will be transferred to operating transportation agencies, research laboratories, and private commercial ventures.

Sustainable Transportation: On Campus and in the Community." NIATT is sponsoring a conference on sustainable transportation that will be held in September 2005 (see page 37).

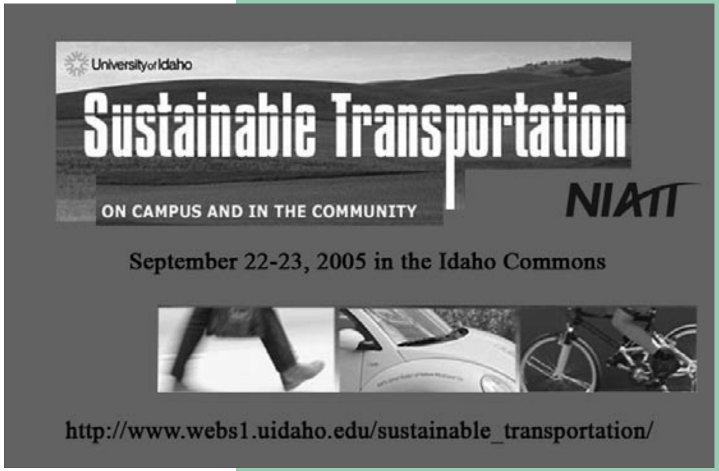
Advance Vehicle Concepts Team members showed their design vehicle at several locations and presented the results of their research at several conferences (see page 38)

NIATT's Idaho Technology Transfer Center conducted a workshop on a new strategic plan in February 2005 (see page 39).

Researcher Judi Steciak testified before the Idaho legislature on emission standards in the Boise metropolitan area (see page 40).

NIATT researchers are planning the 44th annual Idaho Asphalt Conference (see page 40).

Project: Conference to Examine Transportation Sustainability Issues



Principal Investigator: Michael Kyte

Outcomes:

- Concept plans for new Sustainable Energy Laboratory Building
- Plans for introducing sustainable transportation concepts into the university curriculum
- Plans for including sustainability into campus and community systems
- Plan for commercializing biodiesel production in North Idaho and Eastern Washington

NIATT, in collaboration with UI President Tim White, is sponsoring a two-day conference on Sustainable Transportation: On Campus and in the Community, scheduled for the UI campus on September 22 and 23, 2005. More than just a conference, five working groups will consider the following questions:

- How can we make transportation to and within the University of Idaho campus more sustainable and environmentally-friendly?
- How can we design and build a Sustainable Energy Laboratory and Transit Facility?
- How can we integrate sustainability into our curriculum?
- How can we use sustainability concepts in land use and transportation decisions within the Moscow community and region?
- How can we develop a biodiesel fuel production facility on the Palouse?

Each workshop will begin with one or more presentations highlighting the topic and the assigned problem or task, the process by which the problem or task will be tackled, and a set of possible outcomes for the workshop. Our focus is on learning and producing tangible results that can be carried forward after the conference.

The conference will open with presentations from guest speakers with recognized expertise in different fields of sustainability. UTC funds will be used to supplement other conference sponsorships.

The heavy hydraulic on display at EPA headquarters in Ann Arbor, Michigan.

Students Take Research on the Road

NIATT's prototype hydraulic-hybrid pickup truck (see page 27) has been displayed several places in Idaho. The truck debuted in September 2004 at the Idaho Engineering Lab Science and Engineering Expo in Idaho Falls and at the Idaho Transportation Department's conference on transportation investment in Boise, Idaho.

Three students involved with the hydraulic-hybrid research attended the Society of Automotive Engineers World Congress in Detroit in March 2005 to promote NIATT and the hydraulic hybrid project. The students shared a booth with AmeSIM, the corporate sponsor of the project.

The heavy duty hydraulic truck, nicknamed "BUFF" was displayed with other UTC/NIATT projects at the UI's Engineering EXPO in May 2005. Two members of the senior design team gave NIATT's hydraulic hybrid 1988 Ford F350 a real test this summer, driving it from Moscow, Idaho, to Ann Arbor, Michigan, where EPA experts had a chance to learn about the project

Idaho Technology Transfer Center Conducts Planning Workshop

The Idaho Technology Transfer (T2) Center, under director Douglas Moore, completed a two-day workshop in February 2005 to study how we can do our job of training and education more effectively for the transportation community in Idaho.

The workshop included representatives from Local Technical Assistance Program T2 centers from Connecticut, Louisiana, Minnesota and Florida, two FHWA representatives and three representatives from the Idaho Transportation Department (ITD). Dave Ekern, ITD director, participated in the planning session, emphasizing his commitment to training for ITD. The T2 Center is working with ITD to determine how ITD's training needs can be more effectively met by the T2 Center.

Planning Workshop Participants

- Douglas Moore, Idaho T2 Director
- David Ekern, Director, Idaho Transportation Department
- Susan Simmons, Administrator, ITD Administration Services Division
- Greg Laragan, Assistant Chief Engineer, ITD
- Stephen Moreno, FHWA Administrator
- Bill Evans, LTAP Manager, Federal Highway Administration
- Tom Nigh, T2 Board Chairperson
- Joe Haynes, Local Highway Technical Assistance Council Administrator
- Marie B. Walsh, Louisiana LTAP Director
- Gib Peaslee, Florida LTAP Co-Director;
- Donna M. Shea, Connecticut LTAP Program Director
- Cheri Marti, Minnesota LTAP Program Manager
- Bruce Drewes, Idaho T2 Training and Research Director
- Ruthie Fisher, T2 Administrative Assistant
- Irma Sixtos, T2 Administrative Assistant
- Michael Kyte, NIATT Director

Participants interact during the T2 planning workshop.

NIATT Researcher Testifies before Environmental Affairs Committee

NIATT researcher Judi Steciak, a mechanical engineering professor at the UI Boise Center, testified at a hearing of the Idaho Legislature's Environmental Affairs committee about Idaho House Bill 714. The bill would expand vehicle emissions testing to counties with populations exceeding 125,000.

An article in *The Idaho Statesman* quoted Steciak: "All cars pollute, but those that spew more pollutants than normal usually have mechanical problems that can be fixed, such as bad spark plugs, a faulty fuel injector or worn piston rings. A small number of cars cause the most pollution" Steciak noted that emission testing "makes sense."

Transportation and fuels are part of the pollution problem in Canyon County, part of the Boise metropolitan area air-shed, for which this legislation is aimed. Steciak can speak with authority about fuels, since she and co-researcher Steven Beyerlein have been conducting research with UTC funds since 1998 involving alternative fuels and catalytic ignition, with the aim of cleaner vehicles (KLK312, KLK315, KLK316, KLK317, KLK319, KLK342 and KLK346). More than 100 undergraduate students have worked on these projects.

44th Annual Idaho Asphalt Conference in October 2004

The Idaho Asphalt conference is held in October every year in Moscow, Idaho under the auspices of the University of Idaho, the Asphalt Institute, and the Idaho Transportation Department. The conference addresses issues related to asphalt pavements that are of concern to local and state governments as well as consulting and engineering firms. Attendees including contractors and material suppliers have found this conference to be a good forum to address design, construction and management issues.

NIATT researcher Dr. Fouad Bayomy is one of four conference committee members who work hard to bring speakers to cover wide range of practice, from street applications to state-of-the-art developments in the asphalt pavement technologies. Among the speakers at this year's conference were Dr. Bayomy, NIATT researcher James Kingery, and NIATT graduate student Ahmad Abu Abdo.

SECTION 5: Reinvesting to Improve Laboratory Facilities

NIATT uses indirect cost reinvestment funds to improve transportation laboratory facilities.

- Small Engine Laboratory
- Biofuels Research Laboratory
- Traffic data collection equipment

Small Engine Research Facility

Improvements to the Small Engine Laboratory (SEL) will be made using returned indirect cost funds. The improvements include a state-of-the-art eddy current dynamometer and a new five-gas emission analyzer that will be used to test NIATT's new snowmobile designs. Funding for these improvements will also come from the College of Engineering, the Mechanical Engineering Department, and the Idaho Department of Water Resources.

Snowmobile and two-stroke engine manufacturers are interested in working with NIATT for co-development of next generation engine technology. In addition, outfitters have contracted with NIATT researchers to perform emissions testing showing compliance/excellence in meeting pristine/sensitive area standards. NIATT also actively collaborates with a number of organizations promoting catalytic ignition systems that can support combustion of alternative fuels. The upgraded capabilities in SEL will allow NIATT to take advantage of the opportunities with these groups for future research.

Having a modern engine research facility also improves the educational experience for students and provides them with a competitive advantage when they enter the workplace. The equipment will also aid in the success of student senior design projects.

Gas Chromatograph for the Biofuels Research Laboratory

A new gas chromatograph for the analysis and quality control of biodiesel fuels was purchased with $21,102 of NIATT returned indirect cost funds. Also supporting the purchase of the chromatograph were the College of Engineering ($5000), the Department of Biological and Agricultural Engineering ($5000), and the College of Agricultural and Life Sciences ($5000). UI researchers are noted nationally for their development of biofuels.

The instrument has features needed to perform high quality biodiesel research, thus improving NIATT's research infrastructure. The chromatograph will allow us to provide much needed support to new biodiesel plants as they start-up, develop and refine their processes. Additionally, the machine will greatly increase the analytical capabilities to the Biofuels Research Laboratory and its competitiveness in acquiring external funding in the future.

Improving NIATT's Competitive Edge by Expanding Data Collection Ability

A new data collection system will be funded by NIATT and the UI's department of civil engineering. Two systems will be purchased: a server-based system for use with a set of field-deployed cameras and a remote system for single camera installations. The data collection systems will make NIATT more competitive in data-intensive nationally funded research projects, such as those funded through the National Cooperative Highway Research Program.

The Civil Engineering Department donated $10,000 to supplement NIATT's $38,900.

SECTION 6: Research Project Status

Projects Begun in FY05-Year 7

KLK220 Traffic Signal Summer Workshop V
Principal Investigator: Michael Kyte

KLK236 Controller Interface Device Software Documentation
Principal Investigators: Brian Johnson; Richard Wall

KLK237 Area-Wide Performance Measures for Traffic Signal Systems
Principal Investigators: Michael Dixon and Ahmed Abdel-Rahim

KLK238 Experiments in Modeling Urban Surface Transportation Network Dependability and Security
Principal Investigators: Ahmed Abdel-Rahim; Paul Oman; Brian Johnson

KLK239 Traffic Signal Operations Case Studies
Principal Investigator: Michael Kyte

KLK240 Remote Access Laboratory for Testing Advanced Traffic Signal Systems: Operational Manual and Application Guide
Principal Investigator: Ahmed Abdel-Rahim

KLK241 Plug-n-Play Smart Sensor Traffic Signal Systems
Principal Investigators: Richard Wall; Brian Johnson

KLK242 Traffic Signal Summer Workshop VI
Principal Investigator: Michael Kyte

KLK340 A Novel Continuous-Flow Reactor Using Reactive Distillation Techniques for Economic Biodiesel Production--Stage 2
Principal Investigator: Brian He

KLK346 Characterization of Catalytic Igniter Performance and Emissions
Principal Investigators: Judi Steciak; Steven Beyerlein

KLK347 Construction of a Direct-Injection, Two-Stroke Snowmobile for Competition in the SAE Clean Snowmobile Challenge
Principal Investigator: Karen Den Braven

KLK348 Hybrid Heavy Weight Vehicles
Principal Investigators: Donald Blackketter; Steven Beyerlein

KLK349 Safe Adaptive Supplemental Restraint Systems
Donald Blackketter; Karl Rink

Projects Continuing in FY05

KLK230 Development of Traffic Signal Operations Case Studies

KLK231 Applying the TRANSIMS Modeling Paradigm to the Simulation and Analysis of

KLK232 Maximizing Data Quality to Optimize Traffic Signal System Performance

KLK233 Applying Safety-Critical Fault Tolerant Principles to Survivable Transportation Control Networks

KLK234 Assessing Intelligent Transportation System Educational Needs

KLK235 Expanded Controller Interface Device I/O and Software Capabilities

KLK328 Comparison of Esterified and Non-Esterified Oils from Rapeseed, Canola and Yellow Mustard as Diesel Fuel Additives

KLK342 Small Engine Laboratory Support for Multi-Fuel Performance and Emissions Testing

Final reports are available on the NIATT website in both html and Adobe Acrobat formats.

Projects Completed

KLK201 Development of Controller Interface Device for Hardware-in-the-Loop Simulation

KLK202 Actuated Coordinated Signalized Systems: Phase I—Oversaturated Conditions; Phase II: Cycle-by-Cycle Analysis

KLK203 Development of Video-Based and Other Automated Traffic Data Collection Methods, Phase II

KLK204 Development of Internet-Based Laboratory Materials: Phase II—Computer-Assisted Traffic Analysis Training

KLK205 Traffic Signal Summer Workshop II

KLK206 Traffic Controller Laboratory Upgrade

KLK207 Development of Traffic Signal Training Materials Integrating Hardware-in-the-Loop Simulation

KLK208 Software Maintenance Support for Current Generation Controller Interface Device

KLK209 Next Generation Controller Interface DeviceKLK210 Modeling Real-Time Highway Traffic Control Systems

KLK211 Traffic Signal Summer Workshop III

KLK212 Development of Guidelines for Designing & Implementing Traffic Signal Control Systems

KLK213 Engineering Design Problems

KLK214 A Remote Access Hardware-in-the-Loop Simulation Laboratory

KLK215 Assessing the Security and Survivability of Transportation Control Networks

KLK216 CID Road Map

KLK217 Traffic Signal Summer Workshop IV

KLK302 Advanced Vehicle Concepts Team Electric Vehicle: Phase II: FutureTruck 2000, 2001

KLK303 Alternative Powered Snowmobile Development (FY01)

KLK304 Alternative Power Snowmobile Development (FY02)

KLK305 Vehicle Performance Simulation, Phases I-II

KLK306 Vehicle Performance Simulation, Phase III

KLK308 A Parallel-Hybrid Sport Utility Vehicle (FutureTruck 02)

KLK309 Clean Snowmobile 03

KLK310 Biodiesel Fuel from Yellow Mustard Oil, Phase I

KLK311 Biodiesel Fuel from Yellow Mustard Oil, Phase II

KLK312 Catalytic Ignition

KLK314 Mentorship and Performance Assessment of Design Teams in Transportation-Related Projects

KLK315 Spark Ignition Engine Conversion to Aquanol Fuel

KLK317 Diesel Engine Conversion to Aqualytic Fuel—Phases I-II (Homogeneous Charge Combustion of Aqueous Ethanol)

KLK318 Reactor Studies of Water-Alcohol Mixtures, Phase II

KLK319/KLK320 Catalytic Ignition of Aquanol in Reactor, Engine and Vehicle Environments

KLK321 Optimal Design of Hybrid Electric-Human-Powered Lightweight Transportation

KLK323 Idaho Engineering Works

KLK325 FutureTruck 03

KLK327 Essential Elements in Teaming: Creation of a Teaming Rubric

KLK330 Advanced Lead Acid Battery Development

KLK331 High Performance Auxiliary Power Units, Phase II

KLK341 Design and Construction of a Direct-Injection Two-Stroke Snowmobile for Competition in the 2004 SAE Clean Snowmobile Challenge

KLK343 A Novel Continuous-Flow Reactor Using a Reactive Distillation Technique for Economical Biodiesel Production

KLK344 A Parallel-Hybrid Electric-Hydraulic Sport Utility Vehicle: FutureTruck 2004

KLK345 Failure Mode Investigation and Ballistic Performance Characterization of Pyrotechnic Initiators Used in Automotive Supplemental Restraint Inflation Systems

SECTION 7: Funding Sources and Expenditures

Each fiscal year that NIATT has been a University Transportation Center, it releases an RFP to researchers at the University of Idaho affiliated with both the Center for Traffic Operations and Control (CTOC) and the Center for Clean Vehicle Technology (CCVT).

Responses to the RFPs are reviewed by NIATT's peer review panel members and recommendations on funding from those peers are reviewed by Michael Kyte, NIATT director and acting director of the CTOC, and the current director of the CCVT.

Approved projects receive a specified amount of funding for the fiscal year. Expenditures on research projects during the period July 1, 2004 and June 30, 2005 totaled $792,565. Figure 6 illustrates the categories in which those funds were expended. That a significantly large percentage of UTC funds were (and have been) used to support undergraduate and graduate student research is a hallmark of NIATT's program.

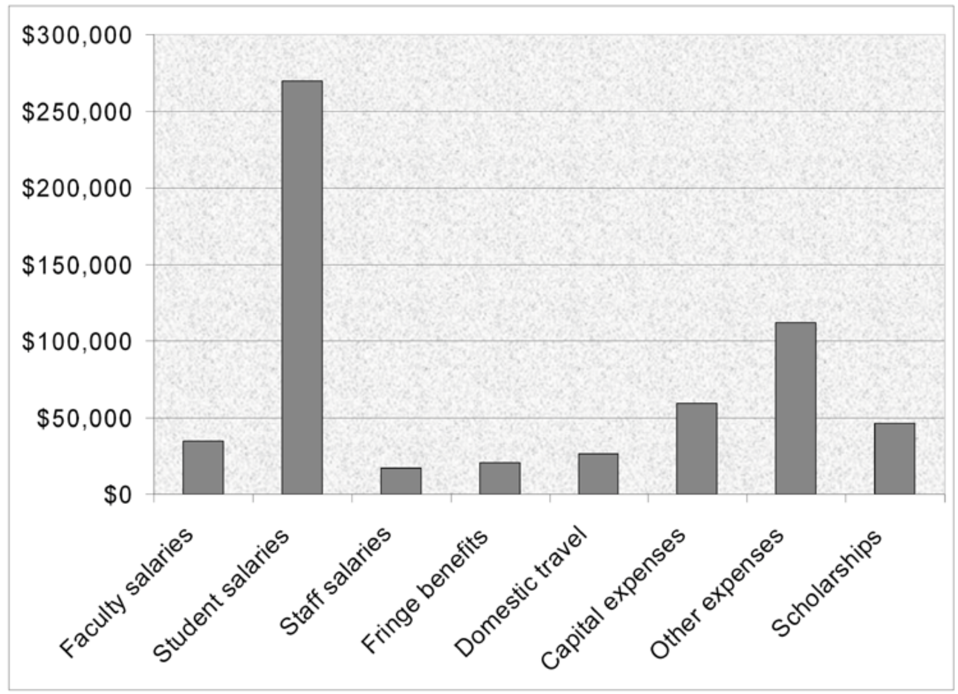


Figure 6: NIATT expenditures of UTC funds in FY05

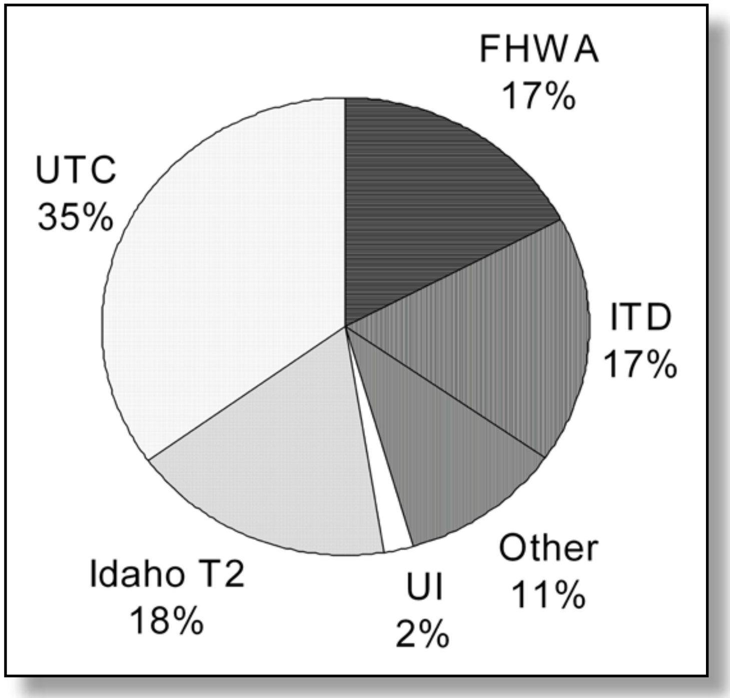


Figure 7   Source of funds for research and training expenditures

In FY05, NIATT expenditures on research and training reached $2,269,961. Figure 7 shows the sources of those funds.

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