TRANSCEND

Development of a Cold Region, Rural Transportation Research Testbed in Lewistown, Montana

Final Project Report

by

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prepared for

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The authors would like to thank the many local, state, and federal partners who helped develop the TRANSCEND research facility and support the numerous research projects that have been conducted there.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report summarizes a multi-year effort to develop, construct, and utilize TRANSCEND, a cold region, rural transportation research test bed facility at the Lewistown, Montana airport. Starting in 2003, the Western Transportation Institute at Montana State University (WTI) and the Montana Department of Transportation (MDT) worked with local, state, and federal partners to develop field research initiatives at the site. In 2007, through the sponsorship of the Research and Innovative Technologies Administration of the U.S. Department of Transportation, the partners initiated a comprehensive research program at the site.

Preliminary tasks included completion of a review of other large scale transportation research facilities, a needs assessment to document existing conditions and facility requirements at the site, and the creation of an advisory committee to guide research activities. Partners constructed and deployed new facilities and infrastructure at the site, including a pump house, office/shop, water storage reservoir, well system, high pressure water main, electricity and power lines. Additional infrastructure installed or deployed over life of project included a snowmaking system, a weather station, communications systems, and a storage building.

Eight testbeds were installed and utilized for research activities:

- Road-animal Detection System Testbed
- Driver Training Track
- Winter Testbed
- Corrosion Testbed
- Subgrade Stabilization Testbed
- Roadside Vegetation Testbed
- Rural Vehicle Communication Systems
- Alternative Materials Testbed

More than 10 research projects were conducted primarily or in part at TRANSCEND. In addition, the team conducted extensive technology transfer using tools that included brochures, virtual tour, website, tradeshow, and video clips. Staff also conducted in-person outreach through presentations, tours, field trips, and participation in national forums.

TRANSCEND has established and demonstrated capabilities to investigate numerous transportation issues of critical importance to rural areas and cold regions, including: wildlife-vehicle collision reduction, defensive driving skill development, safe and sustainable winter road maintenance, rural communication capabilities and infrastructure, highway design and construction techniques for cold regions, and roadside reclamation and erosion control. Emerging issues that may benefit from field research at TRANSCEND include: research related to the impact of climate change; dust management; gravel road construction, maintenance and performance; pavement construction maintenance; accelerated testing; and accelerated construction techniques.

INTRODUCTION

This report summarizes a multi-year effort to develop, construct, and utilize TRANSCEND, a cold region, rural transportation research test bed facility at the Lewistown, Montana airport. The Western Transportation Institute at Montana State University (WTI) and the Montana Department of Transportation (MDT) have worked with Fergus County and the Airport Authority since 2003 to develop field research initiatives at the site. The focus of this report is the development of a comprehensive facility and research program, which began in 2007 through the sponsorship of the Research and Innovative Technologies Administration of the U.S. Department of Transportation. This document summarizes planning and construction of the site, capabilities, research activities, and technology transfer and outreach initiatives. In addition, the report discusses potential next steps and future utilization of the facility.

Background

For a number of years, part of the airport complex in Lewistown, Montana has been closed to air traffic. Originally, this large facility was used to train WWII pilots, but has since been used by citizens as a quarter-mile drag strip in the summer and by the Montana Office of Public Instruction (OPI) to conduct workshops and train emergency medical service personnel, school bus drivers, law enforcement, and other Montana Department of Transportation (MDT) staff. In the spring of 2003, the Airport Authority and Fergus County Commissioners asked the Western Transportation Institute (WTI) to determine whether an underutilized portion of the Lewistown airport facility would be useful to conduct full-scale transportation-related research projects.

WTI and the Montana Department of Transportation (MDT) identified many projects that had the potential to improve transportation not only in Montana, but also in other cold and rural regions. WTI began outreach, planning and partnership development activities to initiate a more detailed implementation plan to conduct research at the Lewistown airport, while MDT reconstructed portions of the old runways to literally "pave the way" for additional research projects. Through these preliminary collaborations, WTI and MDT launched two research projects at the Lewistown airport: the *Road-Animal Detection Systems (RADS)* testbed and an evaluation of the *Effects of Defensive Vehicle Handling Training on Novice Driver Safety* (testbeds and research are described in more detail in the Capabilities and Research chapter).

In 2005, U.S. Senator Max Baucus (D-Montana) secured funds through the federal transportation bill (SAFETEA-LU) to further develop the facility. The grant provided approximately $4.2 million from 2006 to 2012 to create a prioritized, funded research program at the facility, and establish Montana as a national and international leader in cold region rural transportation research.

Goals and Objectives

The overall goal of this effort was to design, build and implement a state-of-the-art, multidisciplinary research facility capable of addressing multiple transportation challenges in a natural, cold-region research environment. The facility would serve the needs of researchers interested in:

- Studying how transportation challenges specific to cold, rural environments interrelate on a single road segment.
- Researching multiple aspects of an issue not only at the same location, but also at the same time.
- Investigating multi-disciplinary transportation challenges in a full-scale environment without interfering with or affecting the traveling public.

To achieve this goal, WTI and its partners identified specific objectives to develop the existing resources at the Lewistown airport into a large-scale, field laboratory:

- Evaluate other comparable research facilities in order to assess needs, identify potential partnerships, and minimize redundancy.
- Assess existing conditions and conduct a thorough needs assessment.
- Assemble key partners who can help establish strategic direction, secure additional funding, and build a foundation for long-term viability.
- Construct and deploy key infrastructure and equipment.
- Identify, prioritize and conduct research projects that address recognized transportation challenges.
- Conduct technology transfer, outreach and marketing initiatives that share research results, identify potential research partners, and establish the facility as a leading, national research center on cold region transportation issues.

REVIEW OF OTHER FACILITIES

In 2007, researchers prepared an inventory of existing large-scale transportation research test facilities to generate ideas about which types of infrastructure may be a higher priority at TRANSCEND, to see and understand some of the lessons learned by other research organizations, and to ascertain how the research facility in central Montana could augment current research capabilities. The information in the inventory included detailed descriptions of four key facilities toured by researchers, as well as a synthesis of summarized information about 28 additional domestic and international transportation research facilities and test tracks.

By visiting selected facilities in person, researchers had the opportunity to learn about the history, current research activities, and infrastructure, as well as talk to personnel involved in the operations and maintenance. They toured the following facilities:

- Smart Road in Blacksburg, Virginia;
- MnROAD near Albertville, Minnesota;
- The Riverside Campus of Texas A&M University near Bryan, Texas; and
- Pennsylvania Transportation Institute's Research and Testing Track Facility in Bellefonte, Pennsylvania.

The four facilities varied considerably in size, organizational structure, and research approach. Smart Road is owned and maintained by the Virginia Department of Transportation, while being fully managed by the Virginia Tech Transportation Institute. TRANSCEND representatives found it to be an impressive example of the diverse transportation research opportunities available when meticulous planning and design culminate in the construction of a realistic highway test bed. Active research occurs on the Smart Road nearly every day and into the night. The infrastructure is extensive: a mechanical gate; various road bed designs; a large bridge; weather stations for snow, rain, and fog; roadway lighting; fiber optic communications and wireless LAN; cameras; and a reconfigurable intersection. For the planning effort in Lewistown, the Smart Road represented a goal of high-quality, diverse research for the effort in Lewistown. However, the size and scope of the facility required high construction, operation, and maintenance costs beyond the capacity of the seed money available for TRANSCEND.

MnROAD is a pavement research facility with high volume and low volume tracks and an extensive data acquisition and sensor network. This test bed represented a more realistic model for TRANSCEND based on the number of personnel employed and the data network. Additional potential similarities included the types of buildings constructed, the trucks and vehicles acquired, and the need for a qualified driver. However, the research scope is narrower and the facility is owned and operated by the state department of transportation instead of a university.

The Riverside Campus of Texas A&M University is built on an abandoned United States Air Force base and thus has some similarity to the Lewistown site with wide runways in triangular configurations. However, the campus totals 2,000 acres, almost ten times larger than the land available in Lewistown, and there were dozens of buildings existing when the university received the land. The variety of research and activities that occurs at this facility includes: emergency vehicle driver training at a 3.5 mile driving track; hydraulics, sedimentation, and erosion control in a large outdoor flume and indoor rainfall simulator; geotechnical research of sand and clay at two experimentation sites; transportation safety at a proving grounds research facility; and pavement research and profiler calibration/certification at a ride/rut facility. Texas A&M receives approximately $10,000-$15,000 in annual legislative appropriations for overhead and maintenance at the Riverside campus test track. This remarkable level of sustainability served as an instructive model and important goal during the development of the facility in Lewistown.

The Pennsylvania Transportation Institute opened a Research and Testing Track Facility in the 1970s on 136 acres of land. Originally, research focused on road and bridge infrastructure and human factors. Bus testing for the Federal Transit Administration dominates the current activities at the track and employs half a dozen personnel for operations and maintenance. Other research that has taken place includes runaway truck ramps and crash testing. For the Lewistown effort, this facility illustrates how research at a test bed can evolve to meet the changing needs of the US Department of Transportation.

These four facilities demonstrate a variety of approaches to implementing large-scale transportation field test facilities, from basic goals and business strategies, to the infrastructure they have developed, to the manner and level of support they provide on a project-by-project basis. The approaches and lessons learned served as ideas and guidance for the development of TRANSCEND.

The second component of the inventory was a brief summary of 28 other domestic and international transportation research facilities and test tracks. This section provided an overview of the current research activities at each facility. The primary purpose was to guide research project selection in order to ensure that TRANSCEND was augmenting, rather than duplicating research efforts. The inventory provided summaries for the following domestic and international facilities:

Domestic Facilities

Alabama

- NCAT: National Center for Asphalt Technology

California

- UCPRC: University of California Pavement Research Center (UC Berkeley and UC Davis)
- BHL: Berkeley Highway Lab (UC Berkeley)

Florida

- Accelerated Pavement Testing and Research Program (Florida DOT)

Illinois

- ATREL: Advanced Transportation and Research Engineering Laboratory (Illinois Center for Transportation)

Kansas

- CISL: Civil Infrastructure Systems Laboratory (Kansas State University)

Louisiana

- LTRC: Louisiana Transportation Research Center

Michigan

- KRC: Keweenaw Research Center (Michigan Technological University)

Minnesota

- Advanced Driving Facility (St. Cloud State University)

Mississippi

- Waterways Experiment Station (US Army Corps of Engineers)

Nevada

- NATC: Nevada Automotive Test Center

New Hampshire

- CRREL: Cold Regions Research and Engineering Laboratory (US Army Corps of Engineers)

New Jersey

- William J Hughes Technical Center (Federal Aviation Administration)

Ohio

- ORITE: Ohio Research Institute for Transportation and the Environment (Ohio University)

Oregon

- Kiewit Center for Infrastructure & Transportation (Oregon State University)

Texas

- Pecos RTC: Pecos Research & Testing Center (Texas A&M University)

Virginia

- TFHRC: Turner–Fairbank Highway Research Center (Federal Highway Administration)

International Facilities

- Australian Road Research Board (Australia)
- Federal Highway Research Institute, BASt (Germany)
- COST 347 (European Union)
- Danish Road Institute – Danish Road Testing Machine (Denmark)
- Highway Engineering Research Group (HERG) University of Ulster (United Kingdom)
- Laboratoire Central des Ponts et Chausées (France)
- Laboratory of Traffic Facilities (LAVOC – Switzerland)
- Road and Railroads Research Laboratory – LINTRACK (The Netherlands)
- Public Works Research Institute (Japan)
- Road Research Center of Cedex (Spain)
- Swedish National Road and Transport Research Institute (VTI – Sweden)
- Transport Research Laboratory (TRL – United Kingdom)

The complete inventory is provided in the Appendix.

PLANNING

Existing Conditions

To develop the research facility, the Airport Board made approximately 230 acres of land with almost four miles of runways available to the Western Transportation Institute and project partners. For planning purposes, project staff conducted an inventory of the Lewistown site in 2007 to assess the condition of the runways and taxiways (referred to as runways), as well as the availability of buildings, power, water, and communications.

Runways

The runways presented diverse research opportunities. Portions of the track are currently being used by two other entities: the Lewistown Drag Racing Association (LDRA) and the Office of Public Instruction (OPI). LDRA conducts drag races during four or five summer weekends. OPI conducts an advanced driver training program called Driver In-Vehicle Education (DR.I.V.E.) for about 13 summer weeks. The location of LDRA and OPI activities and other notable features are labeled on the aerial photograph in Figure 1.

Approximately four miles of runways are available for WTI to use, particularly off-season of LDRA and OPI operations. Some of the available pavement was in good condition and immediately available for research. Other areas were unpaved, but could support low-volume, gravel road, and other research. The paved areas were generally unavailable during the summer, but additional runway sections and land could be used. The lengths and widths of the various tracks are provided in Figure 2.

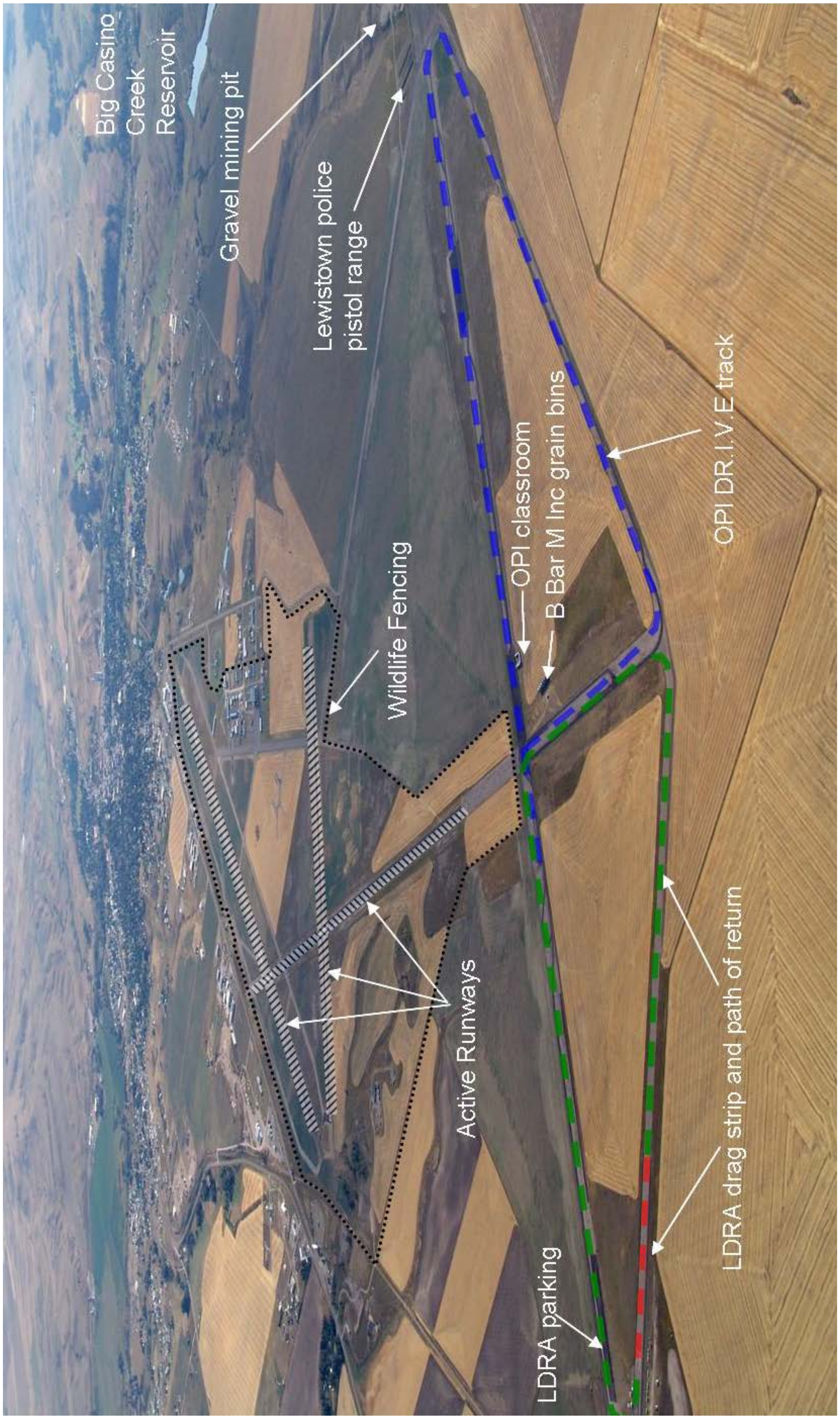

Figure 1: Existing tracks and facilities at the Lewistown airport.

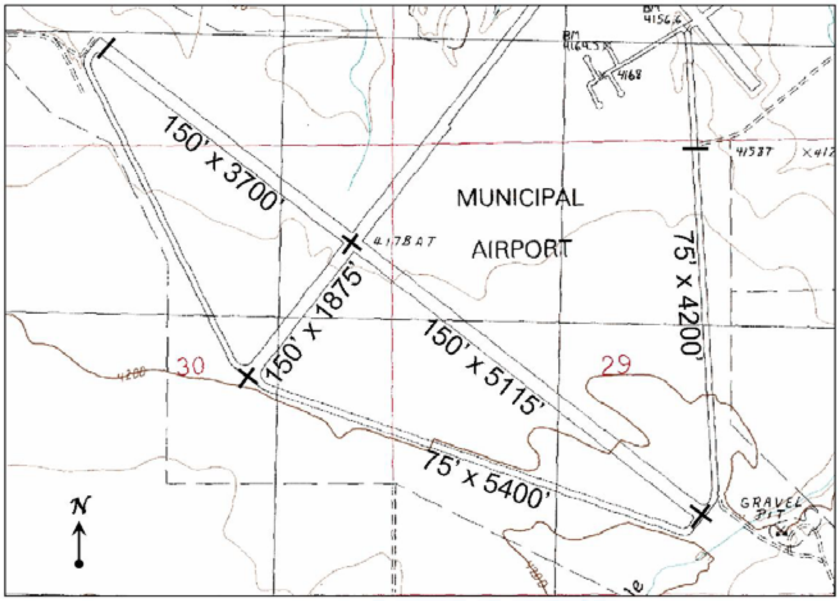

Figure 2: Width and length of the existing runways, in feet (width x length).

Buildings and Facilities

There were few building facilities located near the proposed research facility. The Montana Office of Public Instruction had three mobile trailers near the track. Additionally, the Central Montana Education Center had an office building, shop and garage space near the Lewistown airport (approximately 2 miles from the test site). However, the buildings lacked sufficient space for research needs at TRANSCEND.

Other physical infrastructure present at or near the Lewistown site included a small groundwater well near the Office of Public Instruction's buildings, and a weather station located at the active municipal airport. The existing water supply was not enough to support a snow-making facility. The weather station was a functional automatic surface observation system (ASOS); however, it was not located close enough to the test bed for research purposes.

Communications and Power Infrastructure

Two-phase power was available at the DR.I.V.E. facility. Additionally, single-phase power was extended to a suspended traffic signal about 1,000 feet towards the southeast. For the animal detection system project that was already underway at the time of the existing conditions assessment, single-phase power had already been extended about 1,000 feet from the DR.I.V.E. buildings to the testbed.

There was phone service and dial-up internet at the DR.I.V.E. facility (although OPI typically had the phone line turned off during the winter months). The Lewistown public school district has a broadband antenna located on a bus storage facility within the municipal airport property.

Summary of Existing Conditions

The results of this inventory indicated that significant improvements would be needed with respect to basic infrastructure needs, including a building, power, and water. Snowmaking equipment was planned for the site to provide snow for research and testing purposes. The associated hardware for the snowmaking system requires 3-phase power, which was not available at the site. Additionally, the water was not available for snow production. The other primary feature lacking was uniform pavement. In its original configuration, the driving track used by OPI had variable widths and was not necessarily straight, which could have limited its usefulness for research without first being improved.

However, the existing site and facilities essentially provided a large section of land that could be designed and developed to suit a variety of transportation research objectives. Developing and increasing infrastructure, water capacity, and power access would require time and resources, but would allow for customization to meet research needs.

Needs Assessment

Land

WTI negotiated a long-term agreement to lease the 230 acres of land offered by the Airport Authority. The land included 64 acres of runways and taxiways, and 167 acres of land adjacent to the OPI test track. The land adjacent to the track was needed to provide a location for power, water, and communication lines, as well as possible future expansions of research efforts.

WTI coordinated land use arrangements with the three existing lessees (OPI, LDRA, and a private farmer). WTI held the primary lease and negotiated subleases with other parties.

Facilities

After the land use arrangements were established, WTI identified initial facility needs to support cold region and rural transportation related research at the testbed:

- Pump Houses, Office, and Shop—WTI proposed the construction of several buildings. Two 200 square foot pump houses would be built to protect the high- and low-pressure pump assemblies and the computerized base control for the snowmaking system. The second building (approximately 2,800 square feet) would contain both office and shop space. The shop space, at 2,000 square feet, would accommodate vehicles and equipment. The other portion of the building would provide office space, a small conference room, restrooms, lounge, and kitchenette for research staff.
- Water Storage Reservoir—to support the snowmaking system, WTI proposed construction of a plastic-lined reservoir in an existing gravel pit on the airport property. The reservoir would have sides measuring 150 feet in length, a depth of approximately 14 feet, and a capacity of 1.3 million gallons of water.

- Groundwater Well System—WTI recommended development of a well system to supply water to the reservoir and the buildings. The system would provide approximately 15 acre feet or less of water per year, at a flow rate of 100 to 300 gallons per minute (gpm).
- High Pressure Water Main—WTI proposed to install a high pressure water main (500 psi), approximately 3000 feet in length, to transport water from the reservoir to the snowmaking equipment.
- Minor and research-specific facilities—WTI identified potential additional facility needs related to individual project requirements. Examples included pavement test sections, concrete work pads, fencing, and portable storage sheds.

Power/Communications Infrastructure

The research facility required upgrades to the existing utility infrastructure, in particular communication systems, electricity/power, and information/data systems.

Electricity/Power Backbone—Initially, WTI proposed the construction of power lines from the nearest present service location to supply electricity to the buildings and the snowmaking system. WTI also identified the potential need for additional power infrastructure to support the communication and data systems.

Communication System—WTI identified a need to develop a system for communicating within the facility, and also between the facility in Lewistown and WTI headquarters in Bozeman. Systems researchers assisted with the development of feasible alternatives (i.e. fiber optics vs. wireless). The system would be installed following construction of the shop/office building.

Data Acquisition Backbone—WTI recommended development of a data acquisition backbone, consisting of underground bunkers. The first bunker would be installed near the shop and connected with conduit to facilitate monitoring of the shop floor, with additional bunkers to be added and integrated later as needed.

Advisory Committee

Initially, WTI solicited input and guidance on the development of the research facility from an ad hoc advisory committee consisting of maintenance supervisors from departments of transportation in Montana, Idaho, Washington, and Oregon.

In the fall 2007, WTI identified and invited candidates to join a standing advisory committee, which officially formed in early 2008 with the following membership:

- Ed Adams, Montana State University
- John Blacker, Montana Department of Transportation
- Dennis Burkheimer, Iowa Department of Transportation
- Chris Christopher, Washington Department of Transportation
- Dick Hanneman, Salt Institute

- Scott Jackson, US Fish & Wildlife Service
- Wilf Nixon, University of Iowa and AIT
- Paul Pisano, Federal Highway Administration

WTI provided the Advisory Committee with quarterly updates on issues such as the lease, facility development, and upcoming research projects. Committee members provided valuable input on infrastructure design and requirements, research priorities, marketing and outreach. Other activities in which the Advisory Committee participated included:

- Field Trip—WTI hosted a field trip to the Lewistown site in July 2009 to provide tours and generate discussions about potential research opportunities and partnerships
- Webinar—WTI coordinated an interactive webinar with the Committee on February 24, 2010 to discuss research and marketing opportunities, potential new members, and new research areas.
- Meeting—WTI hosted a face to face meeting with the Committee August 23-24, 2010, which included tours of TRANSCEND, WTI, and COE/MSU. Members provided input and guidance on operations, research prioritization, marketing and partnerships.

Initial Marketing and Outreach Planning

Branding

In the summer of 2007, WTI contracted with a local marketing company (45 Degrees North, Inc.) to generate a name for the research facility. WTI and 45 Degrees North agreed that selection of a single, memorable name would help establish a presence, facilitate marketing and outreach, and eliminate confusion from inconsistent references to the project.

The name "TRANSCEND" was selected in early 2008. Shortly thereafter, the name was transformed into a logo, including a tagline: "open road to discovery: research, development, testing."

Figure 3: TRANSCEND logo and tagline.

The name and logo were immediately incorporated into early branding and outreach tools, such as the first brochure, which was released in mid-2008. The goals of all of these initial activities were to communicate the facility's message to potential partners or researchers, and help them visualize the test site without visiting it in person.

Marketing Plan

In addition to generating the TRANSCEND name and logo, a separate marketing company (O'Berry Collaborative) was contracted to lead the development of a marketing plan. The goals for the plan were to launch TRANSCEND, build awareness, establish strategic connections, and secure projects. The marketing plan was completed and approved in early 2010. Principal elements of the marketing plan included:

- Competition Analysis
- Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis
- Strategic Recommendations
- Branding Recommendations
- Marketing Recommendations, including the development of
    - Launch event (in December 2009)
    - Website
    - Newsletter
    - Trade show booth
    - Outreach video

Implementation of the marketing components will be discussed in greater detail within the Technology Transfer, Marketing and Outreach chapter.

CONSTRUCTION

Shop and Office

Design of the building to house research staff, communications and data acquisition equipment, and a workshop began in early 2007. After considering several building options, WTI selected a steel-framed building as the most cost-effective and functional option. Innovative design components included a floor constructed with 100 percent fly ash concrete and radiant heating. (Researchers at WTI had the opportunity to study curing of the fly ash material using embedded sensors to monitor temperature and strain.) Stahly Engineering and Associates designed and managed the construction of the office and shop building in collaboration with the Office of Facility Services (OFS) at Montana State University.

Foundations and slabs were constructed in mid-2008, followed by the steel frame in the fall of 2008. Principal construction was completed in March 2009, and WTI employees furnished and equipped the office and shop that summer. Some follow-up construction occurred, such as sidewalks (summer 2009), parking facilities and landscaping. The construction contractor reached final completion of the office/shop building on July 22, 2009. In 2011, additional construction was proposed to add office space to the shop building to better accommodate research staff working onsite. Construction of the additional office space and common area was completed during summer 2012. A photo of the shop and office is shown in Figure 4.

Figure 4: Office/shop building.

Snowmaking System

Design of the snowmaking system also began in early 2007. The system has three main components: the water supply and distribution system, the power supply, and the snowmakers.

Turbocristal (Quebec, Canada) was selected as the snowmaking equipment vendor, and also to provide consulting services during design and construction of the rest of the snowmaking system. Stahly Engineering and Associates completed the system design and managed construction activities, in collaboration with the Office of Facility Services (OFS) at Montana State University and a general contractor. As part of the snowmaking system, Turbocristal also supplied four fan guns with a combined snowmaking capacity of 8,000 cubic feet of snow per hour, one 200 horsepower water pump, one 75 hp water pump, control systems for the pumps and fan guns, eight water hydrants and electrical pedestals, and various other associated equipment.

A well (600 feet deep) was drilled in September of 2008 to provide water for the snow machines and municipal water for the shop; the well produced 80 gallons of water per minute during its pump test. Later that fall, the reservoir was constructed and filled with water (Figure 5), pipelines and hydrants were installed (Figure 6), the low-pressure and high pressure pump houses were constructed, and the pumps were installed. The snowmaking system was complete and operational in early 2009, with system start-up in February 2009.

Figure 5: Water reservoir (1.3 million gallons) to support snowmaking system.

Figure 6: Pipeline installation.

Weather Station

WTI purchased a new weather station (Figure 7) with meteorological sensors for air temperature, relative humidity, wind speed and direction, barometric pressure, and solar radiation in fall of 2007. In early 2008, a 20 foot tower was erected on a concrete base at the research facility site. Shortly thereafter, the weather station was installed on the tower, along with the necessary sensors. The weather station was operational and has been collecting data on a regular basis since June 2008. In the fall of 2008, additional sensors were installed to monitor the surface and subsurface pavement temperatures.

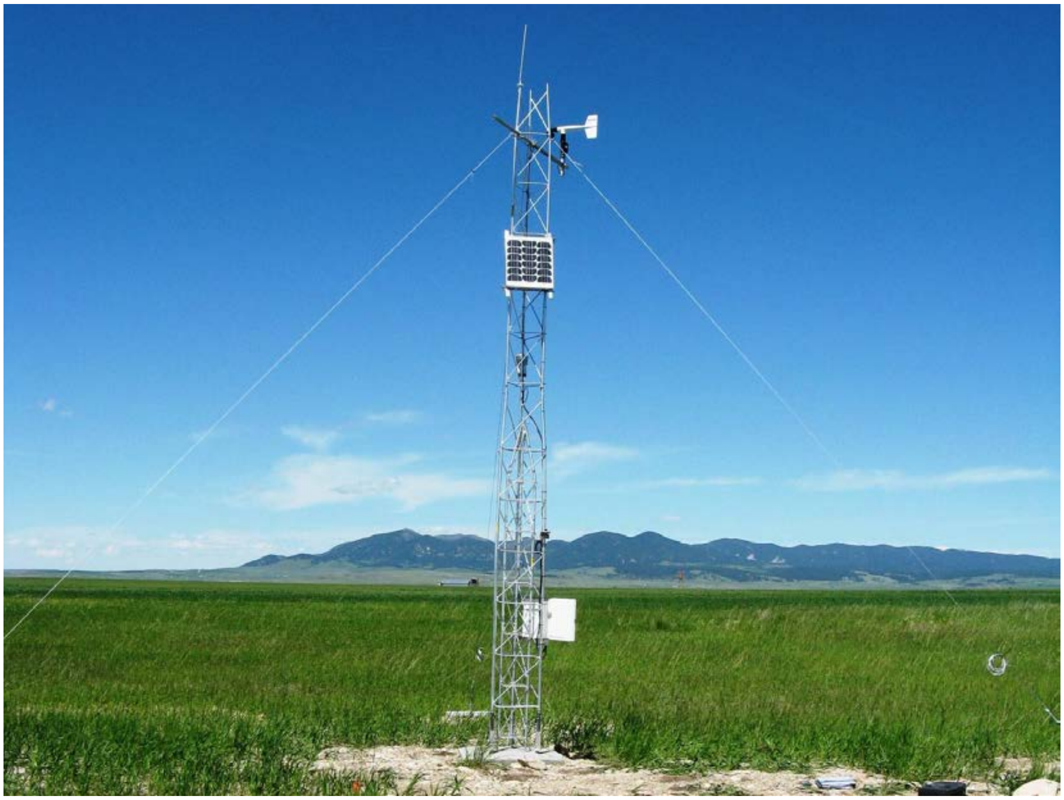

Figure 7: Weather station.

Storage Building

In early 2010, WTI began plans to construct an additional building to provide on-site storage for equipment and vehicles. A fabric building with 4,000 square feet of unheated space and minimal power capabilities was proposed. Lutey Construction of Bozeman constructed the 52 foot by 80 foot building, in collaboration with the Office of Facility Services (OFS) at Montana State University. The building was completed in January 2011; it is used to store large equipment, such as the snow plow, skid steer, and snowmaking equipment (Figure 8).

Figure 8: Storage building completed in 2011.

Utilities and Communications

Electricity/Power Backbone

Initial electricity and power system installations were designed and implemented in conjunction with the snowmaking system and the construction of the shop/office building. Power lines to provide three-phase power to the snowmaking system were installed in the fall of 2008. The shop was wired in the winter of 2008/2009.

Communication System

A temporary wireless internet connection was installed in the office/shop building in early 2009, to provide internet access for researchers. Also in early 2009, WTI staff members drafted design options for a more comprehensive communications infrastructure, which would facilitate communication within the facility, and also between the facility in Lewistown and WTI headquarters in Bozeman. Researchers investigated both wireless (unlicensed ISM band vs. licensed) and wired (fiber optic vs. copper cable) options.

In late 2009, WTI contracted with Stahly Engineering to design the communication system. The cost estimates for the preliminary design were much higher than anticipated; therefore, the team considered and pursued alternative communication modes. The revised design consisted of a centralized communications tower that would provide wireless communication between remote hardware on site and a data server in the shop. The server would be used to temporarily store data as well as act as a communications hub between TRANSCEND and WTI headquarters in Bozeman. Mobile trailers equipped with power, data acquisition, and communications equipment would be used to transmit information from anywhere in TRANSCEND to the server. Another advantage of this approach was that a robust wireless communication system would provide better support to TRANSCEND's large footprint than a hardwired communication system focused within one portion of the leased area.

In the fall of 2010, construction began near the shop on a 35 foot antenna tower, which would serve as the wireless communication hub (Figure 9). The tower was installed on a reinforced concrete foundation. The tower accommodates communications hardware for the weather station and a camera that can be remotely controlled from WTI headquarters in Bozeman.

Figure 9: Communications tower constructed in late 2010.

In the summer of 2011, an additional 10 foot section was added to the tower to improve visibility from the camera. The antenna was installed on the tower, and the server and other supporting hardware were integrated, making the tower operational. In subsequent months, radios and an

Ethernet module were added to provide wireless communication from the weather station to the shop. This connectivity allows staff at WTI headquarters in Bozeman to check real-time weather or other data collected at TRANSCEND.

Data Acquisition Backbone

WTI recommended development of a data acquisition backbone, initially consisting of a series of underground concrete bunkers adjacent to the runways and taxiways, connected by conduit. The layout was to be coordinated with the design of the communication system.

As described in the previous section, the communication system was redesigned in late 2009 to use a wireless system instead of a wired fiber optic system. This also resulted in a re-design of the data acquisition backbone. In 2011, when the wireless communication system was near completion, WTI purchased a suite of reconfigurable data logging and data acquisition systems to provide data collection hardware for projects. The equipment consisted of eight individual systems with varying data collection speeds and channel configurations to support a variety of research needs.

CAPABILITIES AND RESEARCH

Approach

The Advisory Committee worked with researchers at WTI to establish research themes for TRANSCEND. The themes were used to prioritize and select research projects, identify infrastructure needed to conduct research, and develop technology tools and programs, and identify potential research partners. Primary research focus areas included:

- Cold-region
- Safety
- Maintenance
- Materials
- Winter Maintenance
- Product Testing
- Driver's Performance/Training
- ITS Field Testing

Because the research themes guided both project selection and infrastructure development, they also influenced the ongoing development of TRANSCEND's testbeds and capabilities.

Testbeds

Most of the RADS testbeds were developed in response to specific project needs. Some are removed when projects are completed, while others can be easily adapted to subsequent efforts. A summary of testbed development and use is provided in Table 1.

Table 1: Summary of Testbed Development at TRANSCEND

Testbed Name/Capability	Project(s)	Updates/Changes
RADS	• RADS project (2006-2009) • Animal Detection System Sensor test	• Above-ground break the beam detection system added to testbed in 2012
Driver Training Track	• Effects of Defensive Vehicle Handling Training on Novice Driver Safety	
Winter Testbed	• Best Practices for Snow/Ice Removal on CA roadways • Evaluation of Friction Measuring Devices • PNS Inhibitor Longevity & Deicer Performance Study	
Corrosion	• Corrosion Testbed: Proof of Concept	
Subgrade Stabilization	• Field Investigation of Geosynthetics Used for Subgrade Stabilization • Pooled Fund Subgrade Stabilization Project	• Reconfigured and reconstructed from previous testbed in 2012.
Roadside Vegetation	• Projects still in planning phase	
Rural Vehicle Communication	• Roadside-to-Vehicle Communications Project	
Alternative Materials	• 100 percent fly ash concrete for TRANSCEND infrastructure • Fly Ash Concrete Test Pads to Assess Constructability and Durability • Reclaimed Asphalt Pavement (RAP) Concrete Test Pads	

Road Animal Detection Systems (RADS) Testbed

The Road-Animal Detection System (RADS) testbed was one of two research efforts already underway when the overall TRANSCEND development initiative was launched in 2006. The main objective of this project was to evaluate the reliability of different animal detection systems from different manufacturers at the same site under similar circumstances and to recommend minimum standards for system reliability. The Lewistown facility provided a controlled location to conduct these side-by-side tests and evaluation.

For the testbed, nine different animal detection systems from five different manufacturers were installed to detect horses and llamas that moved freely within a fenced enclosure. Data loggers recorded the date and time of each animal detection for each system. The animal movements were also recorded by six infrared cameras with a corresponding date and time stamp. By analyzing the images and the detection data, researchers were able to evaluate the system for a variety of reliability parameters.

Figure 10: RADS test bed with remote office, animal detection systems (attached to poles), the shelter, and a llama (photo courtesy of Marcel Huijser, WTI/MSU).

Figure 11: Sensors of the animal detection systems (photo courtesy of Marcel Huijser, WTI/MSU).

Figure 12: The infrared cameras that monitor animal movements in the enclosure (photo courtesy of Marcel Huijser, WTI/MSU).

The testbed was successfully used for the initial RADS project, which continued through 2008. In early 2012, the RADS testbed was enhanced, through the addition of an above-ground break the beam detection system that uses microwave radio signals. The new system was integrated with the existing array of sensors.

Road-Animal Detection System (RADS) Project

The RADS project began in 2006. Phase 1 of the project involved designing and implementing the backbone of the test-bed at the TRANSCEND facility, followed by the installation of selected animal detection systems. During Phase 2, WTI/MSU measured the reliability and the costs and benefits of the systems. For the final phase, Phase 3, several sites in Montana were reviewed for possible installation of the best performing animal detection system. Finally, the project provided tech transfer to transportation agencies, including FHWA and the Montana Department of Transportation (MDT), vendors of animal detection systems, the general public, and the scientific community.

The results of the reliability tests showed that different detection technologies detect large animals more or less frequently as an animal passes through the detection area or line of detection. The results suggest that some animal detection systems are quite reliable in detecting large mammals with few false positives and false negatives, whereas other systems have relatively many false negatives. The reliability of animal detection systems is also influenced by a range of environmental conditions, such as high winds, temperature and humidity.

As part of the project, researchers developed recommended performance requirements for the reliability of animal detection systems, which were compared to the results of the reliability tests. Five of the nine systems tested met the recommended performance requirements for reliability. Additional deliverables included a concept of operation and a review of Intelligent Transportation System (ITS) architecture and infrastructure for animal detection systems.

In early 2012, the RADS testbed was enhanced, through the addition of an above-ground break the beam detection system that uses microwave radio signals. Researchers conducted testing to evaluate the effectiveness of the new technology.

Driver Training Track

The Driver Training Track was the second testbed in place when the overall TRANSCEND development initiative was launched in 2006. It consists of a triangle-shaped 2.5 mile driving course constructed on a former runway (Figure 13).

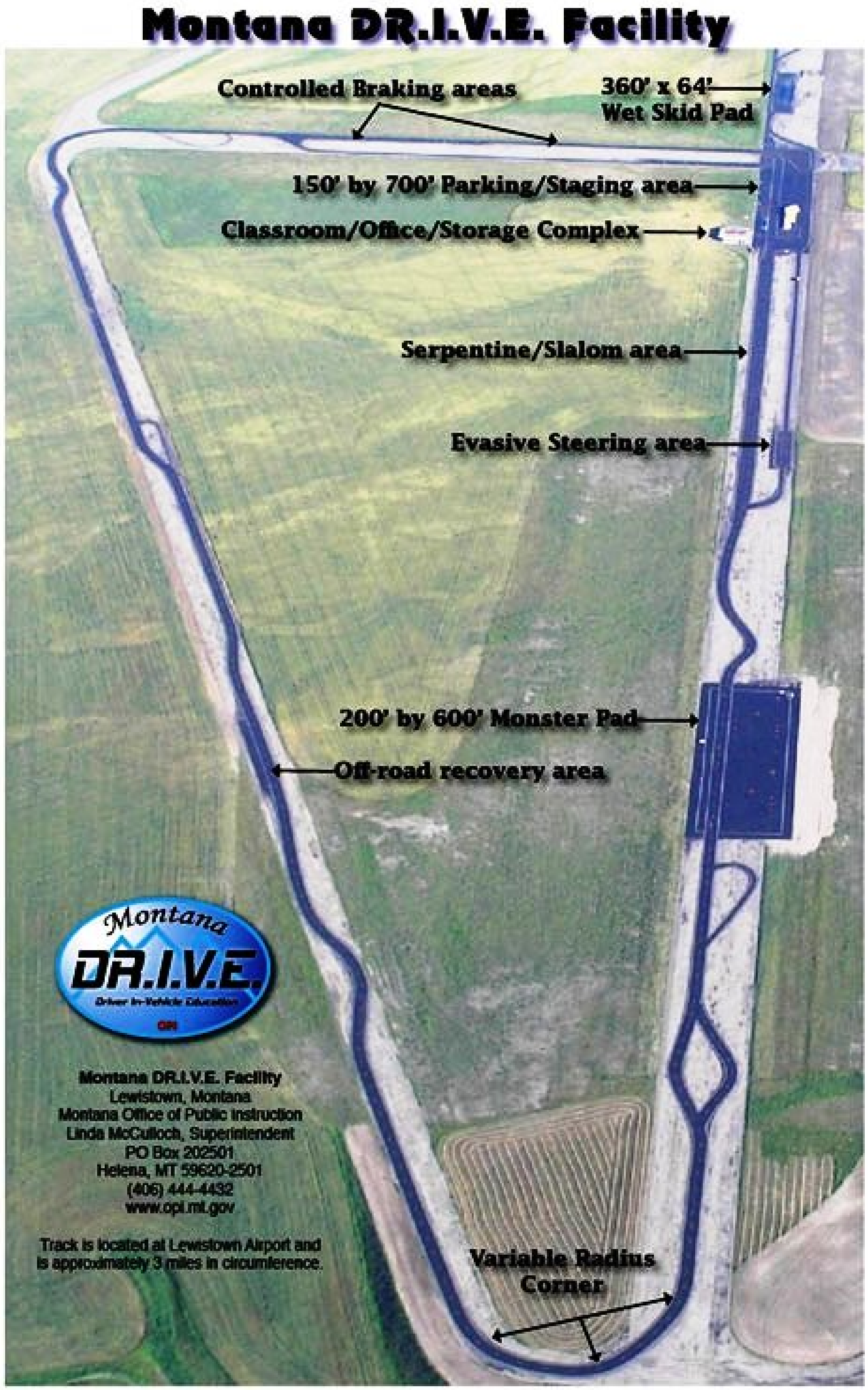

Figure 13: Driver training track.

Prior to the development of TRANSCEND, the Montana Office of Public Instruction was already using the track for an advanced driver training program. In 2004, MDT repaved the driver training track, in anticipation of expanded research and advanced driver training opportunities.

The test track has broad usage capabilities for a variety of training purposes (student drivers, commercial drivers, etc.) and product testing. For human factors research, the test track can be used as a controlled field environment, in order to validate laboratory and simulator research. For these purposes, the test track has been used in integrated research initiatives with WTI's driving simulator and fleet of instrumented vehicles.

Effects of Defensive Vehicle Handling Training on Novice Driver Safety Project

This project was part of a multi-phase research program to examine whether advance training for novice drivers could have a positive impact on decreasing accident rates. The first phase consisted of various curriculum development, coordination, and outreach tasks. Phase II was designed to compare two matched groups of novice drivers: one receiving only the standard driving course, and the other receiving an additional specially designed advanced defensive vehicle handling course.

The driver training for this effort was conducted at the TRANSCEND Driver Training Track. Participants received an intervention that involved a one-day classroom and behind-the-wheel workshop. For the behind-the-wheel instruction, students completed defensive driving exercises and challenges, utilizing three sedans equipped with SkidMonsters, two sedans equipped with levers to activate rear brakes, a regular sedan (Figure 14), and a mid-1990s suburban. At the completion of the day's training, each student received a tailored "report card" concerning their driving performance and exercises they could do on their own to further improve their driving skills.

This project enabled a Phase 3 effort, during which teens were tracked for four years following the project to determine the driving history comparisons of the control group to those who received the intervention. Reported accidents, violations, and driving experience were compared once per year during this monitoring period.

Figure 14: Student participating in SkidMonster behind-the-wheel instruction.

Winter Testbed

The following testbed focuses primarily on winter weather/cold region research challenges. Because of the multi-disciplinary approach to research at TRANSCEND, the capabilities of this testbed (in particular the snowmaking system) is sometimes used in conjunction with other testbeds or projects.

The snowmaking testbed is a key component of the research facility, and as such was the first testbed to be expressly designed and developed for installation at TRANSCEND. Design and development of the testbed began in 2007. The system is composed of water distribution pipelines, a 1.3 million gallon reservoir, a low-pressure pump system, a high-pressure pump assembly, and several snowmaking fan guns (Figure 15).

The snowmaking equipment makes about 8,000 cubic feet of snow per hour using 24,000 gallons of water, drawing from the reservoir. The low-pressure pump system pulls water from the bottom of the reservoir to the high pressure pump. The high-pressure pump system further pressurizes water to the hydrants and the snowmaking guns. A snowmaking event is shown in Figure 16.

The four fan guns are mobile and multi-positional, which increases the capacity to control variables and create a range of environmental condition scenarios, including snow, rain and ice:

- Snow making capacity is maximized when the temperature is below 25 degrees and the relative humidity is low.
- When the temperature is warmer, the snow guns can create a downpour of rain.

- At certain cold temperatures, the guns can be used to simulate an ice storm.

Figure 15: Fan gun snowmaker.

Figure 16: Man-made snow event across the test track.

As part of this testbed, additional infrastructure was constructed to facilitate and assess long-term storage of deciers, as well as performance after roadway application. This infrastructure was installed adjacent to one of the runways, near the snowmaking system. In early 2008, five plastic-lined gravel pads were constructed for deicer storage: two pads for solid deicers stored under a metal shed, two pads with leachate collection systems for uncovered solid deicers, and one large pad for storing six 3,000 gallon poly tanks (Figure 17).

In addition, asphalt and concrete pads each measuring 120 feet by 13 feet were constructed in 2009 to allow field testing of anti-icing on concrete pavement. These pads were added for use in the Caltrans Snow/Ice Removal project described below.

Figure 17: Deicer storage facility.

Another key component of this facility is a deicer application trailer. The customized flatbed trailer holds 5 separate tanks with 25 gallon capacity for applying liquid deicers (Figure 18). The liquid is sprayed through 13 jets at the rear of the trailer. Chemical application rates can be calibrated using various sized nozzles and adjusting the speed of the vehicle. This equipment was originally constructed for the Pacific Snowfighters Deicer study described below.

Figure 18: Deicer application trailer.

Establishing Best Practices: Snow/Ice Removal in California Project

WTI conducted a project for the California Department of Transportation to establish best practices for removing snow and ice from California roadways. The project involved laboratory testing in the Subzero Science and Engineering Research Facility at MSU to determine appropriate application rates for various anti-icing chemicals utilizing different storm scenarios and pavement substrates. Field testing took place at TRANSCEND. Three successful snow events and field tests were conducted in January, February, and March of 2010.

A qualitative and quantitative evaluation of the performance of five typical anti-icing chemicals was conducted. In general, anti-icing methods employed in the laboratory and in full-scale controlled field tests improved the ability of the plow to remove snow from the pavement surface, lowered the temperature at which the snow–pavement bond failed, weakened the bond between compacted snow and pavement, and improved pavement surface friction after plowing when compared to untreated pavements. From the findings, WTI researchers developed a set of guidelines to initiate implementation of anti-icing practices in California.

Evaluation of Friction Measuring Devices during Winter Conditions Project

Friction is considered to be a critical parameter of roads during winter storm conditions; however, there is ongoing debate about how friction should be measured. A parametric study was undertaken to evaluate several friction measuring devices at TRANSCEND, using the snowmaking equipment for typical deicing and anti-icing test sections. The research has contributed to the current knowledge base about friction during winter conditions. The first field test took place in February 2012 using manmade snow, two friction devices (Halliday RT^3 and High Sierra Electronics Ice Sight2020E). The RT^3 provides a physical measure of friction with an instrumented fifth wheel attached to a truck toe hitch. The IceSight is an optical, non-contact sensor that estimates friction based on the presence of ice, snow and/or water. Both friction devices were able to distinguish between bare, snow-covered, and plowed (patchy snow and ice) pavement conditions. Additional field tests were planned that would incorporate winter maintenance activities on the test sections (salt brine and a salt–sand mixture), but an unseasonably warm winter led to canceling additional tests.

PNS Inhibitor Longevity & Deicer Performance Project

The objective of this research was to evaluate the cost effectiveness of corrosion inhibitors in deicing chemicals, and their longevity when in storage or on the road. The project also aimed to establish a reliable measure to quantify the performance of anti-icing and deicing chemicals. Deicer performance was evaluated by application of selected deicer products at various application rates onto pavement test sections at the TRANSCEND facility. Snowmaking equipment was used to simulate winter storm events, and chemical performance and concentrations were evaluated using a variety of methods, including sample collection, photography, and friction measurements. A black ice event was also simulated in February 2010 to determine corrosion inhibitor longevity, as well as a man-made snow event in March 2010. From the findings of this study, researchers were able to develop implementation recommendations for both storage and usage of the deicers evaluated.

Corrosion Testbed

In 2012, WTI researchers developed a corrosion testbed to expose metal specimens to chemical applications in a field environment. The testbed enables side-by-side performance comparison of commercially produced components (e.g., various corrosion-resistant metals, anti-corrosion coatings, anti-icing coatings, corrosion inhibitors, cathodic protection, concrete sealers, and deicer-resistant concrete) by evaluating them in the field elements of UV light, wind, precipitation, and temperature cycling.

The primary components of the test-bed are a custom-made test rack made of steel and measuring approximately 3 feet long and 4 feet high. A hydraulic pump, spray nozzle array and storage tank were installed to spray chemicals directly onto test specimens. In addition, the testbed has the capability to apply mechanical stress on few specimens to study the effect of corrosion on specimens under stress. The testbed has the capacity to hold, treat, and monitor approximately 22 metal specimens for corrosion studies.

Corrosion Testbed Proof of Concept Project

WTI researchers conducted a proof-of-concept research project using the testbed, by conducting a preliminary laboratory testing program in conjunction with the exposure of several material "stack-up/mock-up" geometries at the testbed site. The plan involved conducting laboratory tests at the WTI Corrosion & Sustainable Infrastructure Laboratory in Bozeman, MT to provide data that may correlate with field data. The lab tasks involved cyclic immersion of various concrete and metal specimens in deicer solutions, followed by property and corrosion analysis on a weekly basis.

In the field, the mortar specimens and metallic panels were mounted on test racks and subjected to natural temperature and humidity cycling. Deicer application occurred multiple times per day for several weeks. The chloride exposure, temperature, humidity, digital appearance, weight change, strength change, and rust layers of the specimens were monitored on a weekly basis to facilitate the benchmarking of field results against lab data. The results of this project were used to develop testing protocols, and to develop outreach materials describing testbed capabilities to potential research partners.

Figure 19: Corrosion testbed setup at TRANSCEND.

Subgrade Stabilization Testbed

In 2008, a testbed was constructed to study the benefits of using geosynthetic materials to stabilize unpaved roads with poor subgrade materials. The testbed was initially installed for the Geosynthetic Field Investigation project described below. The testbed was constructed by excavating a pit, filling it with a prepared subgrade, and installing several different geosynthetic materials. The roadway sections were instrumented for monitoring purposes. After the instrumentation, a base course was constructed. The roadway testbed included ten test sections incorporating various geosynthetics, and two control sections without geosynthetics in the subgrade.

Figure 20: Testbed construction: Base course aggregate poured over geosynthetic layer

In 2011-12, the testbed was re-configured and reconstructed for a pooled-fund subgrade stabilization project. This project required 17 test sections, including three control sections. The development of this experiment required excavation of the existing subgrade, placement of a new artificial subgrade, installation of the geosynthetics, setup and installation of the data acquisition system and instrumentation, and construction of the base course aggregate.

Field Investigation of Geosynthetics Used for Subgrade Stabilization Project

In 2008-09, MDT, WTI, and NAUE, a German manufacturer of geosynthetics, co-sponsored a research project to investigate the relative benefit of various geosynthetics on unpaved roads with poor subgrade materials. The gravel-surfaced road was constructed at TRANSCEND on a structurally weak subgrade. As described in the testbed development section above, ten test sections that incorporate various geosynthetics and two control sections (without geosynthetics) were constructed and monitored. A tandem-axle dump truck was used to traffic the test sections. In addition, post-trafficking excavations were conducted to evaluate damage to the geosynthetic, base contamination and deformation of the layers.

The results showed that the welded geogrids, woven geogrids and the stronger integrally-formed geogrid product seemed to provide the best overall performance, while the two geotextile products and the weaker integrally-formed geogrid provided significantly less stabilization benefit. Overall, this research provides additional and much needed insight regarding which properties have a significant role on performance, as well as an assessment of two design methodologies' ability to predict rutting performance. MDT used this information to update their design specifications.

Relative Operational Performance of Geosynthetics Used as Subgrade Stabilization, Pooled-Fund Project

In 2011, the testbed was used again to begin a pooled-fund project to study the effects of geosynthetic reinforcement on weak subgrade soils and to investigate the relative benefit of various geosynthetics available on the market. Study participants include Idaho, Montana (lead state), New York, Ohio, Oklahoma, Oregon, South Dakota, Texas, and Wyoming Departments of Transportation, and the Western Federal Lands Highway Division. Full scale test sections were constructed in the summer of 2012 (modifying the testbed as described in the testbed development section above). An artificial subgrade was constructed to provide equivalent or controlled conditions for each test section; likewise the gravel surfacing along the entire test bed is uniform to be able to make direct comparisons between geosynthetic products.

Testing occurred in the summer and fall of 2012. Researchers conducted controlled traffic loading with frequent rut measurements to indicate performance benefits of each geosynthetic. Additionally, post-traffic examination will provide invaluable information regarding the performance and installation survivability of the geosynthetics. Further analysis will be conducted to illustrate cost savings by optimizing material properties that most influence the design and performance of these materials, thereby increasing the Department's knowledge base, confidence and efficiency as it seeks to update its geosynthetic specifications. The project is expected to be completed by November 2013.

Roadside Vegetation Testbed

In 2012, researchers constructed a testbed to study re-vegetation efforts on cut slopes in arid regions. The slopes were designed to provide controlled field conditions that simulate roadside conditions for evaluating roadside reclamation and erosion control products.

The testbed mainly consists of a large earthen berm, with a length of 50 meters and height of 1.7 meters. The sides have a 2:1 slope ratio, which is the threshold of steepness at which state transportation agencies are required to apply erosion control techniques. The berm provides two test slopes (one north facing and the other south facing), each measuring 5.5 meters by 50 meters, for a total test area of 550 square meters.

The test slopes are north-facing and south-facing to test the environmentally harshest field conditions for plant establishment and growth (south-facing) and to test least harsh site conditions (north-facing). Researchers can artificially water and apply snow to the slopes, so natural moisture conditions can be mimicked for different environments and plant species, if needed. They can also apply different top soils to the test slopes, to allow testing to incorporate soils from potentially difficult roadside reclamation sites (i.e., clayey, serpentine, or alkaline soils).

Figure 21: Earthen berm used for vegetation testbed (photo courtesy of Rob Ament, WTI/MSU).

Rural Vehicle Communication

High speed data transfer from moving vehicles to stationary roadside infrastructure may be of interest to transportation officials to monitor information related to road conditions, traffic levels, travel speeds, weather conditions, etc. using fleet vehicles. In late 2011, WTI researchers began a project to implement several applications of vehicle-to-infrastructure communication in a rural setting to better characterize the potential for rural deployment of such applications. The effect of vehicle speed, terrain, vegetation and other conditions would be measured in conjunction with RF-specific parameters such as frequency, power, antenna type, etc. to characterize performance of the system and to determine the practical limits in the use of such systems in rural areas. The applications would focus on those that might be implemented in conjunction with fleet vehicles such as snowplows or maintenance trucks.

Roadside-to-Vehicle Communications Project

The objective of this project was to develop applications and conduct proof tests in the field. Initial testing was conducted in the Systems Engineering Laboratory at WTI, followed by deployment and testing in the field under controlled conditions. Project funds were used to purchase Moxa radios and other associated hardware necessary for testing. The field experiment consisted of testing access time and data transfer rate from a stationary roadside beacon to a moving vehicle. The project included a successful test to measure the transmission range of Moxa radios on a moving vehicle.

Alternative Materials Testbed

During the planning phase of the development of the TRANSCEND test facility, it was decided that all new concrete placed during the initial construction phase would be manufactured from 100 percent fly ash concrete (Figure 22). This would help promote the use of recycled materials to create a concrete mixture as a viable alternative to traditional Portland cement concrete. The foundations and flooring of the shop building and the two pump houses used 100 percent fly ash concrete. In 2012, WTI researchers installed an alternative materials testbed to allow testing of the durability, behavior and performance of concretes made with materials such as fly ash and reclaimed asphalt. The test site is located on an unpaved road used to access the TRANSCEND test facility.

The testbed consists of concrete pads that can be trafficked and monitored. For the initial research phase in 2012, WTI formed and poured four pads using 100 percent fly ash concrete. The 15-ft wide pads have a total length of 60 ft. The mix designs for the four test pads vary aggregate types and constitutive ingredient proportions. Concurrently, two 15-foot long by 15-foot wide test slabs were constructed using Reclaimed Asphalt Pavement (RAP).

Figure 22: Mixing and pouring of fly ash concrete at TRANSCEND.

Fly Ash Concrete Test Pads to Assess Constructability and Durability Project

WTI and the Civil Engineering Department at Montana State University have conducted several investigations and demonstrations over a 10 year period to produce and evaluate concrete using fly ash as the sole binder in the concrete mix. This research is aimed at assessing the constructability (mix design and commercial mixing and placing) and durability (freeze-thaw, corrosion and trafficking resistance) of fly ash concrete by constructing pads that could be trafficked and monitored.

The research includes development and lab testing of four mix designs (two with natural aggregates and two with crushed glass aggregates) that are capable of maintaining adequate strength and structural integrity after a predetermined number of freeze/thaw cycles (Figure 23). Subsequent tasks include construction of four test pads, laboratory testing of pad samples, visual distress surveys, 18 months of monitoring, and data analysis. The project is projected for completion in 2014.

Figure 23: Fly ash test pads

Field Demonstration: Feasibility of Reclaimed Asphalt Pavement as Aggregate in Portland Cement Concrete Pavements Project

The Montana Department of Transportation (MDT) has previously sponsored research to develop, characterize, and evaluate concrete mix designs using reclaimed asphalt pavement (RAP) as a partial replacement of some of the aggregate. This project is a field demonstration of two promising mix designs from the first phase of the research effort.

For the demonstration, WTI researchers constructed two concrete test slabs using RAP as part of the aggregate mix (Figure 24). The test slabs were instrumented to monitor shrinkage, curling, response to vehicle loads, and temperature. In addition to this continuous monitoring, the slabs will be inspected quarterly for cracking and other distresses. The project is projected for completion in 2014.

Figure 24: Construction and instrumentation of RAP test slabs at TRANSCEND.

Product Testing

The facilities at TRANSCEND can also be used for product research and testing, in addition to the testbed development and longer-term research projects described previously. Product testing can often be accomplished using existing facilities and equipment, rather than constructing a new or specialized testbed. This type of research also expands opportunities for partnerships with private industry.

Research Equipment and Resources

As part of this overall project to develop a state-of-the-art research facility, TRANSCEND has acquired specialized equipment and resources to support and facilitate cold region research projects. This equipment is mostly stored onsite, and is available to be used in numerous testbeds or for a broad range of projects. The availability of these resources has also been used as a marketing tool to attract potential research partners.

Accelerated Bridge Deck Tester (ABDT)

WTI conducted a project at TRANSCEND for the California Department of Transportation to evaluate rehabilitation strategies to extend the service life of concrete bridge decks. As a preliminary task, researchers designed an accelerated bridge deck tester to facilitate the trafficking of full-scale concrete deck panels. It is the first accelerated tester designed specifically for bridge decks.

WTI staff members worked with a design consultant to develop the specifications for the automated tester, which was built by Applied Research Associates (ARA). The test apparatus consists of a steel frame and gantry used to apply the rolling wheel load to a variety of test specimens. The panels are mounted below the apparatus in the frame. This setup has the following characteristics:

- Adjustable full truck axle loading
- Length of test apparatus is 55 feet, with 36 feet of useable testbed length
- 30 kips of loading capacity
- Pneumatic application of load
- Adjustable height to accommodate varying sample dimensions
- Ability to apply unidirectional and bidirectional loads
- Adjustable trafficking speeds between 0 and 6 mph

This machine is able to apply one pass over the test specimens about every 6.25 seconds (just under 10 passes per minute). If the equipment operates continually, then the test apparatus should be able to apply close to 100,000 cycles per week. At this rate, it takes approximately 72 days to apply 1,000,000 cycles.

Figure 25: Accelerated bridge deck tester.

Vehicles

TRANSCEND has the following vehicles available for use by researchers:

- A mobile laboratory, equipped with data acquisition equipment, weather sensors, generator, and video cameras, and workspace (Figure 26)
- Two full-size snowplows previously owned by Montana Department of Transportation (one featured in Figure 27)
- Caterpillar 256C Skid-steer loader
- 2001 Chevrolet Suburban
- 2001 Dodge Ram pickup
- 2012 Ford F350 pickup
- 1993 Suzuki mini-truck
- 2012 Subaru Outback
- 20-ft flatbed trailer

Figure 26: Mobile laboratory.

Figure 27: Snowplow.

Equipment

In addition, TRANSCEND has the following trailers and vehicle-mounted equipment:

- Halliday RT^3 wheel friction device (Figure 28)—this trailer uses a meter that records continuous road surface grip in wet or dry road conditions, as well as during anti-icing, snow removal and deicing operations. It provides grip readings to the operator of a winter maintenance vehicle via an in-cab control panel.
- Deicer trailer—the customized flatbed trailer holds 5 tanks with 25 gallon capacity for applying liquid deicers. The liquid is sprayed through 13 jets at the rear of the trailer.
- Welder
- Terex portable light trailers (2)

Figure 28: Halliday friction wheel.

Data Collection and Storage Systems

- Weather Station—As discussed and shown in the Construction chapter, WTI purchased and installed a new weather station in 2007. The meteorological sensors collect data to measure:
  - air temperature
  - relative humidity
  - wind speed and direction
  - barometric pressure
  - solar radiation
- Computer, Data Acquisition and Instrumentation Equipment—TRANSCEND acquired Campbell Scientific dataloggers and associated equipment for onsite collection of data from instrumentation, as listed below. TRANSCEND also purchased a Leica robotic total station for topographic surveying and mapping purposes.
  - Campbell Scientific CR10 data logger (3)
  - Campbell Scientific CR1000 data logger (8)
  - Campbell Scientific CR5000 data acquisition (5)
  - Campbell Scientific CR9000 data acquisition (2)
  - Dell Server PE Poweredge R710

TECHNOLOGY TRANSFER, MARKETING, AND OUTREACH

Partnership Development

Initially, partnership development activities focused on launching and developing TRANSCEND as a transportation research facility. These tasks included collaboration with USDOT, MDT, the Lewistown Airport Authority and the Fergus County Board of Supervisors during the planning and organizational phases. In addition, WTI spearheaded the development of an Advisory Committee to help identify and market partnership activities.

On an ongoing basis, TRANSCEND staff spearheaded opportunities to meet with potential partners or invite them to tour the research facility. Highlights include:

- Two representatives from Morton Salt toured facility and discussed partnership opportunities (2008)
- The Steering Committee of the Pacific Northwest Snowfighters Association (PNS) toured facilities and viewed progress on their research project (2008)
- The Steering Committee of the North/West Passage pooled fund steering toured TRANSCEND in conjunction with their Annual Meeting at WTI in March 2009.
- WTI's Research Advisory Committee received a formal presentation about TRANSCEND during a visit and meeting at WTI in March 2009.
- WTI hosted a field trip to TRANSCEND for 40 Montana State University employees from various departments of the College of Engineering to view TRANSCEND's research capabilities and discuss collaborative research opportunities (July 2009).
- Program Manager Eli Cuelho traveled to Alaska for meeting with University of Alaska – Fairbanks, University of Alaska – Anchorage, and Alaska DOT to discuss partnership opportunities (Summer 2010).
- Program Manager Eli Cuelho met with National Center for Atmospheric Research in Colorado to discuss collaborative research opportunities (December 2011).

Technology Transfer Forums

TRANSCEND program staff conducted regular outreach at forums hosted by organizations with a shared interest in cold regions transportation research. Through presentations, hosting booths, and person-to-person networking, staff members had the opportunity to disseminate information about TRANSCEND with representatives from numerous entities at one event.

In 2011, TRANSCEND program staff worked closely with WTI staff to develop and host a highly visible and synergistic technology transfer forum. The 2011 Winter Maintenance Peer Exchange was held in Bozeman, Montana. This important gathering, which was co-hosted by the TRANSCEND transportation research facility, brought together state DOT maintenance personnel, vendors, and researchers to share successes, lessons learned, and determine high priority research needs. This event was unique as maintenance personnel, researchers, and vendors actively participated in brainstorming sessions and held frank discussions about the challenges they face during implementation of new winter maintenance technologies and strategies. In all, 96 snow and ice experts and researchers, as well as 26 vendors from 42 states and the District of Columbia attended this two and half day event. Discussions centered on identifying gaps in winter maintenance communication, knowledge and technology, and to develop strategies to bridge those gaps through research and technology transfer. The result of this conference was a prioritized list of research needs. As part of this meeting, a virtual tour of TRANSCEND was given, as well as a tour of the research labs at WTI and MSU. The final session was a brainstorming effort on how to keep research relevant to the stakeholder needs and continue advancing the state of the practice in winter maintenance.

> *"WTI did an outstanding job hosting this year's Peer Exchange. By far, it was the best one I have been to – and remembering back to all the various conferences I have attend over the past 27 years with TxDOT, it ranks as one of the best. Great job!"*
>
> *Michael Taylor, Director of Operations – Amarillo District, Texas DOT*

Throughout the project period, TRANSCEND representatives participated in the forums of numerous national and regional organizations, including:

- Transportation Research Board Annual Meetings
- AASHTO RAC/TRB State Representatives Annual Meeting
- ITS America Annual Meeting
- Aurora and Clear Roads meetings
- Road Dust Best Management Practices Conference
- WASHTO standing committee on Maintenance

Technology Transfer Tools

Over the course of the project, WTI developed a number of Technology Transfer and Marketing tools to facilitate partnership development and other outreach activities. Many of these had been included as recommended actions in the marketing plan discussed in the Planning chapter.

Brochure

In 2008, WTI produced an initial marketing brochure, in partnership with MSU Publication and Graphics. Following the completion of facility construction and major equipment installation (i.e., the snowmaking system), the brochure was updated with numerous site photos. The brochures were disseminated broadly at technology transfer and outreach events.

Videos

A series of videos were developed to allow users to virtually "tour" TRANSCEND and familiarize themselves with the capabilities and research efforts associated with the facility. To date, the videos have been incorporated into multiple presentations and the website. Videos were produced to highlight the following attributes, capabilities and/or research projects:

- General overview of TRANSCEND
- Construction
- Fly ash construction and research
- Snowmaking

Newsletter

In 2008, the Program Manager began development on a newsletter for stakeholders, which would showcase progress at TRANSCEND. The newsletter included statements from Advisory Committee members, and was also intended as an outreach tool for potential research partners.

In addition, TRANSCEND staff provided regular updates to the WTI newsletter, which highlighted TRANSCEND progress in a section called "News from the Labs" that was included in every issue.

Website

Transcend information, including capabilities and progress updates, has been included on the WTI website since 2008. In January, 2010, Transcend launched its own website at www.transcendlab.org (screen shot of homepage is shown in Figure 29). The stand-alone website displays and disseminates more in-depth information, with individual webpages devoted to:

- Capabilities
- Projects
- Partnerships
- News
- About TRANSCEND (history, etc.)

Staff also uses the website to display video showing the lab's capabilities, a valuable outreach tool for an off-site research facility.

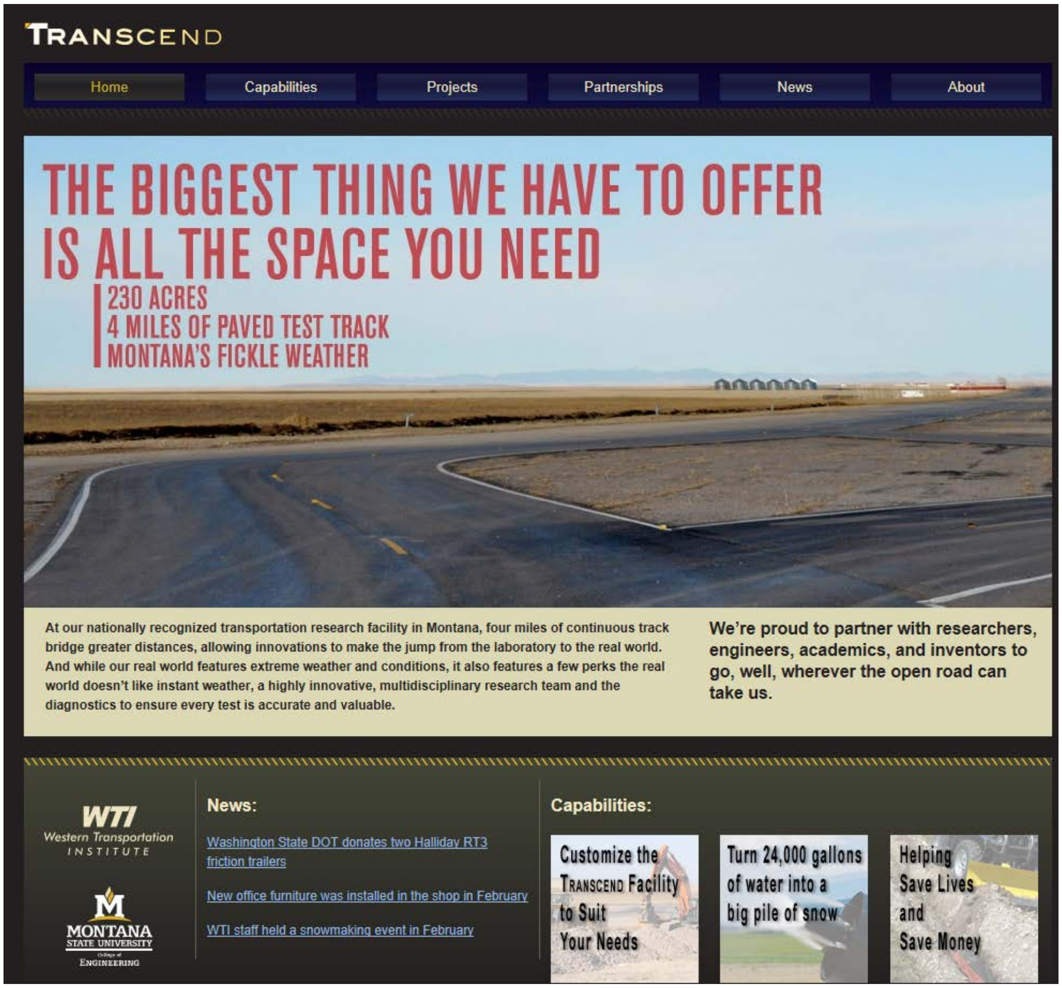

Figure 29: TRANSCEND website homepage.

Tradeshow Booth

Staff created a portable tradeshow booth featuring displays of the TRANSCEND site and capabilities. The booth was used at several technology transfer events.

External Media Coverage and Marketing

Some notable marketing pieces were not produced and/or disseminated directly by the primary TRANSCEND staff. As previously noted, WTI disseminated regular updates and news about the facilities through its website and newsletter. In May 2009, the U.S. DOT office of Research, Development and Technology produced and disseminated a two-page research bulletin specifically about TRANSCEND (Figure 30).

U.S. Department of Transportation
Research and Innovative Technology Administration

RD&T Research Bulletin

OFFICE OF RESEARCH, DEVELOPMENT, AND TECHNOLOGY
RESEARCH BULLETIN

May 2009

TRANSCEND: Open Road to Discovery

Western Transportation Institute's Full-Scale, Outdoor Laboratory for Research, Development and Testing

BACKGROUND

Rural areas in cold regions face unique transportation challenges, such as hazardous driving conditions, remote locations, and wildlife on the roads. Transportation professionals in cold regions must also address the impacts of harsh winter conditions on operation and maintenance activities and how these activities affect the environment, roadway infrastructure, and travelers' safety. Researching and testing innovative designs, maintenance practices, and technology applications to address these challenges can, at times, inconvenience the traveling public, and the research is oftentimes one-dimensional. Few research facilities focus on rural issues, and fewer still have the capabilities to study multiple issues at the same time in a safe and natural environment.

TRANSCEND
open road to discovery research | development | testing

In Lewistown, Montana, located in the very center of the state, the Western Transportation Institute (WTI) has transformed 230 acres of land containing decommissioned runways and taxiways at the Lewistown Airport into a multidisciplinary transportation research facility. In 2003, the Airport Board and Fergus County Commissioners asked WTI to consider using decommissioned portions of the airport for transportation research and testing.

WTI conducted a requirements analysis, identified research priorities, and developed partnerships and an implementation plan for establishing a state-of-the-art research center. Today, the site is known as TRANSCEND, an advanced research facility focused on solving rural transportation challenges.

Photo by WTI

If necessary, an extensive snowmaking system can create winter test conditions to supplement Montana's usually snowy winters.

Included on the 230 acres are 4 miles of paved test track and a nationally recognized Roadside Animal Detection System (RADS) Test Bed that has been operating since 2006. A 1.3 million gallon reservoir and high pressure pumps and pipeline support snow-making equipment used for creating winter test environments. Data acquisition and communication infrastructure are available to support future IntelliDrive℠ research. There is also a heated shop building for instrumenting vehicles, conducting experiments, or maintaining equipment.

OBJECTIVES

The overall objective of TRANSCEND is to provide a state-of-the-art, multidisciplinary research facility capable of addressing multiple transportation challenges through research, development, and testing—all in one location. TRANSCEND provides an **"open road to discovery"** in a natural cold-region research environment. Using a multidisciplinary approach, researchers can study how trans-

Figure 30: USDOT research bulletin.

The Lewistown community newspaper (The Lewistown News-Argus) has published numerous articles about TRANSCEND, particularly in 2007 and 2008 during the early development phases. The publication continues to follow the lab's activities. Other media outlets that have covered TRANSCEND news or interviewed staff includes the Great Falls (Montana) Tribune, KXLO radio in Lewistown, MT, and Yellowstone Public Radio in Billings, MT.

BENEFITS AND ACCOMPLISHMENTS

How TRANSCEND met objectives

By the end of the project term, TRANSCEND was a fully functional, large-scale field laboratory with eight unique testbeds, supported by multi-use facilities and equipment. Researchers from WTI and partner organizations conducted numerous research projects and field testing efforts at the site. As a result, WTI was successful in meeting project objectives, as summarized in Table 2.

Table 2: Objectives and Outcomes of TRANSCEND Project

Project Objective	Outcome(s)
Evaluation of other Research Facilities	Inventory prepared in 2007; updated in 2011
Conduct Needs Assessment	Summary of Existing Conditions completed in 2007, followed by a report documenting facility needs.
Assemble Key Partners to Guide Facility Development and Use	Advisory Committee formed in 2008. Members provided valuable input on infrastructure design and requirements, research priorities, marketing and outreach.
Construct and Deploy Key Infrastructure	All infrastructure identified in initial Facility Needs proposal successfully constructed and deployed, including pump house, office/shop, water storage reservoir, well system, high pressure water main, electricity and power lines. Additional infrastructure installed or deployed over life of project included snowmaking system, weather station, communications systems, and a storage building.
Identify and Conduct Research Projects	More than 10 research projects conducted primarily or in part at TRANSCEND
Conduct Technology Transfer, Outreach & Marketing Initiatives	Tools included brochures, virtual tour, website, tradeshow, and video clips. Staff conducted in-person outreach through presentations, tours, field trips, and participation in national forums.

How TRANSCEND Advanced Transportation Research and Provided Solutions to Practitioners

The broader, longer-term goal of TRANSCEND is to advance cold regions transportation research and facilitate the development of solutions for transportation agencies in areas subject to severe or cold weather. The research conducted at TRANSCEND produced relevant and useful results. Examples include:

- The geosynthetics research projects provided specific design and materials guidance to state transportation agencies. *Field Investigation of Geosynthetics Used for Subgrade Stabilization* helped Montana Department of Transportation (MDT) to update their specifications for subgrade materials to more broadly encompass materials with which they have had good experience, as well as open up the application to other suitable materials. This is particularly important since new geosynthetics and manufacturing processes are regularly introduced into the market. A follow-up *Subgrade Stabilization Project* will help identify the most appropriate geosynthetic properties to be considered for a subgrade stabilization application. This information will provide planners and designers at state DOTs with the necessary information to objectively select an appropriate geosynthetic for a particular job.
- *Road-Animal Detection System (RADS) Testbed Project* provided the opportunity to evaluate the reliability of relatively new technologies to detect animals on or new roadways, which will facilitate advancement of the technology and refinement of these systems.
- For *Establishing Best Practices: Snow/Ice Removal in California*, researchers evaluated the performance of five typical anti-icing chemicals. From the findings, researchers developed a set of guidelines to initiate implementation of anti-icing practices in California.

TRANSCEND's Value as a Research Facility

As a research facility, TRANSCEND has established unique capabilities that have value to the transportation research community as well as to agencies and other practitioners.

- Ability to expand. TRANSCEND's size and location allow significant expansion possibilities as well as the ability to accommodate large scale projects.
- Ability to integrate and tailor research. Facilities and equipment are designed to work together to evaluate multiple aspects of a research problem at one time or one location, or to customize research for a particular project.
    - Example: the Caltrans Snow/Ice project used anti-icing trailers in conjunction with the snow making system.
- Ability to repurpose existing testbeds and equipment.
    - In 2011, the subgrade stabilization testbed created for a Montana Department of Transportation project was re-configured and reconstructed for a pooled fund subgrade stabilization project.
- Ability to "provide" winter weather conditions. The northern climate and location, combined with the snowmaking equipment, allows TRANSCEND to offer broader options and opportunities for severe weather research and testing. This has value to research partners located in areas with infrequent severe weather.

- Ability to partner with private industry to test and validate ideas and technologies related to rural or cold transportation challenges.

FUTURE/IMPLEMENTATION

Potential Future Benefit of TRANSCEND

TRANSCEND's research agenda to date has identified and investigated numerous transportation issues of critical importance to rural areas and cold regions, including:

- Wildlife-vehicle collision reduction
- Defensive driving skill development
- Safe and sustainable winter road maintenance
- Rural communication capabilities and infrastructure
- Highway design and construction techniques for cold regions, including use of recycled materials
- Roadside reclamation and erosion control

TRANSCEND provides the infrastructure, facilities and equipment to conduct continued research on these topics. In addition, emerging issues that may benefit from field research at TRANSCEND include:

- Research related to the impact of climate change
- Dust management
- Gravel road construction, maintenance and performance
- Pavement construction maintenance
- Accelerated testing
- Accelerated construction techniques

Next Steps

Technology Transfer of Research Findings

While principal construction and development of TRANSCEND is complete, it may be beneficial to conduct or assist with additional technology transfer for individual projects completed at the facility. By showcasing successful research, these efforts can have synergistic benefits for both project sponsors and TRANSCEND. Potential technology transfer activities could include:

- Continuation of TRANSCEND website with updates on completed projects: links to final reports, photos, sponsor contact information, etc.
- Joint presentations on projects by P.I. and TRANSCEND program manager.
- Research forums
- Research publications, journal articles and conference proceedings

Partnership Opportunities

Identifying and securing a broad range of research partners will play an important role in achieving a sustainable business plan for TRANSCEND. WTI will continue to explore repeat partnerships with previous sponsors as well as new opportunities, including collaborations with:

- Research organizations, pooled fund studies, and other entities with complementary research interests. Examples: Winter Maintenance Peer Exchange, Clarus, Clear Roads, and Pacific Snowfighters Association.
- International agencies or business entities interested in conducting research in U.S. location or on U.S. equipment.
- Product Testing for U.S. manufacturers.

APPENDIX: REVIEW OF OTHER FACILITIES

TRANSCEND RESEARCH LABORATORY

INVENTORY OF LARGE-SCALE OUTDOOR TRANSPORTATION RESEARCH FACILITIES

prepared by

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Western Transportation Institute

College of Engineering

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Bozeman, Montana

for

Research and Innovative Technologies Administration

U.S. Department of Transportation

Washington, D.C.

July 2007 (updated 2011)

Table of Contents

Executive Summary

As part of the development of a transportation research facility in Lewistown, Montana (TRANSCEND), tours of other large-scale transportation research test facilities were conducted to provide ideas about which types of infrastructure may be a higher priority at this facility, as well as demonstrated some of the lessons learned by other research organizations. This inventory of other transportation research test facilities was conducted to ascertain how the research facility in central Montana could augment current research capabilities. Visits to four facilities provided the opportunity to learn about the history, current research activities, and infrastructure, as well as talk to personnel involved in the operations and maintenance of the facilities. The four facilities toured were the Smart Road in Blacksburg, Virginia, MnROAD near Albertville, Minnesota, the Riverside Campus of Texas A&M University near Bryan, Texas, and Pennsylvania Transportation Institute's Research and Testing Track Facility in Bellefonte, Pennsylvania.

The Smart Road, owned and maintained by the Virginia Department of Transportation while being fully managed by the Virginia Tech Transportation Institute, is an impressive example of the diverse transportation research opportunities available when meticulous planning and design culminate in the construction of a realistic highway test bed. Active research is occurring on the Smart Road nearly every day and into the night. The infrastructure is extensive: a mechanical gate; various road bed designs; a large bridge; weather stations for snow, rain, and fog; roadway lighting; fiber optic communications and wireless LAN; cameras; and a reconfigurable intersection. The Smart Road represents a goal of high-quality, diverse research for the effort in Lewistown. However, the high cost of construction, operation, and maintenance will need to be kept in mind and scaled down to effectively utilize the seed money for Lewistown.

MnROAD is a pavement research facility with high volume and low volume tracks and an extensive data acquisition and sensor network. This test bed represents a more realistic model for Lewistown based on the number of personnel employed and the data network. However, the research scope is narrower and the facility is owned and operated by the state department of transportation instead of a university. There are still many potential similarities between MnROAD and the Lewistown effort: the types of buildings, the need for trucks and a qualified driver, and the data network.

The Riverside of Campus of Texas A&M University is built on an abandoned air force base and thus has some similarity to the Lewistown site with wide runways in triangular configurations. However, the campus totals 2000 acres, almost ten times larger than the land available in Lewistown, and there were dozens of buildings existing when Texas A&M received the land. The variety of research and activities that occurs at this facility includes: emergency vehicle driver training at a 3.5 mile driving track; hydraulics, sedimentation, and erosion control in a large outdoor flume and indoor rainfall simulator; geotechnical research of sand and clay at two experimentation sites; transportation safety at a proving grounds research facility; and pavement research and profiler calibration/certification at a ride/rut facility. Only about $10,000-$15,000 is legislatively appropriated annually for overhead and maintenance at the Riverside campus test track. This remarkable level of sustainability is definitely a goal to consider while developing the facility in Lewistown.

The Pennsylvania Transportation Institute opened a Research and Testing Track Facility in the 1970s on 136 acres of land. Originally, research focused on road and bridge infrastructure and human factors. Bus testing for the Federal Transit Administration dominates the current activities at the track and employs half a dozen personnel for operations and maintenance. Other research that has taken place includes runaway truck ramps and crash testing. For the Lewistown effort, this facility shows how research at the test bed can evolve to meet the changing needs of the US Department of Transportation.

These four facilities demonstrate a variety of approaches to implementing large-scale transportation field test facilities, from basic goals and business strategies, to the infrastructure they have developed, to the manner and level of support they provide on a project-by-project basis. Thus, they offer many ideas about how to proceed with the development of TRANSCEND. A brief summary of many other domestic and international transportation research facilities and test tracks that were not visited are also included in this inventory to provide an overview of the current research activities and ensure that TRANSCEND is not duplicating research efforts.

Introduction

There are several large-scale outdoor transportation research facilities in the United States. In addition to WTI's new facility TRANSCEND in Lewistown, MT, 22 other facilities were identified. They are listed below and shown in Figure 1. Several facilities have common research themes, including accelerated pavement testing (15), winter testing (5), and human factors (6) as at least one of their major initiatives. These facilities are identified in Figure 2. Four sites were visited to thoroughly assess the capabilities and research activities. These were the Smart Road in Virginia, MnROAD in Minnesota, Texas A&M Riverside Campus, and PTI Research and Testing Track Facility in Pennsylvania. The detailed findings from these site visits are presented in the next chapter. Less detailed information related to the research activities and capabilities of the other facilities, both domestic and international is also provided.

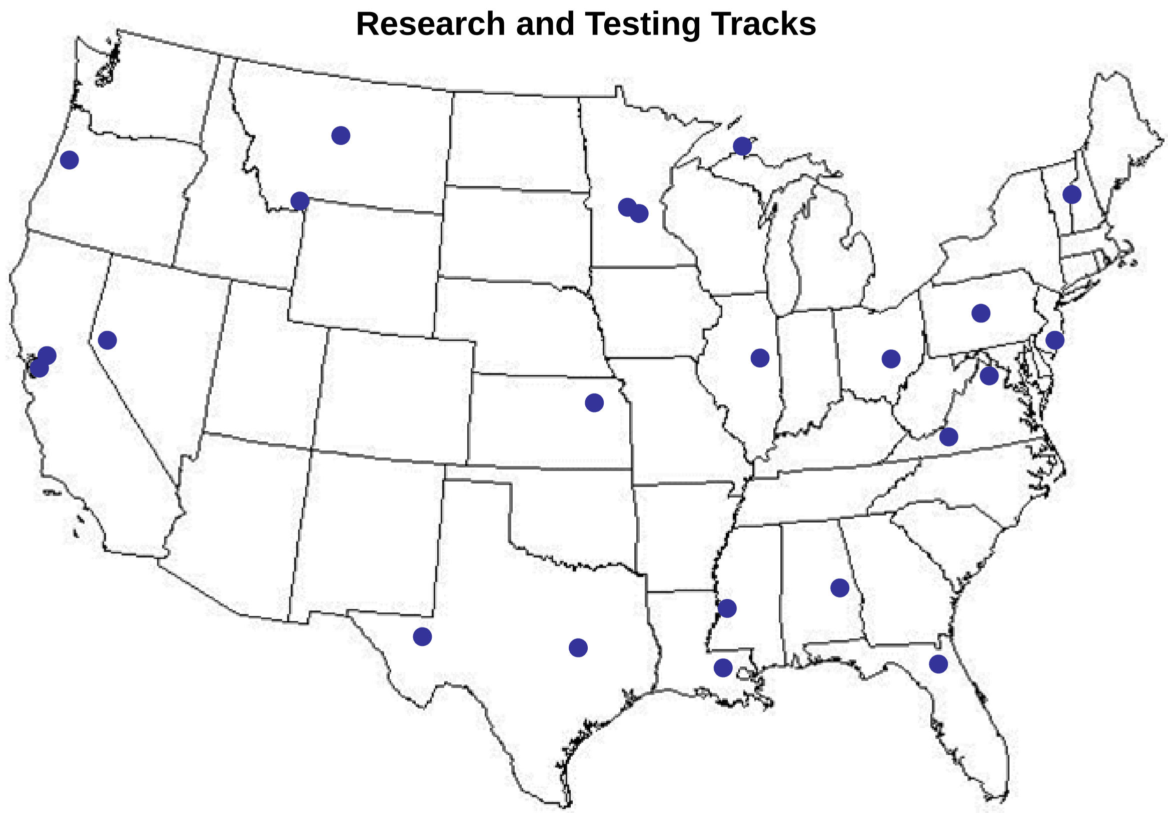

Figure 1: Location of 23 large-scale outdoor transportation research facilities in the United States.

Alabama

- NCAT: National Center for Asphalt Technology

California

- UCPRC: University of California Pavement Research Center (UC Berkeley and UC Davis)
- BHL: Berkeley Highway Lab (UC Berkeley)

Florida

- Accelerated Pavement Testing and Research Program (Florida DOT)

Illinois

- ATREL: Advanced Transportation and Research Engineering Laboratory (Illinois Center for Transportation)

Kansas

- CISL: Civil Infrastructure Systems Laboratory (Kansas State University)

Louisiana

- LTRC: Louisiana Transportation Research Center

Michigan

- KRC: Keweenaw Research Center (Michigan Technological University)

Minnesota

- MnROAD (Minnesota DOT)
- Advanced Driving Facility (St. Cloud State University)

Mississippi

- Waterways Experiment Station (US Army Corps of Engineers)

Montana

- TRANSCEND (Montana State University)
- NATC Winter Test Facility: Nevada Automotive Test Center

Nevada

- NATC: Nevada Automotive Test Center

New Hampshire

- CRREL: Cold Regions Research and Engineering Laboratory (US Army Corps of Engineers)

New Jersey

- William J Hughes Technical Center (Federal Aviation Administration)

Ohio

- ORITE: Ohio Research Institute for Transportation and the Environment (Ohio University)

Oregon

- Kiewit Center for Infrastructure & Transportation (Oregon State University)

Pennsylvania

- Research & Testing Track Facility (Pennsylvania State University)

Texas

- Pecos RTC: Pecos Research & Testing Center (Texas A&M University)
- Riverside Campus (Texas A&M University)

Virginia

- Smart Road (Virginia DOT and Virginia Polytechnic Institute and State University)
- TFHRC: Turner–Fairbank Highway Research Center (Federal Highway Administration)

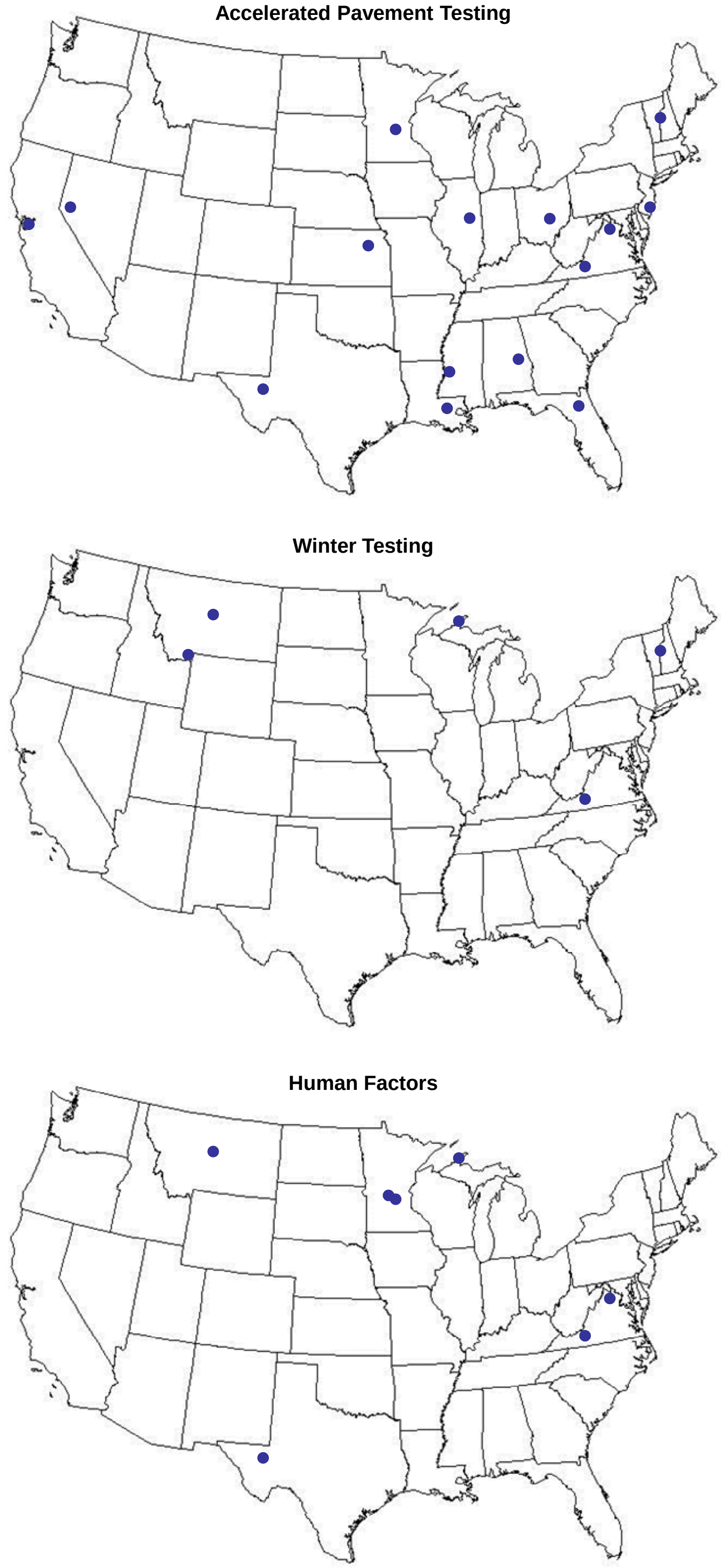

Figure 2: Locations of facilities whose research initiatives include at least accelerated pavement testing, winter testing, and human factors.

TRANSCEND

General Description

TRANSCEND is a large-scale transportation research and testing center for the Western Transportation Institute (WTI) at Montana State University (www.transcendlab.org). The facility is located in central Montana on a portion of the Lewistown municipal airport that is now closed to commercial air traffic (Figure 3). It offers a safe place to conduct research that is more realistic than the laboratory yet more controllable than the real world.

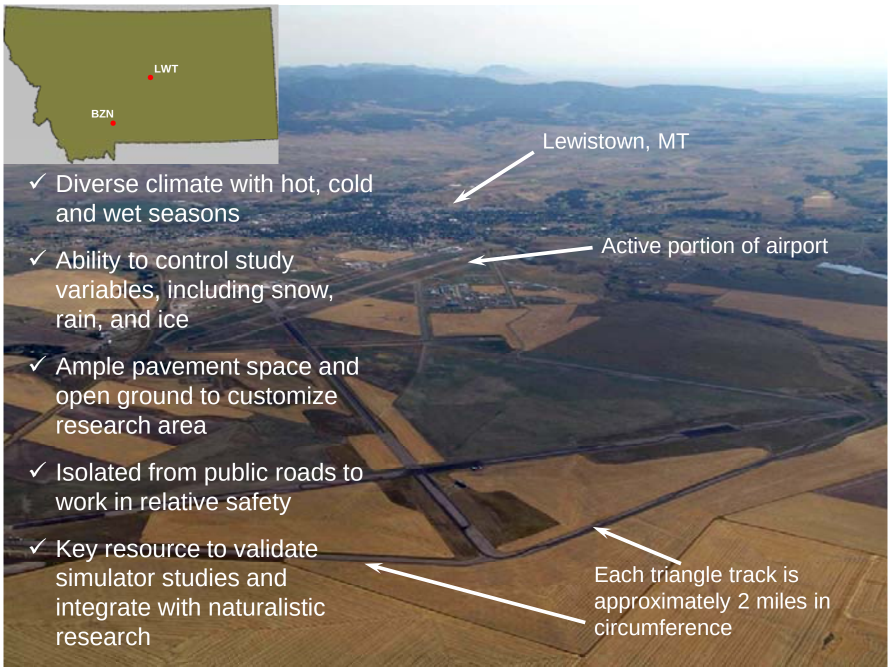

Figure 3: TRANSCEND is located at the Lewistown Municipal Airport about 160 miles from WTI headquarters in Bozeman, Montana.

Infrastructure

TRANSCEND is located on 230 acres of runways, taxiways, and land at the Lewistown Municipal Airport. Infrastructure at the facility includes (Figure 4):

- 2-mile paved driving track with straight sections, curves, corners, off-road recovery, skid pad, and vehicle handling pad
- A heated shop and storage building equipped with tools
- Weather station with sensors for air temperature, relative humidity, barometric pressure, solar radiation, wind speed and direction, and pavement temperature
- Communications tower with high-definition video camera
- Snow-making infrastructure with a well, 1.3 million gallon reservoir, low and high-pressure pumps (1,000 gallon per hour capacity), 4 repositionable snow machines capable of producing 1.5 acre-ft of snow in 8 hours
- Winter maintenance equipment (snowplows, chemical applicators)

- Remote office with wireless communications at Transcend and ability to communicate to WTI headquarters in Bozeman
- Equipment and tools including a skid steer, three snowplows, friction trailer, welder, air compressor, and other tools
- 30-kip accelerated bridge deck tester, 32 feet long

Figure 4: Infrastructure at TRANSCEND, a) driving track, b) weather station, c) heated shop, d) storage building, e) snow machines, f) snowplow.

Research and Activities

Research at TRANSCEND is multi-disciplinary and has ranged from winter maintenance, infrastructure, road ecology, and human factors:

- *Establishing Best Practices of Snow and Ice Removal from California Roadways*: field testing at TRANSCEND of anti-icing with various products, application rates, pavement types, and weather conditions
- *Inhibitor Longevity and Deicer Performance Study*: field testing at TRANSCEND to measure longevity of corrosion inhibitor in deicers during storage and roadway applications
- *Geosynthetic Stabilization of Weak Subgrade*: field testing at TRANSCEND in which a weak subgrade, instrumented geosynthetics, and typical gravel base were carefully constructed and trafficked with a truck until failure.
- *Evaluation of 100 percent Fly Ash Concrete*: The concrete in the shop, pump houses and sidewalks at TRANSCEND were constructed with fly ash concrete, which utilizes an industrial waste product (fly ash) as the cementitious material instead of Portland cement.
- *The Comparison of Animal Detection Systems in a Testbed*: roadside animal detection systems that warn drivers of animals on or near a road were tested side-by-side for system reliability and operation and maintenance aspects at TRANSCEND using horses, and llamas.
- *Effects of Defensive Vehicle Handling Training on Novice Driver Safety*: groups of teenagers were recruited to participate in a 1-day course of advanced driver training and are being compared to a control group over a period of 5 years.

Existing testbeds at TRANSCEND include:

- Road Animal Detection Systems testbed-side-by-side comparison of several animal detection systems using live animals
- Geosynthetic testbed-full-scale unpaved roadway to study the relative performance of various geosynthetics using simulated traffic

Ideas currently under development:

- Roadside vegetation testbed-study re-vegetation efforts on cut slopes in arid climates under various conditions
- Low-volume roads testbed-study stabilization and dust mitigation strategies on unpaved roads
- Fly ash test area-test durability of concrete made with fly ash as the sole binder
- Test area for communications equipment associated with the connected vehicle initiative

Management

Transcend is managed by research staff at Western Transportation Institute, Montana State University (www.westerntransportationinstitute.org), a University Transportation Center with 38 full time research staff. Eli Cuelho, a research engineer, is the manager for TRANSCEND (elic@coe.montana.edu; 406.994.7886). Research program areas and lab facilities at the Western Transportation Institute and Montana State University include:

- Infrastructure Maintenance and Materials program
- Winter Maintenance and Effects program
- Road Ecology program
- Systems Engineering Development and Integration program
- Safety and Operations program
- Mobility and Public Transportation program
- Logistics and Freight Management program
- Transportation Planning and Economics program
- Full-size drivers simulator lab
- Corrosion and Sustainable Infrastructure lab
- Materials laboratory
- Alternative Materials lab
- Sub-zero Science and Engineering Research facility

Funding Sources & Partnerships

Initial funding for TRANSCEND is from the US Department of Transportation Research and Innovative Technology Administration. TRANSCEND is currently seeking partnerships with several other research institutes, universities and/or governmental agencies. Since its inception, research projects conducted at TRANSCEND have supported improvements and maintenance with the following partners:

- Federal Highway Administration
- Montanan State University
- Murdock Charitable Trust
- Pacific Northwest Snowfighters
- Montana Department of Transportation
- Montana Office of Public Instruction
- Washington State Department of Transportation
- Idaho Transportation Department
- Oregon Department of Transportation
- California Department of Transportation
- NAUE GmBH & Co. KG

Site Visits

Introduction

An inventory of existing transportation research facilities was conducted in an effort to ascertain how the Lewistown airport facility can help augment what already exists and to advance rural and cold-region transportation state-of-the-practice. An assessment of research capabilities, infrastructure, funding sources, and partnerships for several facilities was compiled. Additionally travel to several sites permitted detailed tours and facilitated communication with key personnel involved with the development and operation of each facility. The Virginia Smart Road, Minnesota MnROAD, Texas A&M Riverside Campus, and Pennsylvania Transportation Institute Research and Testing Track Facility were selected from a larger list of research and test facilities to tour.

Other facilities given some consideration include the *Pavement Test Track* at Auburn University's National Center for Asphalt Technology, *WesTrack* Road Test Facility in Nevada, and the *Cold Regions Research and Engineering Laboratory* (CRREL) of the US Army Corps of Engineers in New Hampshire. The former two are primarily focused on pavement and road design with several test sections along the 1.7-mile and 1.8-mile (respectively) track configurations. Both of these tracks undergo accelerated testing with trucks, the Pavement Test Track uses human drivers while WesTrack tractor-trailers are controlled electronically Neither of these facilities experience significant cold weather or frost. CRREL consists primarily of laboratories and other indoor facilities with the exception of fairly small Ground-Penetrating Radar and Intrusive Detection System test sites.

Smart Road

General Description

Virginia's Smart Road was constructed to be a 5.7 mile limited-access highway connecting Interstate 81 to Blacksburg, Virginia. Currently incomplete, the facility has provided researchers and product developers with a lab to study new transportation technologies before becoming a more direct route to Blacksburg from I-81. Currently, the two-lane test bed is about 2 miles long; the remaining 3.7 miles needed to connect to I-81 is currently on hold.

The Virginia Tech Transportation Institute (VTTI) is located adjacent to the test bed and only a few miles from the university campus of Virginia Tech. The location is convenient for both VTTI researchers and faculty to travel between the Smart Road and the university.

Funding Sources and Partnerships

While the concept for the Smart Road as an innovative solution to congestion and research was embarked upon in 1989, the first funding source came from a federal transportation bill in the form of $5.9 million for research and planning. A $3 million federal grant was awarded to Virginia Tech's Center for Transportation Research in 1993 specifically for research on the Smart Road. In 1994 the state of Virginia funded the construction of Phase I of the test bed, 1.7 miles at the northern end, which was completed in 1997. Phase II was completed in 2001, which includes Virginia's tallest bridge at 175 feet tall, 2000 feet long and a cost of $17.4 million. Funding for Phase III is not yet available, but once secured, the final 3.7 miles of two-lane test bed will be constructed. However, concurrent with the planning and construction of the Smart Road, a Route 460 bypass to I-81 around Blacksburg was constructed which relieved much of the traffic and the need for an additional access route.

Because the Smart Road will eventually be open to public traffic, Virginia Department of Transportation (VDOT) owns and maintains the test bed. However, the facility is fully managed by VTTI since it is currently used only for research. A cost center was established and is reviewed annually to provide a means to collect revenue needed to operate the test bed.

The list of sponsors, clients, and partners available on the VTTI website is extensive and includes Montana State University – Western Transportation Institute.

Infrastructure

The infrastructure at the Smart Road is extensive, consisting of a road, bridge, all-weather towers, lighting towers, an underground communications network, weather stations, surveillance cameras, signalized intersection, among many other features. The Smart Road itself contains over a dozen pavement designs. Approximately 2,000 feet of length of the Smart Road is the bridge over Wilson Creek, standing 175 feet tall, 40 feet wide, and weighing about 20 thousand tons. It is a cast-in-place cantilever box girder bridge with 18-ft wide box girders of varying height from 12 to 35 feet. The bridge consists of three 472-ft spans and two 283-ft spans. The Smart Road intersection is reconfigurable and has two high-speed and two low-speed approaches. Additionally, the intersection is signalized, has customized controllers and sensors, and interfaces with the communications system. The intersection can be viewed from the control room located in the primary building for VTTI staff (Figure 5).

Figure 5: Smart Road control room and signalized intersection

There are 75 all-weather towers that can produce rain, snow, ice, and fog on a half mile of roadway. A 500,000 gallon above-ground storage tank and pump house with three high-capacity pumps supplies water to the towers. Up to 180,000 gallons per minute can be used at peak capacity to produce 4 inches of snow per hour. Compressed air is also supplied to the towers to atomize the water. Each tower has a concrete bunker for access to the water and air hydrants (Figure 6). Hoses are used to connect the water and air lines to the weather tower (Figure 7).

Figure 6: Bunker for weather tower electronics and hoses


Figure 7: Hoses connecting air and water from hydrants to towers

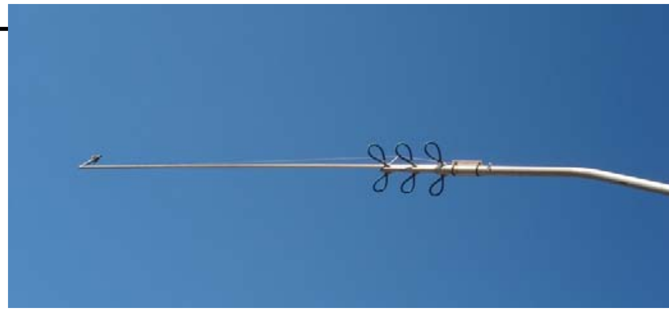

Figure 8: Weather tower with rain nozzles installed

Road lighting at the Smart Road consists of 39 light poles designed to reproduce most highway lighting situations and create different visibility conditions by selecting an assortment of poles and using different types of luminaires.

The instrumentation system is accessible on the side of the road. Conduit runs parallel to the road with occasional access points via concrete bunkers constructed from concrete. The instrumentation system works with a communication system consisting of a wireless LAN interfaced with a fiber-optic backbone. There are also AC power outlets available along the road.

Research and Activities

The Smart Road has a variety of research capabilities:

- All-weather testing facility (half mile) that produces rain, snow, ice, and fog.
- Variable lighting section (three-quarter mile) that allows a multitude of visibility conditions to be created on demand
- Advanced communications system that includes a wireless LAN interfaced with a fiber optic backbone.
- Intersection collision avoidance, violation, and decision support
- In-pavement sensors that provide data regarding pavement performance under real loading conditions.
- UV-sensitive pavement markers and striping.
- Experimental pavement sections that include flexible pavement test sections and continuously reinforced rigid pavement.

MnROAD

General Description

MnROAD is a national research and technology center located near Albertville, Minnesota. It consists of a cold-region testing laboratory with a 3.5-mile Interstate-94 roadway and a 2.5-mile low volume roadway. The site, located 40 miles northwest of Minneapolis-St. Paul, was constructed from 1990 to 1994 based on the idea that the national interstate system was a product of historic technology that may not be suitable for current and future transportation needs. The research project was envisioned to last at least twenty years.

There are a total of 51 cells differing in road materials and design on the two test beds, as seen in Figure 9. A description of the type and depth of pavement, base, and subgrade for each section is available online. The Mainline test bed has an ADT of 26,400 while the closed loop bed uses a controlled 5-axle semi tractor-trailer. Traffic is diverted from westbound I-94 to MnROAD Mainline for approximately 3 days each month.

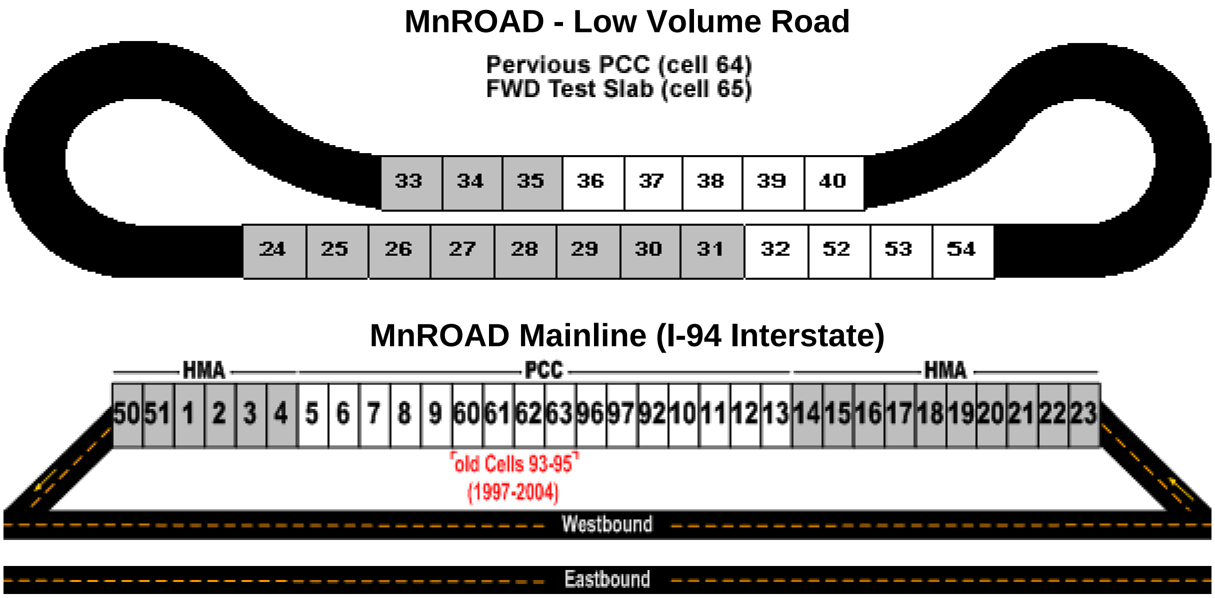

Figure 9: The MnROAD test sections parallel Interstate 94 (reprinted with permission)

The objective of Minnesota Road Research is "to improve the quality and value of the Minnesota Road Research System while reducing future taxpayer costs by extending pavement life."

Funding Sources and Partnerships

The $25 million original investment for planning, design, and construction of MnROAD was from state and federal sources. State, federal, international, and academic interest in MnROAD has resulted in a long list of research partners, such as:

- CRREL (Cold Regions Research Engineering Laboratory) of the U. S. Army Corps of Engineers
- Finnish National Road Administration
- Federal Highway Administration (FHWA)
- Long Term Pavement Performance (LTPP)
- Minnesota Department of Transportation (Mn/DOT)
- Minnesota Local Road Research Board (LRRB)
- Transportation Research Board (TRB)
- University of Minnesota Center for Transportation Studies
- University of Minnesota Civil Engineering Department
- University of Minnesota Pavement Research Institute
- Wisconsin Department of Transportation (Wis/DOT)

Additionally, phase-II of MnROAD saw the creation of a new conglomeration of partners known as TERRA, the Transportation Engineering and Road Research Alliance in 2004. The mission statement of TERRA is "to develop, sustain, and communicate a comprehensive program of research on pavement, materials, and related transportation engineering challenges including issues related to cold climates."

Infrastructure

The MnROAD Research Center Building has a daylight basement and double-wide manufactured building (70'x28'), as shown in Figure 10. The main floor has a lobby, conference room (25'x28', Figure 11), kitchenette, storage room, two bathrooms, shower, and a work area with cubicles. The lower level has a heated garage (37.5'x28'), bathroom, and large work area with cubicles and storage. A well and septic system are used for supply and treatment of water. The sidewalk outside of the building was constructed with porous concrete to observe its durability in a freeze-thaw environment.

Figure 10: MnROAD Research Center Building

Figure 11: Conference room within MnROAD Research Center Building

A large steel building (Figure 12) is primarily used to repair trucks and store samples, although it also has a small heated machine shop. As money became available, additions to the building were made on each side. Eight inches of porous concrete pavement was constructed on one side with a few different sections for different mix designs.

Figure 12: Large steel building at MnROAD

The pavement and environment instrumentation is extensive. There are cabinets alongside each road to house the data acquisition equipment. A typical data acquisition cabinet is shown in Figure 13. Conduit carries wires from embedded sensors to the cabinets. There is roughly one cabinet for every two pavement sections. The power running to each cabinet is 240 volts; there are multiple transformers on site. Metal oxide varistors (MOVs) are used for lightning protection. The cabinets are heated in the winter to 40°F and fans cool equipment in the summer. The newer fans will shut off the instrumentation when the temperature reaches 120°F and will start the system back up at 100°F.

The data acquisition is fully programmable from the building; an Ethernet connection is used to transmit data, although the Ethernet hub is the least robust piece in the cabinet and fails easily in cold temperatures. MnROAD has some fiber optic cable and would prefer to convert everything to fiber optic (sensors and transmission), but the change would be too expensive.

Interesting details:

- the cabinet doors are on the leeward side of the primary wind patterns to provide some protection from the elements
- rodents love to chew the fiber optic cable, but they don't chew through the electrical cable
- AC power needs to be in a different trench five feet away from any copper (phone) lines, but AC can be in the same trench as fiber optic cable.
- sometimes the cabinets are used as targets for shooting guns from vehicles!

MnROAD was collecting more data than they could analyze. They started to collect dynamic data automatically on the Low Volume Road when the truck "tripped" a pressure-sensitive line to trigger the commencement of data collection. MnROAD is also working on making data more accessible.

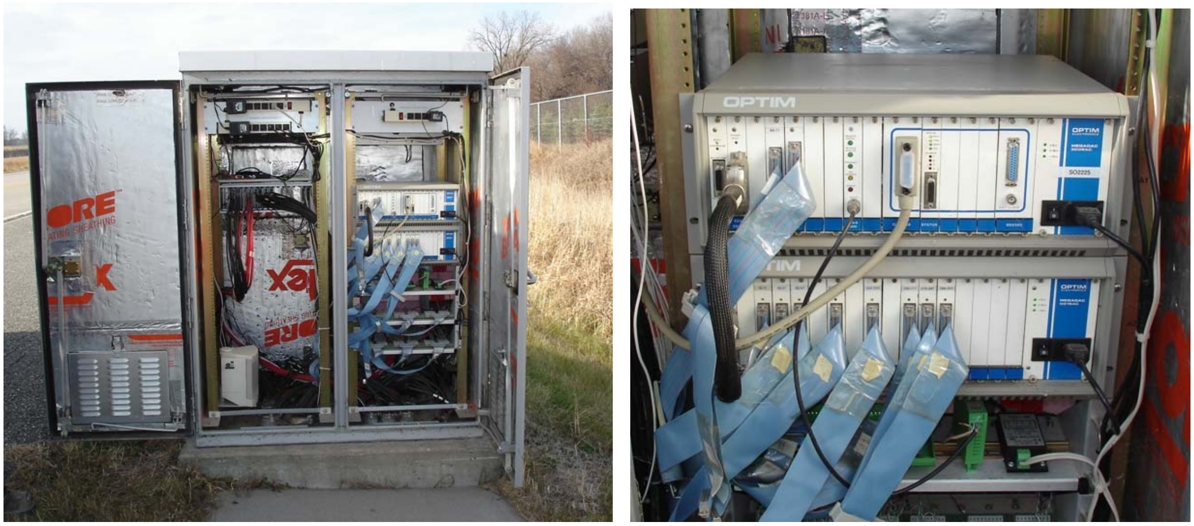

Figure 13: Typical data acquisition cabinet at MnROAD

Research and Activities

The original research objectives of MnROAD included pavement design models (empirical and mechanistic based), axle load during spring thaw conditions, vehicle load damage factors, effect of pavement material properties on performance/distress, improved instrumentation, among other objectives.

Quantifying cost savings as research benefits has been a very successful marketing tool for MnROAD. Managers will get on board with new practices, materials, etc. when the potential cost savings are available and soundly based.

Future research ideas that are being considered beyond pavement designs involve trucks, tires, and diesel fuel alternatives.

Texas A&M Riverside Campus

General Description

The Texas Transportation Institute is a research unit of the Texas A&M University System (TAMUS) College of Engineering. The Riverside Campus of Texas A&M is a 2,000 acre research and training facility located near Bryan, TX 10 miles from the main campus. A significant portion of the Riverside Campus is the test track (Figure 14). Portions of the old concrete runways that made up an air force base are paved for testing purposes.

Figure 14: Texas Transportation Institute Riverside Campus and test track (reprinted with permission)

The mission statement of Texas Transportation Institute is to "solve transportation problems through research, to transfer technology, and to develop diverse human resources to meet the transportation challenges of tomorrow."

Site Development History

In the 1950s a former federal air force base was essentially abandoned. In 1964 it became available for use by the Texas A&M University System with the plan that in 20 years it would be given to the university if the use of the facilities was deemed valuable. Over the course of the 20 years the university wrote to the federal government about the ongoing activities and in 1984 the title was transferred to Texas A&M University.

The facility was not designed as a test track, but TTI has adapted it for different uses over time. There are many buildings used by other departments of Texas A&M.

Funding Sources and Partnerships

Ninety percent of TTI's budget is earned through competitively awarded research contracts. About a third each is from federal, state, and private industry sources. TTI responds to proposals or is approached by industry and then an agreement is signed for TTI to perform the work. Only about $10,000-$15,000 is legislatively appropriated annually for overhead and maintenance at the Riverside campus test track.

TTI does sometimes team with other research agencies when responding to proposals, including the University of Texas, University of Michigan, and Battelle. During a visit to the sight, they were very interested in potentially working with the Western Transportation Institute.

Infrastructure

The infrastructure at the riverside campus includes the following items.

- 3.5 miles of track - The driving track has the following designated areas: a serpentine, obstacle course, fast track, precision maneuvering, edge drop, fire truck training, braking/evasive lane change, backing and parking
- Roadside equipment laboratory (for nearby Highway 6)
- Proving Grounds Research Facility
- Ride/Rut Facility
- The Central and Western Field Test Center
- The Outdoor Pendulum Facility
- The Parametric Measurement Facility
- TxDOT/TTI Hydraulics, Sedimentation, and Erosion Control Laboratory (HSECL)
- Visibility and Retroreflectivity Laboratory

Research and Activities

Hydraulics, sedimentation, erosion control. The Hydraulics, Sedimentation, and Erosion Control Laboratory is mostly used for product testing. TxDOT has a list of approved products for erosion and sediment control; actually 22 other states use the list and still others will also contact TTI to have products tested. Products on the TxDOT list require recertification every three years. Twelve laboratory tests are performed to determine basic material properties.

A 22-foot tall embankment was constructed for field-testing product performance with a 1:2 gradient on the west-facing side and 1:3 gradient on the east-facing side. Six inches of an erosive sandy loam soil are on one half of the embankment surface and six inches of a tight clay soil on the other half. A concrete channel collects the runoff from 20-foot wide plots. This embankment is no longer used for the TxDOT product testing, but is now part of a long-term vegetation study. Inclement weather led to the development of a new indoor rainfall simulator facility in 2001.

The rainfall simulator consists of two parallel tracks in which the soil is tilled, provided standardized moisture content, rolled, and vegetated outside. The 6-foot wide, 32-foot long beds are rolled indoors and hoisted up on one side to create the desired slope. Rainfall is supplied from a rack set to the same slope as the vegetated bed and is capable of gyrating to realistically simulate rain events. The test involves three consecutive rainfall events that last 30 minutes with a rainfall intensity of 3.75 inches/hour. Each test is completed three times and the average dry weight of soil loss is given to TxDOT. Three in-line flowmeters were installed to measure the flow rate instead of relying on the design specifications. The average drop size is 45 mm and good correlation has been found between actual and simulated rain events.

Vegetation establishment is also tested for each product in a greenhouse. The samples are 18-inches by 24-inches and vegetation is grown at both 1:3 and 1:2 gradients. The products are seeded by the same method that would be used in the field. Vegetation is quantified by weight and photo-imaging. The photo-imaging counts the pixels according to color and is considered better than the weight method.

Products intended to line river channels also undergo testing. A second greenhouse grows beds of vegetation on the testing product to be put in a flume. The flume is 18 inches wide and 30 feet long. A product is tested at (bottom) shear forces of 2, 4, 6, 8, and 10 pounds. Two runs lasting 20 minutes are conducted each day. After each run a depth caliper maps out the surface at 29 locations along the length of the flume at the three locations (the center and two inches from each side). The elevation difference from consecutive mapping events indicates the amount of soil eroded.

Ride/Rut Facility. The Ride/Rut Facility was constructed in 1999 jointly by TTI and TxDOT to "aid in the evaluation, support, and implementation of profiling products, technology, and initiatives[1]." The facility has a 2,000-foot long 13-foot wide asphalt track constructed on the shoulder of the concrete runway. Two wheelpath profiles are maintained as the reference profiles. The results from the profiler under testing are compared to the reference profiles for both accuracy and repeatability. The profiler can fail certification if either accuracy or repeatability is less than the standard.

Adjacent to the profiler test track are test sections for verifying and calibrating the rut bars on inertial profilers. The rut bars vary from ¼, ½, 1, and 3 inches in height. Both profilers and operators are certified at the Ride/Rut Facility by TTI staff, including the profilers used for TxDOT's annual pavement condition surveys. Finally, the Ride/Rut Facility includes an asphalt-overlay-on-concrete section where prototype equipment can be tested by developers before marketing and use on pavement construction/rehabilitation projects.

Maintenance of the profiler test track has included two fog seals since 2001 and crack sealing when necessary. Eventually, the track will need to be resurfaced with hot-mix asphalt. Additionally, the grass on the shoulder requires regular mowing.

National Geotechnical Experimentation Sites (Clay and Sand). Another endeavor of the TTI Riverside campus is the study of geotechnical engineering research that began in the late 1970s. In 1988 the clay and sand research sites were recognized as National Geotechnical Experimentation Sites under the NSF and FHWA as a prestigious Level I site because it closely fits a combination of research area criteria. There is only one other Level I NGES; there are three Level II sites and 37 Level III sites. Sites classified as Level I and Level II are eligible for immediate funding and contribute to a database of test results to undergo review.

Safety & Structural Systems Division (SSSD). The crash testing activities at TTI are widely known and consist of staff for construction, evaluation and reporting, and photography and instrumentation. The crash tests performed within the SSSD are for structures, such as guardrails, concrete barriers, and anti-terrorist/anti-ram devices. Pendulum or bogie tests can indicate the low speed dynamics of a crash and a load frame is used for static testing. However, the full-scale crash tests offer the most detail for the crashworthiness of structures. A tow-cable system is used for acceleration and maneuvering of lighter vehicles; heavier vehicles are operated by a remote control.

Instrumentation and sensors for vehicles for data collection are encased in a box which is fully prepared in a lab and then installed in a vehicle, usually in the trunk if a car is used or the bed if a truck is used. During testing, a high gain amplifier and voltage control oscillators manipulate the voltage data, which is then transmitted on a wide band FM analog telemetry signal. At the

[1] TTI website (2006) Available http://tti.tamu.edu/facilities/facility_detail.htm?loc_id=3222&fac_id=20

building an antenna picks up the signal and sends it to a receiver and recorder. There is a sub carrier discriminator for each voltage control oscillator. A bandwidth of 500 Hz has been deemed adequate and actually only about 300 is needed. The recorder was a 28-track 1-inch tape built in the 1980s but now the analog in/analog out channels are recorded to a digital memory card. Shunt calibrators are put on each transducer before testing. While recording, there is also complete digitization (at 10 kHz) of data with custom-written software. The data is then sent to TRAP, a reporting program. The accelerometers used in tests require annual calibration (protocol SAE J211). However, instead of shipping off the many accelerometers they stock, they are calibrated at the TAMUS Riverside Campus in a shaker. This means only the reference accelerometer in the shaker needs to be shipped out for calibration once a year. By the way, the new accelerometers are capable of measuring ±2000 G's, although the older ones with a range of ±100 G's are still used.

The photography and film capabilities of the crash testing program are dependent on a very experienced photographer and impressive inventory of cameras. For photography, some relatively simple point-and-shoot cameras are used, but there is also an impressive SLR that shoots eight pictures per second – a fast-shooting camera with a long lens is needed to safely shoot at a distance and capture several images during the ~3 second crash. Some photos are put in the report, but all are archived on CD or DVD. For video, there are lots of small and light cameras because staff is often walking around during the test. A crash documentary is about 18-20 minutes, so don't need huge storage; these video cameras record to MiniDVs. The Cannon XL1 shoots 30 frames per second. Film has not been completed replaced by digital video. Actually, all the analysis is currently done with film, but do expect to phase in digital analyses. With digital the images are immediately available. With film, however, about $200 is spent on each camera for each crash test to process, print, transfer, and put on tape all the images. None of this is done at TTI; instead they opt to ship out the film for this processing. Three film cameras are used for each test and they operate at 500 pictures per second. There are four hi-speed digital video cameras used for each test that also run at 500 frames per second.

Advice given regarding this program are listed below.

- Be involved at the professional level of all government committees affiliated with the research theme, and be involved in the policy-making.
- Have a good instrumentation guy: one that is resourceful, can build gadgets, and understand data.
- Film/photography is a very important product of tests; manufacturers may even use these for marketing.

Pennsylvania Transportation Institute Research and Testing Track Facility

General Description

The Pennsylvania Transportation Institute is a research unit of Penn State's College of Engineering. The institute operates a 5042-foot length test track built in 1970 in Bellefonte, Pennsylvania. The test track features a variety of tracks for researching bridges, vehicle durability, vehicle handling, crash safety, pavement durability, buses, roughness, and structure impact loading (Figure 15).

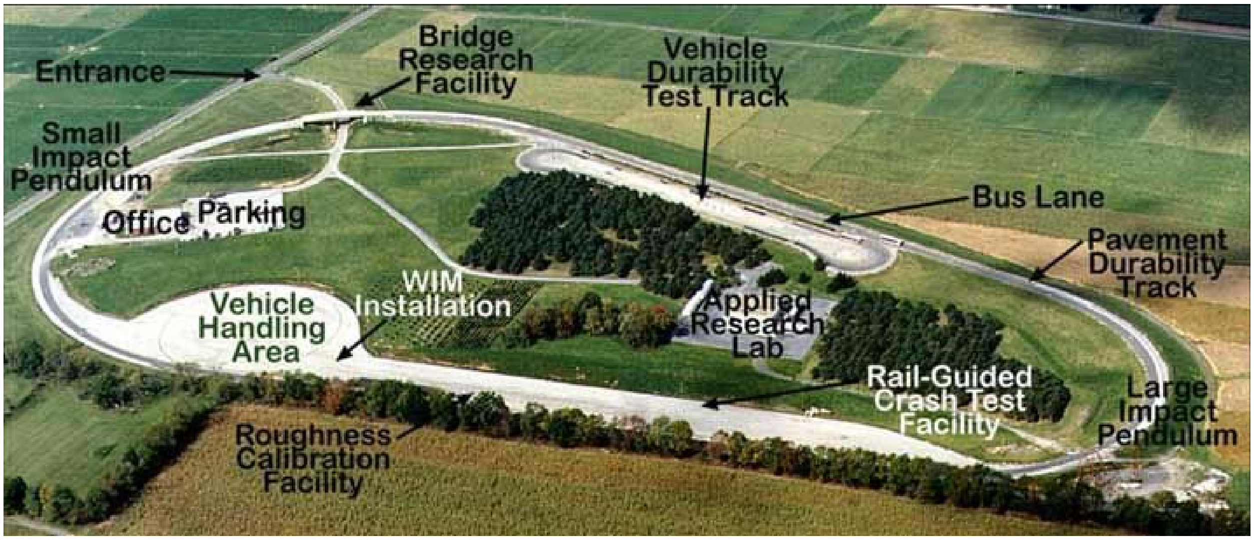

Figure 15: Pennsylvania Transportation Institute Research and Testing Track Facility (reprinted with permission)

Site Development History

The Pennsylvania Transportation and Traffic Safety Center (PTTSC) and the Pennsylvania Department of Transportation (PennDOT) began working together in 1968 with the idea that a full-scale pavement research and development center was needed to validate and refine the state's pavement design procedure. For 21 months beginning in March 1969 the feasibility of three facility concepts was studied. One involved simply using a portion of an existing heavy-truck route. A slightly more sophisticated plan of constructing a road parallel to a route towards which traffic could be diverted onto during studies was also proposed. In the end the decision was made to invest in developing "a full-scale test track type of facility."

The facility was built on 136 acres of land designed by Penn State for PTTSC research. The test track was configured as a lopsided oval for several reasons. The loop configuration that was considered limited the speed at which the curves at each end could be traveled. The oval configuration would have been too large (and expensive) if it incorporated the desired 1000-ft tangent lengths. Thus the lopsided oval ensured a combination of good traffic speeds (minimum 35 mph) and tangents lengths.

Under the planning phase, technical considerations regarding size and frequency of loading, instrumentation, and experimental pavement designs were discussed in workshops attended by specialists throughout the nation. The design phase incorporated a geometric design of the earthwork, grading, and drainage; track configuration; preliminary soils investigation; pavement design; and bridge design. Construction occurred between June 1971 and September 1972 and the facility was officially opened and dedicated on October 3, 1972.

Research and Activities

Original research on the track focused on pavement and infrastructure. Four experimental pavement blocks composed of several test sections separately investigated base materials and thicknesses of bituminous concrete base, surface course, and subbase. A 120-ft, two-span bridge was built with two different deck types: 1) a conventional reinforced concrete deck and 2) a three-inch thick precast, prestressed concrete deck with a composite cast-in-place concrete topping. The former utilized removable wood forms on one half and stay-in-place steel forms on the other half.

In applying traffic to the track, several human-factor-type questions were posed that were analyzed based on the commercial driver alert system installed in the test vehicle. The system identified steering wheel reversals and alerted the driver when drifting beyond his typical pattern occurred. The following queries were investigated: 1) is there a "significant difference in the driving characteristics of the drivers employed;" 2) is there any "significant difference in a driver's response from the first hour of operation to the last hour of the day;" 3) do "external conditions (e.g., fog and snow) produce a significant difference in a driver's reversal rate;" and 4) whether "a driver's reversal rate significantly changes with more experience."

In the 1980s research of runaway truck ramps was undertaken at the PTI test track. Two beds were created tangent to the oval, one filled with limestone and the other river gravel, although the beds were not inclined and thus represented a very conservative solution.

The activity at the test track is currently dominated by the testing of buses, a program that developed in 1989 "in response to legislation requiring that all new and modified bus models be thoroughly tested before being purchased with federal funds." Testing takes place at the PTI test track as well as at the indoor Altoona Bus Research and Testing Center in Altoona, Pennsylvania. The test track was modified with vehicle durability sections designed to expose the bus to accelerated stresses and approximate 25 percent of its service life.

A relatively new research theme active at the PTI test track is crash testing. The rail-guided and cable-tow facilities are capable of testing vehicles up to 15,000 pounds and comply with NCHRP, AASHTO, and FMVSS standards.

Funding Sources, Partnerships, and Functional Requirements

The track construction was originally funded by PennDOT.

The bus testing program was initially funded by the Surface Transportation and Uniform Relocation Assistance Act. Continued funding is from industry (20%) and the Federal Transit Administration (FTA) under the Intermodal Surface Transportation Efficiency Act and the Transportation Equity Act.

A cost center was established, and is currently under review, in which sponsored research needing to use the test track facilities is charged a daily rate.

Infrastructure

The first building at the PTI test track was simply an unheated pole barn that was deemed inhospitable in the winter and is now used solely for storage. A double-wide manufactured building was brought in during the 1980s and received with high praise for its heating and plumbing (no more outdoor toilets!). This building has several offices as well as the comforts of a kitchen, lounge, and television. Both of these facilities can be seen in Figure 16. The newest building is a 100,000-square-foot, $1.8 million facility that is still being equipped with bus testing resources, including a chassis dynamometer-based emission tester (Figure 17).

Figure 16: Pole barn (left) and manufactured building (right) at PTI

Figure 17: Newest building at PTI test track

The pavement instrumentation that was originally deployed at the test track was very advanced. However, it reached its useful life many years ago and there are only ghostly remains of various wires.

The entire test track is sloped and drains to a pond at the lower end (Figure 18). It is rarely dry and always freezes during the winter. Water fowl frequently visit during warmer weather and there has been no indication of any impact to the nearby airport; the pond is about 3000 feet from the runway.

Figure 18: Drainage pond at PTI test track

Summary

Touring several facilities provided an opportunity to see the infrastructure and talk to personnel involved in the daily operations of each facility. Information learned from each facility was put in the context of the development of the research facility in Lewistown, Montana. For instance, regarding a building on-site, which is currently lacking at the Lewistown site, several options are apparent. Both MnROAD and the PTI track have double-wide manufactured buildings, the former on a day-light basement. The Smart Road has two permanent buildings, but requires enough space to house the entire staff of VTTI. There are dozens of buildings (including a hangar) at the Riverside Campus that were given to Texas A&M, similar to the many historic buildings located on the active portion of the Lewistown Municipal Airport.

Instrumentation and communication backbones exist at the Smart Road and MnROAD facilities. The Smart Road utilizes underground bunkers with conduit connecting each one, while MnROAD has above ground data acquisition cabinets. The Smart Road has fiber optic cable along the road to bring information to the research building, while MnROAD relies primarily on Ethernet for data transfer.

Just as the infrastructure at these four facilities was taken note of, the operation was also considered. For instance, both the Smart Road and the PTI track utilize a cost center for research activities occurring at the test beds.

In conclusion, the infrastructure and operation of each of the facilities considered will be taken into account during the planning and development of the research test bed in Lewistown, Montana. The information gained from touring each of these facilities will contribute to a desirable and sustainable laboratory-like transportation research center.

Other Domestic Transportation Research Facilities

Accelerated Pavement Testing and Research Program (Florida DOT)

Location: State Materials Research Park of Florida DOT in Gainesville, Florida
http://www.dot.state.fl.us/statematerialsoffice/pavement/research/apt/index.shtm

General Description:

- Accelerated pavement testing with heavy vehicle simulator

Goals, Objectives, Strategic Direction:

- Focus on the Florida's most critical issues
- Determine solutions
- Facilitate implementation
- Validation of existing methods / materials
- Validation of innovative methods / materials
- Long-range research
- Trouble-shooting type problem solving

Types of research (past, current, future):

- Pavement research
- Asphalt rubber membranes
- Heavy polymer binders
- Bottom-up cracking
- Early strength requirements for concrete slab replacement
- Composite pavements
- Rut initiation mechanisms

Site development history (and if current operation differs from original plans):

- Put into service in October 2000

Facilities/Equipment

- Heavy Vehicle Simulator (HVS), Mark IV can simulate 20 years of service in as little as 3 months
- 10 straight 150-ft long, 12-ft wide test tracks
    - 2 with water table control in base and subgrade

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Advanced Driving Facility

Location: St. Cloud, MN
http://www.stcloudstate.edu/continuingstudies/mhsrc/range.asp

General Description:

- Driver training facility of the Minnesota Highway Safety and Research Center (MHSRC)

Goals, Objectives, Strategic Direction:

- The mission of the Minnesota Highway Safety and Research Center is to provide educational activities which prevent financial loss, human trauma and to promote the safe and efficient operation of the highway transportation system.

Types of research (past, current, future):

- Develop educational programs
- Alcohol involvement in motor vehicle operation
- Rollover effects on passenger vans
- Hydroplaning
- Anti-lock brake systems
- Distracted driving
- Cell phone usage

Facilities

- 3 mile paved track
- 2.5 mile gravel track
- Driver training courses for law enforcement, advanced driving skills for public and professional drivers, or customized courses

Contacts:
320-255-3123
mhsc@stcloudstate.edu

Advanced Transportation Research and Engineering Laboratory

Location: University of Illinois at Urbana Champaign

http://www.engineering.uiuc.edu/communications/engineering_research/2003/html.php?department=Research%20Organizations,%20Centers,%20and%20Laboratories&part=rcl-listing&year=2002&id=176887

http://www.ict.uiuc.edu/Documents/(Final)ICT.Bro.pdf

General Description:

- Research, education, and testing laboratory

Goals, Objectives, Strategic Direction:

- "Train IDOT employees and contractors in the integration and cording relationship of the railroad and highway signal systems."
- New technologies should be implemented frequently
- Technologies improve safety, improve reliability, reduce congestion, increase utilization of infrastructure, optimize resources

Types of research (past, current, future):

- Airport and highway: pavements, materials – Full Scale
- transportation systems
- railroad facilities – Full Scale
- Safety, congestion, environment, community impacts
- Pavements, structures, materials

Facilities

- 3 Laboratories & high bays
- 47 acres
- Former Chanute Air Force Base, Rantoul, Illinois
- 60,000 sq. ft. of laboratories, classrooms, offices, and library
- Large Land Area- full-scale pavement test facility

Contacts:

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Berkeley Highway Lab

Location: West Berkeley and Emeryville, CA; part of UC Berkeley
http://bhl.calccit.org:9006/bhl/

General Description:

- 2.7 section of Interstate 80 with traffic monitoring capabilities provides unique traffic data sets that are individualized instead of aggregate

Goals, Objectives, Strategic Direction:

- The research testbed collects unique databases of real-time and historical traffic data; data available for partners and independent research

Funding sources, partnerships:

- Caltrans (California DOT)
- California PATH (Partners for Advanced Transportation Technology)
- CCIT (California Center for Innovation Transportation)

Types of research (past, current, future):

- Traffic monitoring

Facilities/Equipment

- 2.7 miles of Interstate 80
- 14 surveillance cameras and 16 direction dual-inductive-loop-detector stations

Contacts:
Email bhl@its.berkeley.edu.

Civil Infrastructure Systems Laboratory

Location: Manhattan, KS part of Kansas State University
http://www.k-state.edu/pavements/
http://www.ce.ksu.edu/node/207

General Description:

- Large Scale testing of pavement and materials

Funding sources, partnerships, infrastructure, and functional requirements:

- Midwest States Accelerated Pavement Testing Pooled Fund Program
- Private Industry
- Kansas Asphalt Paving Association
- Kansas DOT
- Missouri DOT
- Iowa DOT
- Nebraska Department of Roads
- Federal Highway Administration

Types of research (past, current, future):

- Pavement and Materials—large-scale asphalt and concrete pavement testing, pavement temperature can be controlled between -10 and 140°F, full-scale loading to simulate highway truck traffic

Facilities:

- Accelerated pavement tester
- Kansas Outdoor Concrete Exposure site

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Cold Regions Research and Engineering Laboratory (CRREL)

Location: Hanover, NH
http://www.crrel.usace.army.mil/facilitieslabstestsites/

General Description

- The Engineer Research and Development Center of the US Army Corps of Engineers operates a Cold Regions Research and Engineering Laboratory (CRREL) located in Hanover, New Hampshire.

Goals, Objectives, Strategic Direction

The mission of CRREL is to gain knowledge of cold regions through scientific and engineering research and put that knowledge to work for the Corps of Engineers, the Army, the Department of Defense, and the Nation. Specifically, CRREL's mission encompasses the following:

- Conducting research to characterize the constraints placed on Army materiel and operations in a realistic winter battlefield environment
  - Developing techniques and equipment to mitigate those effects.
  - Providing engineering and consulting services on cold-related problems to developers of Army doctrine and materiel.
- Conducting research to characterize the nature and the impact of cold effects on construction, operations, and maintenance of army and civil works facilities and activities
  - Develops new procedures and equipment to minimize costs.
  - Provides environmental services on cold-related problems to developers of equipment, managers of Army and civil works facilities, and other field users.
- Conducting research and recommends mitigative measures on the impact of human activity on the environment in cold regions
- Conducting fundamental research to understand the nature and characteristics of snow, ice, frozen ground and other materials in cold environments including their interrelationship with other environmental parameters
- Performing other research and development as required by agreements between the Office of the Chief of Engineers (OCE) and other Army and government agencies, and the private sector

Facilities/Laboratories:

- Cold Rooms, Frost Effects Research Facility, Geophysical Research Facility, Greenhouse, Ice Adhesion Testing Facility, Ice Engineering Research Facility, Materiel Evaluation Facility, Remote Sensing and Geographic Information System
- Laboratories: Asphalt Laboratory, Chemistry Laboratory, Concrete/Microstructures Laboratory, Geotechnical Laboratory, High-Performance Materials Laboratory, Mobility Laboratory, Soil Microbiology Laboratory, Technical Engineering and Calibration Laboratory
- Test Sites:Ground-Penetrating Radar, Intrusion Detection System
- Equipment:CRREL Infrared Research Camera

Keweenaw Research Center's Institute of Snow Research

Location: Calumet, MI part of Michigan Technological University
http://www.mtukrc.org/services.htm

General Description:

- Provide solutions to questions and problems with snow
- Research snow mobility of vehicles ranging from army tanks to snowmobiles

Funding sources, partnerships, infrastructure, and functional requirements:

- Alumni
- Industrial Sponsors
- Equipment Donations

Types of research (past, current, future):

- Snow Processing – Snow Paver
- Control Snow characteristics
- Deicing, Anti-icing chemical performance
- Elastomeric Coatings
- Snowmobile studies
- Vehicle Mobility Testing

Equipment:

- 500 acre winter test facility located on Michigan's Keweenaw Peninsula – (which receives a lot of snow!), hundreds of miles of snowmobile trails
- Cold chamber, acquisition equipment, frost simulation, Snow/Ice shear strength measurement, deicing chemical performance tests, chemical spreaders, traffic simulation rollers, water trucks, pavement surface friction measurement vehicle, snow grooming equipment, snowmobiles, snow characterization equipment, Geodimeter

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Kiewit Center for Infrastructure & Transportation

Location: Oregon State University
http://kiewit.oregonstate.edu/

General Description:

- Base organization for most research within School of Civil and Construction Engineering
- Sponsors a continuing education program

Goals, Objectives, Strategic Direction:

- Provide "variety of outreach activities to support practicing professionals throughout the Pacific Northwest"

Funding sources, partnerships, infrastructure, and functional requirements:

- Former and Current Kiewit employees

Types of research (past, current, future):

- Bridge maintenance, Wave and Storm Surge Forces on Bridges, Roof collapse
- Coastal & Ocean affects, Construction, Geotechnical, Structural, Transportation, Water Resources,

Site development history (and if current operation differs from original plans):

- Originally Transportation Research Institute started in 1962
- Geotechnical Engineering Field Research Site – Est. 1997

Facilities

- Materials Laboratory
- O.H. Hinsdale Wave Research Laboratory
- Strong Floor Facility

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(541) 737-4273

Louisiana Transportation Research Center – Pavement Research Facility

Location: Louisiana State University
http://www.ltrc.lsu.edu/research_alf.html

General Description:

- Concerned with long term durability of roads

Goals, Objectives, Strategic Direction:

- "The cooperative research effort of the pavement research facility provides a unique opportunity for researchers for LTRC, state universities, and industry to work together for the future of our nation's transportation system."
- Increase roadway performance, increase pavement life, increase safety, and reduce construction, operation, and maintenance costs

Funding sources, partnerships, infrastructure, and functional requirements:

- Louisiana Department of Transportation and Development
- Federal Highway Administration
- $3 million into site development

Types of research (past, current, future):

- Pavement testing – loading, rideability, friction, non-destructive pavement layer examinations, tire noise

Facilities/Equipment

- 6 acres
- Across Mississippi River form Baton Rouge
- Accelerated Loading Facility

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National Center for Asphalt Technology – Pavement Test Track – Auburn University

General Description
The NCAT Pavement Test Track is a 1.7 mile oval track located about 30 minutes from the Auburn University campus. There are 45 test sections about 200 feet in length. Coordinated research begins every three years: the first year is for reconstruction of the test sections and the next two years for accelerated performance testing. Over the two-year testing period a design lifetime of truck traffic is accomplished with the application of ten million equivalent single axle loads. The 2000 and 2003 tracks are completed. The reconstruction for the 2006 track will take place from March to October 2006.

Figure 19: NCAT Pavement Test Track in Alabama

Goals, Objectives, Strategic Direction
The Mission Statement of NCAT is "to be a world leader and authority in hot mix asphalt research, development, technology, and education in the areas of:

- Structural Design
- Construction Methods
- Materials and Testing
- Performance Measurement and Prediction
- Pavement Preservation, Rehabilitation, Recycling, and Maintenance
- Environment and Highway Safety"

Funding sources, partnerships, infrastructure, and functional requirements
The original construction of the test track in 2000 was funded by the Alabama Department of Transportation. Auburn University purchased the 309 acres of land where the test track and affiliated buildings are located. The test sections require sponsors and the cost depends on pavement alteration (costs are per test section per year for three years): $50,000 is needed for traffic loading with no change to the existing pavement; $100,000 allows for mill and inlay over an existing perpetual foundation; and $150,000 will allow the sponsor to participate in the structural experiment for 2006. An entity will often sponsor at least two test sections for comparison purposes.

Many state DOTs have sponsored test sections, including, but not limited to: Alabama, Florida, Georgia, Indiana, Mississippi, North Carolina, South Carolina, Oklahoma, and Tennessee. The Federal Highway Administration has also sponsored test sections as well as provided Westrack trailer trains, reducing the cost of trucking for NCAT.

A fleet of 5 trucks average 680 miles per day per truck six days a week. NCAT hires drivers to operate the trucks for two shifts: 5am to 2pm and 2pm to 11pm. By using human drivers, vehicle handling and wandering on the track is more consistent with that of actual roads. Vehicle maintenance and track measurements are performed every Monday. A scanning laser is used to determine wheelpath roughness, macrotexture, and rutting for each test section. "Every month, wet ribbed surface friction testing, falling weight deflectometer testing, and structural high speed response data is collected, along with videologging to provide a permanent visual record of surface performance. Every quarter, cores are cut from the wheelpath of every section so that densification of each layer can be considered."

Types of research (past, current, future)

Phase I and Phase II of the pavement test track have been completed. Phase III is currently underway with reconstruction activity in 2006. During Phase I the research focused on asphalt concrete (AC) mixtures: modified AC vs. non-modified AC; fine-graded vs. coarse-graded; effect of aggregate type; and SMA vs. OGFC vs. dense-graded HMA. SMA refers to stone matrix asphalt and OGFC refers to open-graded friction course, while HMA is an acronym for hot mix asphalt.

During Phase II some test sections were not reconstructed to observe the effects of additional traffic loading. Other sections were milled and overlaid with various mixtures. A structural study investigated three thickness of HMA, two grades of AC (modified and non-modified), and the "rich bottom" concept. The rich bottom is when a high-asphalt-content HMA course is installed at the "bottom of the asphalt pavement structure to minimize the initiation of potential fatigue cracking from the bottom upwards," implemented to study the replacement of existing PCC (Portland Cement Concrete) pavement with HMA pavement.

Phase III will continue research for mill and overlay as well as non-reconstruction. However, it will also investigate the mechanistic pavement design procedure and mechanistic-empirical model for flexible pavements. The NCHRP Project 1-37a was the development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures, while NCHRP Project 1-40 will review and recommend any changes for the Guide. Thus, the 2006 pavement test track will work with NCHRP Project 1-40.

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Nevada Automotive Test Center

Location: Carson City, NV and West Yellowstone airport, MT
http://www.natc-ht.com/index.html

General Description:

- Independent testing and evaluation, research and development facility

Goals, Objectives, Strategic Direction:

- NATC
  - "We Are Pioneers Driving The Leading Edge Of Transportation Technology
  - We Help People Understand Their World Environment (We Are Teachers Transferring The Knowledge)
  - We Contribute To The Financial Security And Personal Growth Of Our Team
  - We Provide A Meaningful And Memorable Experience Endearing The Customer To The Pioneering Spirit
  - We Take Responsibility For The Definition Of Customer Issues Within Their Market, Providing Unique, Timely, Creative, Useful And Cost Effective Solutions With The Highest Integrity"
- WesTrack
  - To continue the development of performance-related specifications (PRS) for hot-mix asphalt construction by evaluating the impact on performance of deviations in materials and construction properties (e.g., asphalt content, air void content, and aggregate gradation) from design values in a large scale, accelerated field test.
  - To provide early field verification of the SHRP Superpave Level III mix design procedures.

Types of research:

- Ground vehicle systems
- Vehicle component evaluation and certification
- Weapons systems and ammunition tests

Facilities:

- A variety of test courses in Nevada (about 3 miles total): gravel, 2" washboard, radial washboard, 6" washboard, Belgian block, standard slag road, abrasive mud traction, clay/mud traction, lahontan marsh, stream fording, salt splash trough, etc.
- Pavement testing at Westrack: driverless vehicles that simulates 10 million ESAL or 1.7 million total vehicle miles within 2 years; evaluates deviations in materials and construction properties
- Winter testing grounds at West Yellowstone airport for traction, acceleration, braking, snow packing, mobility, and handling and stability

Contacts:
775-629-2000

Ohio Research Institute for Transportation and the Environment

Location: Ohio University
http://www.ohio.edu/orite/

General Description:

- Government and industry research, workshops, conferences
- One of the first to integrate environmental and geotechnical engineering

Goals, Objectives, Strategic Direction:

- Solve environmental and transportation problems

Types of research (past, current, future):

- Acid Mine Drainage, Field Evaluation of Bridges, Field Evaluation of Pavements, Human Factors, Noise Abatement, Ohio SHRP Test Pavements, Subsurface Exploration

Site development history (and if current operation differs from original plans):

- Founded 1987 as Center for Geotechnical and Environmental Research
- ORITE was established in 1997 and CGER was integrated into it
- In 2000 Center for Pipe and Underground Structures joined ORITE

Equipment:
MTS hydraulic loading devices, Resilient Modulus device to evaluate mechanical properties of asphalt concrete mixes, Multiaxial machines, Direct shear tester, Georgia Wheel Tester, Beam fatigue device, Gyratory compactor, Centrifuge, Cone penetrometer truck, Automated dynamic cone penetrometer, Sensors, Ground-penetrating radar, research vehicles

Facilities:
Accelerated Pavement Load Facility, Outdoor load cell facility, Center for Geotechnical and Environmental Research, Center for Pipe and Underground Structures, Material Characterization Lab, Outdoor Load frame facility, HDPE Thermoplastic Pipe NTPEP Facility

Contacts:
Gayle F. Mitchell – Director
Stocker Center 143
(740) 593-1470

Pecos Research & Testing Center

Location: Pecos, TX
http://www.pecosrtc.org/index.stm

General Description:

- Large scale center with variety of test tracks and range of support facilities. It's an academic–industry collaboration between.

Funding sources, partnerships, infrastructure, and functional requirements:

- Partnership between Texas Transportation Institute, Applied Research Associates, and the Pecos Economic Development Corportation

Types of research (past, current, future):

- Pavements
- Vehicle, tire and component testing
- Human factors
- Intelligent transportation systems
- Air quality
- Vegetation management

Site development history (and if current operation differs from original plans):
For several decades, the site was the primary testing facility of B.F. Goodrich and has also been used by automakers.

Facilities:

- Main Buildings: office and storage areas, 30-bay garage
- High Speed Test Track
- El Camino Road Course
- Skid Pad
- Off-Road Courses
- Serpentine Road
- Lateral Acceleration Circles
- City Course Squares
- Magic Hill Clime

Contacts:

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Rocky Mountain Division
Pecos, Texas 79772
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Turner-Fairbank Highway Research Center

Location: McLean, VA
http://www.fhwa.dot.gov/research/tfhrc/

General Description:

- The Federal Highway Administration's national research facility

Types of research (past, current, future):

- Infrastructure: pavement materials, pavement design and construction, longterm pavement performance, bridge and foundation engineering, hazard mitigation, infrastructure management
- Safety and human factors
- Operations
- Innovation management and communications,

Facilities:

- Infrastructure Laboratories:
    - aerodynamics,
    - coatings and corrosion,
    - geotechnical,
    - highway materials complex,
    - hydraulics,
    - nondestructive evaluation,
    - pavement testing, and
    - structures
- Transportation Operations Laboratory
- Safety Laboratories:
    - Arens photometric and visibility,
    - digital highway measurement,
    - federal outdoor impact,
    - geometric design, and
    - human factors

Contacts:

Turner-Fairbank Highway
Research Center
6300 Georgetown Pike
McLean, VA 22101

University of California Pavement Research Center

Location: Richmond, CA
http://www.ucprc.ucdavis.edu/

General Description:

- Pavement research facility that is a partnership between UC Davis and UC Berkeley

Goals, Objectives, Strategic Direction:

- Dedicated to providing knowledge, the Pavement Research Center uses innovative research and sound engineering principles to improve pavement structures, materials, and technologies.

Types of research (past, current, future):

- Development of a Caltrans Pavement Management System
- Pavement Smoothness
- Pavement Preservation
- Quiet Pavements
- Pavement Construction Practices
- Mechanistic-Empirical Design
- Long-life Pavements
- Pavement Recycling and Sustainability

Facilities/Equipment

- Fabrication facilities to make asphalt and concrete pavement samples
- Testing equipment to test samples (beam testing, flexural testing, rheometry, etc.)
- 2 heavy vehicle simulators
- Indoor and outdoor pavement testing facility
- Climate control equipment
- Sensors (deflectometers, profilometers, crack meters, joint activity meters)

Contacts:

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jtharvey@ucdavis.edu

Carl L Monismith
University of California, Berkeley
510-665-3560
clm@maxwell.berkeley.edu

Waterways Experiment Station

Location: Vicksburg, MS
http://www.wes.army.mil/Welcome.html

General Description:

- U.S. Army Engineer Research and Development Center has seven laboratories, four of which are located at the Waterways Experiment Station

Goals, Objectives, Strategic Direction:

- U.S. Army Engineer Research and Development Center (ERDC) "has as its mission to conceive, plan, study and execute engineering investigations and research and development studies in support of the civil and military missions of the Corps of Engineers and other federal agencies."

Types of research (past, current, future):

- Coastal structures, coastlines, dredging, erosion control, estuaries, flood control, hydraulic structures, fish passage, wetlands
- Airfields and pavements, aggregates, geotechnical centrifuge research, materials testing, earthquake engineering and geosciences
- Aquatics, endangered species, invasive species, water quality, fate and transport, ecological monitoring
- High performance computing and networking, software engineering and informatics, and computational science and engineering

Site development history (and if current operation differs from original plans):

- Established in response to Mississippi River Flood of 1927 (one of the nation's most destructive natural disasters)
- First federal hydraulics research facility
- Now there are four other separate, but closely interrelated laboratories

Facilities/Laboratories

- 673 acre complex
- Coastal and Hydraulics Laboratory
- Geotechnical and Structures Laboratory
- Environmental Laboratory
- Information Technology Laboratory

Contacts:

Public Affairs Office
ceerd-pa-z@erdc.usace.army.mil

William J Hughes Technical Center

Location: Atlantic City International Airport, NJ
http://www.faa.gov/about/office_org/headquarters_offices/ato/tc/

General Description:

- Aviation research, development, test and evaluation center is the national scientific test base of the Federal Aviation Adminstration

Types of research (past, current, future):

- Air traffic control, including new equipment and software
- Communications
- Navigation
- Airports
- Aircraft safety
- Security

Facilities/Groups:

- Test and Evaluation Services Group
- Air Transportation System Evaluation Group
- Technical Strategies & Integration Group
- Communications, Flight Service & Weather Engineering Group
- Human Factors Research and Engineering Group
- Target Generation Facility
- Flight Deck Simulation Facility
- Airport Facilities Terminal Integration Laboratory
- Flight Program

Contacts:

General Information
609-485-4000

International Transportation Research Facilities

Australian Road Research Board (ARRB) Research

Location: Australia
http://www.arrb.com.au/index.php

General Description:

- Consulting research for all aspects of transport

Goals, Objectives, Strategic Direction:

- "Conduct public interest research"

Funding sources, partnerships, infrastructure, and functional requirements:

- Not-for-profit part of ARRB Group

Types of research (past, current, future):

- Road asset management, Road use management, Transport policy, Road safety, Incident investigation and reconstruction, Fleet safety and risk management, Environment, Materials, Road surveys and data collection, Products and software, Library, publications and knowledge transfer
- Original research focused on materials and road pavement
- Grown to multidisciplinary transportation research

Site development history:

- Founded 1960

Research tools:

- Pavement profiling systems,
- Digital imaging systems,
- Road geometry and mapping systems,
- Network survey vehicles,
- Software tools,
- Traffic information systems

Federal Highway Research Institute, BASt

Location: Germany
http://www.bast.de/cln_007/nn_75442/EN/e-Home/e-homepage__node.html?__nnn=true

General Description:

- Performs research for consulting and assessment reports

Goals, Objectives, Strategic Direction:

- Reduce environmental stress and improve traffic safety

Types of research (past, current, future):

- Efficiency of construction and maintenance – roads and bridges
- Road safety
- Road Use
- Environmentally friendly – building methods, pollution, energy
- Road networking

Site development history (and if current operation differs from original plans):

- 1950: Founded by Federal Ministry of Traffic: merger of Federal Agency for Testing Road Building Materials and Federal Agency for Hydraulic Engineering, Earthworks, and Soil Engineering
- 1965: Renamed Federal Highway Research Institute

Large-Scale Testing Plants:

- Accident research Hall, Halls for Dynamic Testing of Road Models, Interior Drum Testing Facility, Lab for Acoustic Scale Model Technology, Light Test Hall, Turntable Road-Marking Test System, Vehicle Engineering Test Facility, Vehicle-Pavement Interaction Facility
- Home of three hydraulic plate loading rigs to simulate traffic

Contacts:
Petra Peter-Antonin, Head

COST 347

Location: European Union
http://cordis.europa.eu/cost-transport/src/cost-347.htm

General Description:

- Central hub for ALT facilities to coordinate their research and develop a code of good practice

Goals, Objectives, Strategic Direction:

- "To develop a European code of good practice to optimize the use of Accelerated Load Testing (ALT) facilities and to improve the application of results form them."
- Increase pan-European cost-sharing research ventures
- Collaborate research ventures between public and private sectors
- Broaden the number of non-owner organizations using ALT facilities
- Co-operation with pavement research groups outside Europe
- Establish and international association for ALT to strengthen international ties

Types of research (past, current, future):

- Accelerated load testing of pavements – Primary
- Accelerated Pavement Testing
- Accelerated Scale Testing
- Real-time Load Testing

Site development history (and if current operation differs from original plans):

- Est. October 2000 under European Commission
- (More of a Paper work center than a test center, I think)

Contacts:
Gregers Hildebrand, Chairman
ghb@vd.dk

Danish Road Institute - Danish Road Testing Machine (DRTM)

Location: Denmark
http://www.vejdirektoratet.dk/dokument.asp?page=document&objno=76929

General Description:

- Consultant on asphalt, material, and environment
- Home of indoor linear track facility for testing full-scale pavements under wheel loads

Goals, Objectives, Strategic Direction:

- Advise national road administrations, construction companies, manufacturers and road users
- Durable pavements, noise reducing pavements, recycle road material, integrated road management, update road standards

Types of research (past, current, future):

- Pavement Durability, noise, recycling

Site development history (and if current operation differs from original plans):

- Started form National Road Laboratory est. 1928
- 1988: the Road Data laboratory became part of the National Road Laboratory
- 1994: Renamed Danish Road Institute

Highway Engineering Research Group (HERG) University of Ulster

Location: United Kingdoom
http://www.engj.ulst.ac.uk/SCOBE/TRAC/hergintro.htm

General Description:

- Roads and materials testing

Goals, Objectives, Strategic Direction:

- "Promote new and innovative research into road construction leading to improved understanding and prediction of highway material performance."

Types of research (past, current, future):

- Mixture performance, long term performance of bituminous mixtures, reuse and recycling of resources
- Aggregate assessment, Bitumen testing, Assessment of hot and cold bituminous mixes, On-site assessment, Quarry assessment, Specialized testing, Dynamic loading

Site development history (and if current operation differs from original plans):

- Est. 1985

Contacts:

David Woodward
wdh.woodward@ulster.ac.uk

Laboratoire Central des Ponts and Chaussees

Location: Nantes, France

http://www.lcpc.fr/en/presentation/moyens/manege/index.dml#mac

General Description:

- Largest circular test track

Goals, Objectives, Strategic Direction:

- Full scale experimental pavement study
- "reproduce in less than a week up to a full year's truck traffic load supported by a heavily-trafficked pavement"

Types of research (past, current, future):

- Pavement submitted to heavy traffic levels
- Test new pavement and maintenance and reinforcement techniques

Site development history (and if current operation differs from original plans):

- 1980s: Roads Division set up Accelerated pavement Test facility
- Circular test track: four-arm rotating loading system, two wheel assemblies on inner track
- Three test rings

Contacts:

Division for Pavement Structures and Materials
Chantal de La Roche

Laboratory of Traffic Facilities (LAVOC)

Location: Switzerland
http://lavocwww.epfl.ch/EN/index.php

General Description:

- "Design, operation and maintenance of transport infrastructures"

Goals, Objectives, Strategic Direction:

- Teaching for future engineers
- Research

Types of research (past, current, future):

- Design Projects and their Environmental Impacts, Construction and Pavement Materials, Road Behavior, Infrastructure maintenance management, Transport Telematics

Road and Railroads Research Laboratory - LINTRACK

Location: Delft University of Technology, The Netherlands
http://vbk.ct.tudelft.nl/LINTRACKhome/index.htm

General Description:

- "A full scale heavy vehicle simulator for accelerated pavement testing"

Goals, Objectives, Strategic Direction:

- Simulate a large amount of traffic in a short time
- Sections being tested can be built very accurately, so calculation models for road structures can be verified, redesigned, calibrated, validated, tested

Types of research (past, current, future):

- Performance of road constructions under traffic
- Validation of empirical and theoretical models for rutting and cracking in flexible pavements,
- Evaluation of the damaging effects of various wheel configurations
- Performance evaluation of innovative pavement structures

Site development history (and if current operation differs from original plans):

- LINTRACK is owned by The Road and Railroad Research Laboratory of the Delft University of Technology and the Road and Hydraulic Engineering Division of the Dutch Ministry of Transport Public Works and Water Management
- Commissioned in 1991

Contacts:

L.J.M Houben, Research Manager
A.E. van Dommelen, Research Manager

Public Works Research Institute

Location: Japan
http://www.pwri.go.jp/team/pavement/eindex.html

General Description:

- Pavement Technologies

Goals, Objectives, Strategic Direction:

- Studies rational and economical pavement management, pavement performance, theoretical design, sustainability, environment

Types of research (past, current, future):

- Management target for pavement, evaluation of using by-products to pavement, practical use of underground infiltration technology of road rain water, effective maintenance method of pavement, improvement of the theoretical pavement structure design method, recycling system of aged asphalt, advancement performance appraisal method of pavement, evaluation method of pavement technology to mitigate environmental impacts, develop a snow and icy road classification method, requirements for drainage asphalt pavement
- Superpave Tests: Volumetric Strain Test, Uniaxial Strain Test, Simple shear test at constant height, Frequency sweep test at constant height, Repeated shear test at constant stress ratio, Repeated shear test at constant height

Road Research Center of Cedex

Location: Spain
http://www.cedex.es/cec/documenti/indexeng.htm#CECARRETERAS1

General Description:

- "organization specialized in research, technological development, high level technical assistance and standardization, concerning planning, project, construction and management of road networks, including traffic engineering and road safey."

Types of research (past, current, future):

- Testing basic road materials (aggregates, cement, and bituminous binders), bituminous mixtures, granular layers, bounded layers, and concrete.
- Testing pavements on the Full Scale Road Test Track
- Road surveying and maintenance, Pavement Management Systems software
- Traffic engineering, road signing, traffic safety

Site development history (and if current operation differs from original plans):

- Started in the Transport and Soil Mechanics Laboratory, created in 1944 at the Faculty of Civil Engineering in Madrid, 1957 Center of Research and Experimentation of Public Works, 1976 changed name to Roads and Geotechnics Laboratory, 1985 separated and created Road Research Center
- Three areas: Laboratory of Road Infrastructure, Area of Full Scale Evaluation, Area of Traffic and Road Safety

Contacts:

Aurelio Ruiz – Director of Road Infrastructure Lab
Aurelio.ruiz@cedex.es

Francisco Achutegui – Director of Area of Full Scale Evaluation
Francisco.achutegui@cedex.es

Swedish National Road and Transport Research Institute (VTI)

Location: Sweden
http://www.vti.se/templates/Page____2783.aspx

General Description:

- Emphasis on safety, economy, environment, traffic and transport analysis, public transport, behavior and the man-vehicle-transport system interaction, and in road design, operation and maintenance.

Goals, Objectives, Strategic Direction:

- Sustainable Development
- Improve knowledge of transport sector

Funding sources, partnerships, infrastructure, and functional requirements:

- Research for clients (Principal client: The Swedish National Road Administration)

Types of research (past, current, future):

- Aviation, Commercial Traffic, Economics and Society, Environment and Energy, Man in the transport system, Public Transport, Railbound Traffic, Road Construction, operation and maintenance, Traffic and transport analysis, Traffic Safety Vehicles
- Frost penetration
- Crash tests: child seats, effect of vehicle on barriers, traffic sign posts, bridge parapets, for cars and buses.
- Human machine interface, driver behavior, effects of fatigue and drugs to road design, tunnel design, reactions of the human body, drivers with impairments and new systems in vehicles.

Site development history (and if current operation differs from original plans):

- Equipment: Driving simulator for light and heavy traffic, road laboratories, tire testing installation, crash tracks, frost penetration meter, frost tester, Heavy Vehicle Simulator, Portable Friction Tester, Material testing system, Road Deflection Tester, Road surface tester
- 1975: Located on university campus in Linkoping
- 1998: Branch opened in Borlange, where headquarters for the Swedish National Road Administration and the National Rail Administration are located.
- Accredited Laboratories: VTI road lab, Crash safety lab,

Contacts:
Head Office e-mail: vti@vti.se
General Director: urban.karlstrom@vti.se

Transport Research Laboratory (TRL)

Location: United Kingdom
http://www.trl.co.uk/default.asp?id=1

General Description:

- "Independent and impartial world class research, consultancy, advice and testing for all aspects of transport."

Goals, Objectives, Strategic Direction:

- Vision: "Creating the future of transport"

Funding sources, partnerships, infrastructure, and functional requirements:

- Non-profit distributing foundation
- Have both public and private customers

Types of research (past, current, future):

- Facilities: Car driving simulator, Impact test, Crash test dummies, structural testing, mobile high speed survey vehicles, large scale halls, test track, library
- Material, surfaces, and major infrastructure behavior

Site development history (and if current operation differs from original plans):

- 1933: Established as part of UK government
- 1996: Became private – Owned by the Transport Research Foundation

Contacts:
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