Designation of Automated Vehicle Proving Grounds Proposal

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Prepared by the

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at

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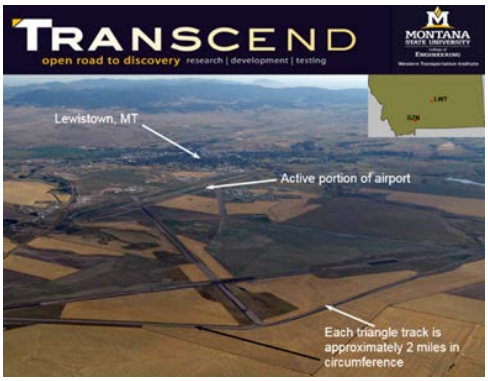
Introduction

The Western Transportation Institute (WTI) at Montana State University (MSU) is proud to offer TRANSCEND, WTI's cold region, rural transportation research test bed facility, for USDOT's consideration of an Automated Vehicle Proving Ground designation. Established in 2007 through sponsorship of the Research and Innovative Technologies Administration of the U.S. Department of Transportation (USDOT) and in partnership with the Montana Department of Transportation (MDT), TRANSCEND is a large-scale field facility providing space for researchers to study multi-disciplinary transportation challenges in a full-scale environment without interfering with or affecting the traveling public.



TRANSCEND is well-positioned to serve as a test ground to support the research and development of Autonomous and Connected Vehicles (AV/CV) and provides the USDOT with a unique opportunity to conduct research in a cold and rural environment.

Rural roads also lack local emergency services, have a high percentage of fatal crashes caused by high speeds, lack traffic signals at intersections, and are victim to rapidly-changing weather and road conditions. Forty percent of vehicle miles are traveled in rural environments, highlighting the need for effective rural highway research.

With the recent explosion of autonomous and connected vehicle technology and research, one thing has been made abundantly clear: although 60% of U.S. traffic fatalities (or, more than 20,000 annually) occur in rural areas, the vast majority of AV/CV research and investment has been aimed at and performed in urban areas. The reason is simple: monetization. To investors, the value of mobility is clear; the areas where autonomy proves to be profitable first are urban areas, where the density of mobility service customers is sufficiently high to attract high levels of investment which will produce extremely high returns. There is a reason that the valuation of Uber exceeds that of Ford or GM by almost 50%: hassle-free mobility is extremely attractive to consumers.

What is missing from the national picture, however, is rural safety and rural mobility. Of the 60% of rural fatalities described above, 60% result from Single Vehicle, Road Departure (SVRD) crashes. Autonomous vehicle technology can prevent a significant number of these SRVD events, saving thousands of lives annually. In addition, AV/CV technologies, if properly designed, tested, and deployed, can provide mobility and safety services to rural and tribal populations.

- Rural populations are aging, resulting in a significant demographic which is mobility challenged. Improvements in mobility, enabled by AV/CV technologies, can open new doors and allow these disadvantaged communities to remain functional and safe in their homes longer than they can today, improving their quality of life and well-being.
- Tribal communities are typically small, rural, and faced with poor and unimproved roads. Serving this population will require AV/CV technologies which can operate reliably on these rural, unimproved roads. By doing so, connectivity between tribal and adjacent communities is increased, creating opportunities with local non-tribal communities due to reduced isolation arising from improved mobility.

Development and testing of technology to serve rural areas requires evaluating in environments which are common in rural areas: unimproved roads, low visibility (due to rain, fog, ice, sleet, snow), high winds, and bright sunlight at or near the horizon (a particularly difficult challenge for vision-based system), and snow or ice covered roads, creating problems both with respect to road-tire friction as well as obfuscation of lane

boundary markers used by vision-based systems. Evaluating in a "real" environment, such as TRANSCEND, will have a significant impact on encouraging new levels of public safety.

As is described below, TRANSCEND offers what developers of AV/CV technologies need to develop, test and evaluate their systems: variable visibility, variable road conditions and pavement types, and exposure to weather and atmospheric conditions which challenge the most robust of systems.

The Western Transportation Institute (WTI) is the nation's largest transportation institute focusing on rural transportation issues The Institute was established in 1994 by the State Departments of Transportation of Montana and California, in cooperation with Montana State University – Bozeman (MSU). WTI has an annual budget exceeding $8 million and a 75-person multidisciplinary staff of professionals, students and associated faculty from engineering (mechanical/industrial/civil), computer science, fish and wildlife, ecology, business, and economics. WTI has conducted research in more than 36 states, at local, state, and federal levels, as well as conducted international work in 17 countries.

WTI's research encompasses diverse areas including advanced transportation technologies, road ecology, winter maintenance, rural transit, and sustainable infrastructure. WTI has worked with federal agencies, state departments of transportation and private partners to conduct nationally prominent research on effective deployment of Intelligent Transportation Systems and other technologies on rural roads. WTI projects and researchers have been honored with national awards from the Federal Highway Administration (Environmental Excellence), Federal Transit Administration (Planning Excellence), Intelligent Transportation Society of America, California Alliance for Advanced Transportation Systems, and the National Association of Development Organizations.

WTI has twice been awarded a National University Transportation Center and currently leads the Tier 1 Small Urban and Rural Livability Center and is a member of the team for the Center for Environmentally Sustainable Transportation in Cold Climates (CESTiCC). In addition, WTI has been awarded the following national Centers of Excellence:

- National Center for Rural Road Safety – FHWA
- The Regional Surface Transportation Workforce Center
- FTA Paul S. Sarbanes Transit in Parks Transportation Technical Assistance Center

Background

In 2003, the Airport Authority and Fergus County Commissioners in Lewistown, Montana asked 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 projects with 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. WTI and 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.

The 230-acre facility offers four miles of real-world paved test surface, a highly innovative, multidisciplinary research staff, and a comprehensive communications, power, and data networking infrastructure. TRANSCEND has a state-of-the-art snowmaking system to simulate winter snow and ice conditions on-demand in a controlled manner.

A 2000 square foot heated shop building is available for instrumenting vehicles, conducting experiments, and maintaining equipment. Multiple research offices are connected to the shop to allow researchers access to computers and the internet. An intranet connection allows researchers to access databases housed at the main research office in Bozeman. A weather station and a robust communication system are also available for use.

Qualifications

Mandatory Criteria

Designated Safety Officer –

WTI's Eli Cuelho P.E., will serve as the Test Ground's Designated Safety Officer and will participate in the Community of Practice's regular quarterly meetings of Safety Officers. Cuelho has been a Research Engineer at WTI since 1998 and currently serves as the Project Manager for TRANSCEND, as well as the Program Manager for WTI's Infrastructure Maintenance and Materials program area. He is also the Director for the Unpaved Roads Institute, an organization that provides tools and services to manage unpaved roads through research, services, education and technology transfer. His project experience covers a wide variety of topics such as: geotechnical engineering, geosynthetic design, low-volume roads, pavement maintenance, bridge construction and evaluation, winter maintenance and operations, and remote sensing and data acquisition equipment. Eli has 20 years of experience testing geosynthetic materials and is the chair of an ASTM task group dedicated to developing new test procedures for geosynthetics used as pavement and subgrade reinforcement. Cuelho serves as an active member of the Geosynthetics committee at TRB.

Commitment to Sharing Approaches

WTI has a strong record of collaboration and is committed to sharing approaches to safety and safety data generated through testing and operation. Through multiple centers and collaborative efforts WTI is recognized as a technology transfer innovator and has a demonstrated ability to disseminate research results, spur implementation, and conduct continuing education programs. Significant demonstrated technology transfer efforts are highlighted in Table 1:

Table 1: Collaboration and Technology Transfer Success

Experience	Outcome
URi UNPAVED ROADS Institute (formerly Road Dust Institute) Founding Members/Current Leaders: UC-Davis, WTI, UNLV, UAF	✓ 3 National Conferences (4th in planning stage) ✓ Provides training courses/webinars ✓ Conference publications
Office of the Assistant Secretary for Research and Technology University Transportation Centers	✓ WTI National Center: 1998-2011 ✓ CESTiCC Tier 1: 2013-2016 ✓ SURLC Tier 1: 2013-2016
National Center for Rural Road Safety Lead: WTI Partners: Rutgers, Iowa State University, IdT Group, Cambridge Systematics, Bubar & Hall LLC, LTAPs (IA, LA, MT, New Jersey)	✓ Serves transportation practitioners at all levels ✓ Provides monthly safety webinars ✓ Provides training for and advocates tribal needs
West Region Transportation Workforce Center Lead: WTI Partner: North Dakota State University	✓ Provides better data on transportation job needs and priorities within each region ✓ Provides better alignment: of education and training to workforce skills gaps

Experience	Outcome
Serving: Nebraska, S. Dakota, N. Dakota, Montana, Wyoming, Idaho, Washington, Oregon, Alaska, Hawaii	
Lead: WTI Partners: Shapiro Transportation Consulting, University of S. Florida, David Evans & Assoc., University of Vermont, University of Maine, Vanesse Hangen Brustlin, Inc., Gimmler Consulting	✓ Provided technical training and resources to Federal Land Managers ✓ Provide implementable transportation solutions for federal and public agencies ✓ Facilitates Public Lands Transportation Scholar Program
California-Oregon Advanced Transportation Systems (COATS) Spearheaded by WTI: 15-year collaboration with the California and Oregon Departments of Transportation.	✓ Serves multiple regional and local agencies ✓ Deployed and evaluated $2.5M in ITS projects in rural areas of western states.
Pooled Fund Studies: By joining forces and leveraging resources in pooled fund research, consortium member universities have been able to undertake projects of larger scale and increase their collaboration network. Examples of partner pooled fund participation are provided in the next column.	✓ Aurora (focus on road weather and sensors) ✓ Clear Roads (focus on winter maintenance) ✓ Pacific Northwest Snowfighters (focus on winter maintenance products) ✓ Transportation Pooled Fund Program
Corridor coalitions: Recognizing the value of coordinated, cross-border collaboration, consortium members have teamed with other states to developing solutions to transportation challenges across state and provincial borders. Examples are included in the next column.	✓ Northwest Passage (I-90 Wisconsin to Washington) ✓ CANAMEX Corridor (I-15 Canada to Mexico) ✓ Greater Yellowstone (Montana, Wyoming, and Idaho)

Proposed Contributions

- Automated Vehicle Program. The deficiencies in investment in rural AV/CV systems had become apparent to WTI over the course of the last three years. While need for rural-focused AV/CV work was clear, the attention and level of investment was not commensurate with the need.

  To address these shortcomings, WTI hired Dr. Craig Shankwitz, an experienced AV/CV R&D engineer with significant rural experience. Dr. Shankwitz started at WTI on 01 July 2016, and has been chartered with developing WTI's rural AV/CV program. Dr. Shankwitz directed the Intelligent Vehicles lab at the University of Minnesota from 1998 – 2012, and was responsible for the development of RTK/Radar-based Driver Assist Systems for Snowplows (with deployments in MN, AK, and CA), Driver Assist for Transit buses (MN), and rural thru-stop decision support systems for rural thru-stop intersections (MN, WI, MI, IA, NC, NV, GA, CA).

  At MTS systems from 2012 until starting at Montana State, Dr. Shankwitz developed a motorcycle-riding robot for durability and performance testing, and developed a (patent-pending) system for testing AV/CV crash avoidance systems using actual road-going vehicles, not balloon facsimiles. (Test method and system using a highly agile ground vehicle for intelligent vehicle testing, U.S. Patent Office Publication number 20160154407.)

- Leadership Capabilities. WTI has a strong and proven record of providing leadership at both national and regional levels and will leverage this capacity to contribute to the solution of both

long-range and immediate mobility challenges through the testing and deployment of automated vehicle technology.

Table 2: WTI Demonstrated Leadership History

Focus	Entity	Description
UTC	UTC Leadership	• WTI: National UTC from 1998 – 2012 • WTI: Tier 1 UTC (SURLC) from 2013 - 2016 • WTI: Tier 1 UTC from 2013 - 2016
	CUTC Leadership	• WTI (Steve Albert), President (2010) • WTI (Albert) Administrative Leadership Award (2013)
NATIONAL AFFILIATIONS	USDOT ITS Advisory Board	• WTI (Steve Albert) Invited member of National Advisory Board on Intelligent Transportation Systems
	Unpaved Roads Institute	• WTI: Founding Members of Institute
	Institute of Transportation Engineers	• WTI (Albert) Lifetime Achievement Award for efforts on rural transportation issues and ITS
	AASHTO	• WTI (Albert) Research Advisory Committee
	Transportation Research Board (TRB) Committees	• WTI: Co-Chair of Rural Road Safety Policy Committee • WTI: Chair, Research Subcommittee of the Transportation Needs of National Parks and Federal Lands Task Force • WTI has members on Geosynthetics, Winter Maintenance, and Low Volume Roads Committees
	ASCE	• WTI: Member, Advanced Technologies Committee
CONTRIBUTIONS TO TRANSPORTATION SOLUTIONS	FHWA Environmental Excellence Award	• WTI: Awarded to WTI partnership with WASHDOT and WA Fish & Wildlife for Habitat Connectivity Study (2011) • WTI: FHWA Environmental Excellence Award (2015) for ARC Solutions, new designs in wildlife crossing infrastructure.
	ITS America Achievement Award	• WTI: Outstanding Achievement in Advanced Rural Transportation Systems (1998)
	ITS America, Best of ITS Awards	• WTI: Evaluation of Utah DOT Weather Ops/RWIS Program (2007)
	NRITS, Best of Rural ITS Awards	• WTI: Responder Systems-Best New Innovative Application (2010)
	FHWA National Center for Rural Road Safety	• WTI leads National Center of Excellence – supports local, state, and tribal road owners and stakeholders

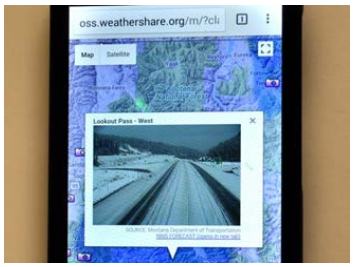
Although WTI is relatively new to the AV/CV area, Dr. Shankwitz brings a 22-year history of AV/CV expertise, including numerous on-road deployments with vehicles operating under the extremely harsh conditions found in rural deployments. Complementing those deployments on the road, short term investigations include an innovative technology to equip the existing U.S. fleet (including motorcycles and bicycles) with Dedicated Short Range Communications (DSRC) in a short (5-year) timeframe[1], and longer term research includes truck platoons consisting of cooperative human-driven and autonomously guided trucks. This technology addresses fuel consumption, greenhouse gases, and a worsening over-the-road truck driver shortage.

[1] WTI has a provision patent filed, and has submitted a proposal to the 2016 FHWA Exploratory Advanced Research (EAR) program to develop and field test this technology.

- Contributions to the Community of Practice. The focus of WTI has always been applied research and problem solving, with an emphasis of putting that research into practice. WTI will contribute to the Community of Practice by leading cutting-edge, rural-focused transportation research, sharing established safety management plans, providing access to testing data, and engaging with stakeholders. Examples of WTI applied with broad applicability include:

  The One-Stop-Shop (OSS) for traveler information was developed in 2014 by WTI and funded by the California Department of Transportation (Caltrans) and the Western States Rural Transportation Consortium. (Please see Figure 1.) The web-based tool provides road conditions and weather information for 11 Western states, and unlike state transportation department websites, OSS road information doesn't stop at jurisdictional boundaries. Combined with real-time weather information, OSS provides motorists with a seamless decision-making tool for traveler safety. The OSS mobile version was released in November 2016.

OSS: Winner of 2014 Intelligent Transportation Society of America International Award Winner



The National Weather Service, trucking and recreational vehicle groups, broadcast meteorologists, chambers of commerce and local, state and federal government agencies have linked to the OSS website.

Figure 1. One-stop-shop awards, screen shot, and description.

Operations and Travel Information Integration Sharing (OTIIS) In 2012, North/West Passage initiated the Operations and Travel Information Integration Sharing (OTIIS) project to develop a website to assist with trip planning across the I-90 and I-94 corridors. FHWA selected OTIIS for federal funding through the Multistate Corridor Operations Management Program (MCOM) Program. MCOM promotes regional cooperation, planning, and shared project implementation for research programs and projects that improve multimodal transportation system management and operations. WTI developed the North/West Passage traveler information website (www.roadstosafediscovery.com). The site creates the opportunity for truckers and long-range travelers to view beyond one or two states to all eight states and plan accordingly based on some current and forecasted information for routing and timing decisions. Routing decision is possible based on the traditional current road conditions/traffic information as well as forecast weather, and recreational opportunities which may also foster greater visitor experience and increased economic activity. A screenshot for OTIIS is shown in Figure 2.

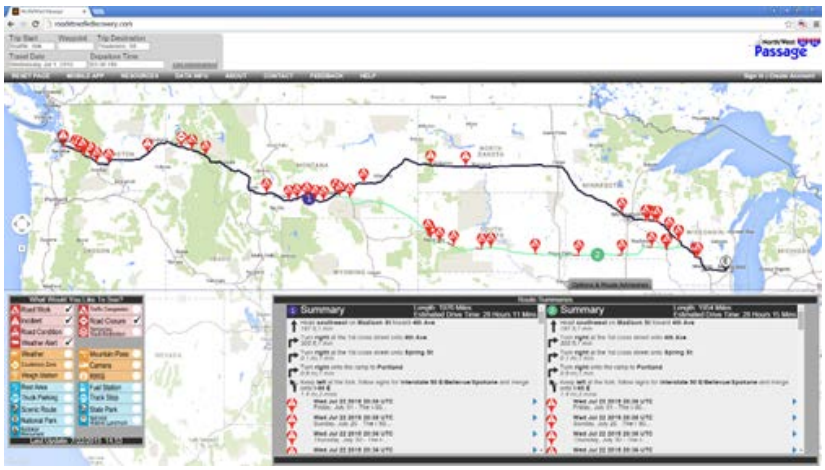


Figure 2. Screen shot of the OTISS System for the North/West Passage.

Responder System Funded by Caltrans, WTI developed and tested a mobile data system that allows first responders to an accident or incident scene to collect and transmit data. The system enables first responders to input information on incidents, such as Hazmat and rock slides, that affect travelers and disrupt roadways. The availability of such tools is particularly important to first responders in remote rural areas because their communications options are often limited.

Redding Responder System
2010 BEST OF RURAL ITS AWARD:
Best New Innovative Product, Service, or Application

The Responder system consists of a tablet PC, an optional communications briefcase, and purpose-built software. The briefcase houses cellular and satellite communication equipment for more rural areas, or the tablet PC can use an integrated cellular radio.

The Responder software is used to import photos from a camera, annotate them with sketches or text, and include them in an email along with text describing the incident to be sent back to the traffic management center.

- Working relationship with Department's relevant research program offices. WTI has a strong positive working history with the USDOT and relevant research program offices. WTI's Executive Director serves on the USDOT ITS Advisory Committee and has provided three United States Senate/Congressional Testimonies. Through this ongoing participation, he has made direct contributions to DOT policy. With multiple awards as a National and Tier 1 University Transportation Center, and FHWA awards for the National Center for Rural Road Safety and the Western Region Workforce Development Center, WTI has demonstrated compliancy with regard to submission of activity and financial reports, participation in conferences and meetings, and joint research efforts. Over the last 20 years, WTI has sponsored and hosted the: National Rural ITS Conference, Western States Rural Transportation Technology Implementers Forum, National Winter Maintenance Peer Exchange, National Summit for Rural Traffic Safety Culture, Road Dust Institute, National Summit on Transportation in Rural America.

As a Designated Proving Ground, WTI would continue this same level of commitment to participate in these events and other technology transfer activities, as well as fulfill reporting requirements deemed by the Department.

Commitment to Safety

- Demonstrated capability to control risks. The Principal Investigators who will be supervising and performing research at TRANSEND have a history of innovative research which required exemplary safety planning and risk control. Two examples are provided below.
  - Effect of Alcohol on Motorcycle riding skills. In this particular study[2], an instrumented motorcycle equipped with outriggers allowed test subjects, dosed at 0.02, 0.05, and 0.08 Blood Alcohol Concentration (BAC), to be objectively evaluated for performance and safety while riding the Motorcycle Safety Foundation course. Safety precautions included paramedics on scene in the event of a crash (of which there were none), wireless "kill" switches in case of rider run-away (a possibility under 0.08 BAC), full protective gear (helmets, armor-padded jackets and pants, gloves, and boots), and a strict protocol for alcohol dosing and subsequent recovery. An image of the instrumented motorcycle with rider and outriggers is shown in Figure 3.
  - Haptic feedback for Adaptive Cruise Control. The subject of this study[3], conducted in 2004, was adaptive cruise control, with feedback provided to a driver through a haptic accelerator pedal. If the following vehicle encroached upon the lead vehicle, the accelerator pedal would push against the driver's foot, indicating that an increase in distance to the leave vehicle was needed.

    This study required the use of real vehicles, not balloon vehicles, as lead vehicles, for two reasons

    1. The radar used to sense distance to the lead vehicle needed a realistic radar-cross section. Balloon targets do not provide that same cross section.
    2. As a human factors-based study, realism is key. Using a balloon target would remind test subjects that they were part of an experiment, and would lead to biased results.

    Pictures of the two vehicles (lead vehicle and test vehicle) are provide in Figure 4. The test protocol was for the lead vehicle (which communicated to the following vehicle via Wi-Fi (this was before DSRC)) to brake heavily when the following driver was distracted when the two vehicles were travelling under the test condition. (The test condition was a function of vehicle speed, vehicle spacing, and relative vehicle velocity.) When conditions were correct, the lead vehicle would brake and the response of the following vehicle recorded.

    If the distracted driver were to not respond to the haptic feedback pedal, the risk of collision increased. If the collision risk exceeded a safety-based threshold, the lead vehicle would accelerate away, avoiding a crash.

    Both of these studies passed the requirements of the University of Minnesota Institutional Review Board (IRB), and neither experiment suffered from a collision or any type of injury.

- Applicant demonstrates that specific safety considerations have been met over the course of operation, including safety of proving ground personnel, safety protocols when making use of public roads, and attention to safe design, deployment, and operation of automated devices.

[2] Creaser, J.I., Ward, N.J., Rakauskas, M.E., Boer, E., Shankwitz, C., Nardi, F., "Effects of Alcohol on Motorcycle Riding Skills" US DOT HS 810 877, December 2007.
[3] http://drivingassessment.uiowa.edu/DA2005/PDF/64_ErwinBoerformat.pdf

Figure 3. Picture of instrumented motorcycle with outriggers used for BAC study.

Figure 4. Experimental vehicles used for ACC study involving haptic pedal feedback. Vehicles were programmed to create braking events; should a following driver fail to respond, the lead vehicle was programmed to accelerate away from the following vehicle to avoid a collision.

Safe operation has been a hallmark of the vehicle research undertaken by the WTI Team. Examples of safe, successful deployments are highlighted below.

- Snowplows in Valdez, Alaska. In 2002, a snowplow and a snow blower used to clear the Thompson Pass near Valdez, Alaska were equipped with RTK-GPS and radar-based Driver Assist Systems (DAS) which allow operators to clear that pass in conditions of zero visibility. The system was successful, and in 2011, three additional vehicles were added to the fleet. These vehicles have operated reliably and safely since installation, and are entering their 14'th year of service. Please see http://www.govtech.com/e-government/Smart-Snowplows-Keep-the-Highway-to-Valdez-Alaska-Clear.html for more detail.
- Snowplows in Minnesota equipped with the RTK-GPS and radar-based DAS not only enable highway maintenance in low-to-zero visibility, but they've also been used to rescue stranded motorists. Please see www.dot.state.mn.us/research/accelerator/Accelerator16PRESS.pdf for details.

- Transit buses in Minneapolis. Using similar technology to that used in the snowplows described above, 10 transit buses were equipped in 2009 with Driver Assist Technology. Those buses operate on narrow shoulders, enabling drivers to transport their passengers safely and reliably regardless of weather or traffic conditions. Additional information regarding these 10 buses can be found here: http://www.nxtbook.com/ygsreprints/ygs/1-27910831nxtbook/index.php#/0. This program was quite successful, and 11 more buses are being equipped with this technology in the 2016-2017 timeframe.

Research, Application, and Data Sharing

- Applicable solutions for the broader region and surrounding corridor for improved mobility. As described in the introduction, the majority of research and investment in the AV/CV segment has been for urban areas because of the ease with which mobility services can be monetized. Although only 9% of Americans live in rural areas, 40% of miles driven, and 54% of all crashes occur in rural areas. As the rural population ages, mobility becomes an increasingly important concern. TRANSCEND offers three unique capabilities and characteristics which serve not only Montana and the Pacific Northwest, but the entire nation.

  1. Rural. The TRANSCEND test facility is located in a rural MT town (Lewistown), and is located adjacent to rural Montana highways. Road designs and road construction is consistent with most rural areas throughout the U.S.
  2. Weather. Snow, rain, and fog present significant challenges to today's vision-based AV/CV technologies. In addition to natural snowfall, TRANSCEND can create artificial snowfall, and "flood" test pads to create low coefficient of friction surfaces upon which AV/CV technologies can be tested and evaluated in difficult conditions. Atmospheric snow combined with "iced" pavement presents a formidable challenge to any AV/CV designed to operate in a northern climate.
  3. Demographics. The rural population in MT is becoming increasingly "top-heavy," with the percentage of Montanans in the older age groups increasing disproportionally compared to the rest of the MT population. In addition to health and financial issues faced by older Americans, mobility for older rural residents poses a much more difficult problem than it does for urban and suburban residents. The TRANSCEND facility can be used as a demonstration site for these older, rural residents, who can provide important feedback to system developers as well as provide usability and satisfaction feedback to residents with similar demographics in other states which face similar mobility issues. If improved rural mobility can delay the inevitable transition to town-based assisted living or nursing home care, the quality of life and well-being of these rural residents can be maintained for a longer period of time.

- Demonstrated research and extension resources. Although Dr. Shankwitz is a recent hire at MSU specifically for AV/CV technologies, a number of faculty and staff at MSU are currently active in areas directly related to AV/CV systems. A brief list of faculty and their expertise relating to AV/CV systems include:

  - Professor Nic Ward. Professor Ward is currently a Professor of Mechanical and Industrial Engineering at Montana State University. Professor Ward is the Director of the Center for Health and Safety Culture in the Western Transportation Institute at Montana State University.

    As a founding member of the National Summit for Rural Traffic Safety Culture and the Transportation Research Board Subcommittee on Roadway Safety Culture, Professor Ward is a national leader for the definition and advancement of traffic safety culture. He has authored the first United States government (FHWA) white paper on traffic safety culture, helped AASHTO develop the traffic safety culture chapter in support of the

National Toward Zero Death strategy, and recently published "A Primer for Traffic Safety Culture" for traffic safety practitioners.

- Professor Qing Yang. Professor Yang is a RightNow Technologies Assistant Professor in the Gianforte School of Computing at Montana State University. His research interests include Online Social Network, Trust Management, Vehicular Ad-Hoc Networks (VANETs), Wireless Sensor Networks (WSNs), Network Privacy and Security. He has published papers in prestigious journals such as IEEE Transactions on Dependable and Secure Computing, ACM/Springer MONET, IEEE Network Magazine and IEEE Communications Magazine, in prestigious conferences such as INFOCOM, CNS and SECON.
- Professor John Sheppard. Dr. John Sheppard was the inaugural RightNow Technologies Distinguished Professor in Computer Science at Montana State University and currently holds an appointment as College of Engineering Distinguished Professor in the Computer Science Department at MSU. He is also an Adjunct Professor in the Department of Computer Science at Johns Hopkins University.

  Professor Sheppard's research interests lie in the areas of Machine Learning, Data Mining, Bayesian Networks, Neural Networks, Deep Learning and Deep Feature Extraction, Evolutionary and Swarm-based Methods, Factored Optimization Methods, System-Level Fault Diagnosis, System-Level Fault Prognosis, and Measurement Uncertainty.

- Dissemination of results, commitment to open data and sharing performance metrics, and results of objective tests. A major U.S. research, land-grant university, Montana State has a charter to disseminate research findings through reports, peer-reviewed papers, meetings, and conferences. Because TRANSCEND operates under the auspices of the Western Transportation Institute, research reports, peer-reviewed papers, and other documentation related to work at TRANSCEND can be found on the WTI website[4]. WIT is an active participant in the TRB/National Academies transportation committees, and is well-represented at the TRB annual meeting.

Demonstrated Investments

In 2005, U.S. Senator Max Baucus (D-Montana) secured funds through the federal transportation bill (SAFETEA-LU) to further develop the TRANSCEND 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.

Of particular relevance to AV/CV testing is the winter testbed.

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 5, left side).

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

[4] Please note that the WTI website is presently undergoing a major upgrade, so specific example links aren't given as they are likely to change within the next few weeks. Should questions arise, WTI is happy to provide examples of data or walk the U.S. DOT through a document search.

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 5 (right).

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 5: Fan gun snowmaker (left), Man-made snow event across the test track (right).

Complementing the ability to change the tire-road coefficient of friction at TRANSCEND is the ability to quantify road-tire friction coefficient. On-site, TRANSCEND has this capability with a Halliday RT3 wheel friction device (Please see Figure 6.). The Halliday RT3 wheel friction device 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. This device allows the quantification of road-tire friction prior to, during, and after testing.

WTI is presently creating a proposal to the NSF Division of Advanced Cyberinfrastructure Division for funding to support the procurement and installation of wireless DSRC networks and other supporting cyberinfrastructure to support research for rural AV/CV systems. This application is made through the Cyberinfrastructure for Emerging Science and Engineering Research (CESER) program. Although this cyberinfrastructure is not critical for TRANSCEND to operate as an AV/CV proving ground, the installation of permanent wireless and computational hardware would greatly increase the efficiency with which AV/CV research and analysis can be performed.

Readiness

The TRANSCEND facility is in operation today, thereby meeting the requirement that the facility be open for testing by 01 January 2018.

TRANSCEND supports a wide based of users; some of the projects underway and/or completed are listed in **Table 2**.

It is important to note that many of the other activities at TRANSCEND are compatible with AV/CV technologies. For instance, the RADS system, if equipped with a Roadside Unit (RSU), could broadcast via DSRC the presence and location of roadside animals to approaching vehicles, providing advanced warning. In 2014, animal-vehicle collisions claimed 166 lives.

Figure 6: Halliday friction wheel.

Table 3. Projects underway and completed at TRANSCEND.

Testbed Name/Capability	Project(s)
RADS (Road Animal Detection System)	• RADS project (2006-2009) Animal Detection System Sensor test
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
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

The multi-purpose nature of TRANSCEND provides many opportunities to investigate rural transportation issues in the AV/CV framework, and may inspire new applications when other users of TRANSCEND are exposed to AV/CV technology.

As a Designated Automated Vehicle Proving Ground, the Designated Point of Contact will be Craig Shankwitz. Craig may be reached at (406) 994-6030 craig.shankwitz@montana.edu.

With respect to operation on public roads, Dr. Shankwitz brings more than 15 years of experience with on-highway applications. In the early days of RTK GPS, neither virtual reference networks nor cellular data connections existed; RTK GPS corrections were broadcast on FCC-approved VHF and UHF channels. To ensure sufficient broadcast range, VHF and UHF antennas were mounted on local community water towers – communities that these snowplows served. Once the city council was made aware of the application and the positive effect it would have on the community, approval was always granted.

Education is the key to cooperation; if the community is made aware of what is happening, and the benefits from which they will benefit if the work is successful, requests will be approved. Open houses, presentations, and even short stories in the local newspaper maintain connections, and ensure a collaborative work environment.

Adherence to Laws, Regulations, and Federal Policy

WTI and MSU have a strong history of operational, on-road deployments of driver assist systems, and a similar history of on-road human-factors experiments using human-subjects. The Minnesota State Patrol and the Minnesota Department of Transportation were early participants in these on-road studies, and as such, laws, rules, and regulations were adhered to closely.

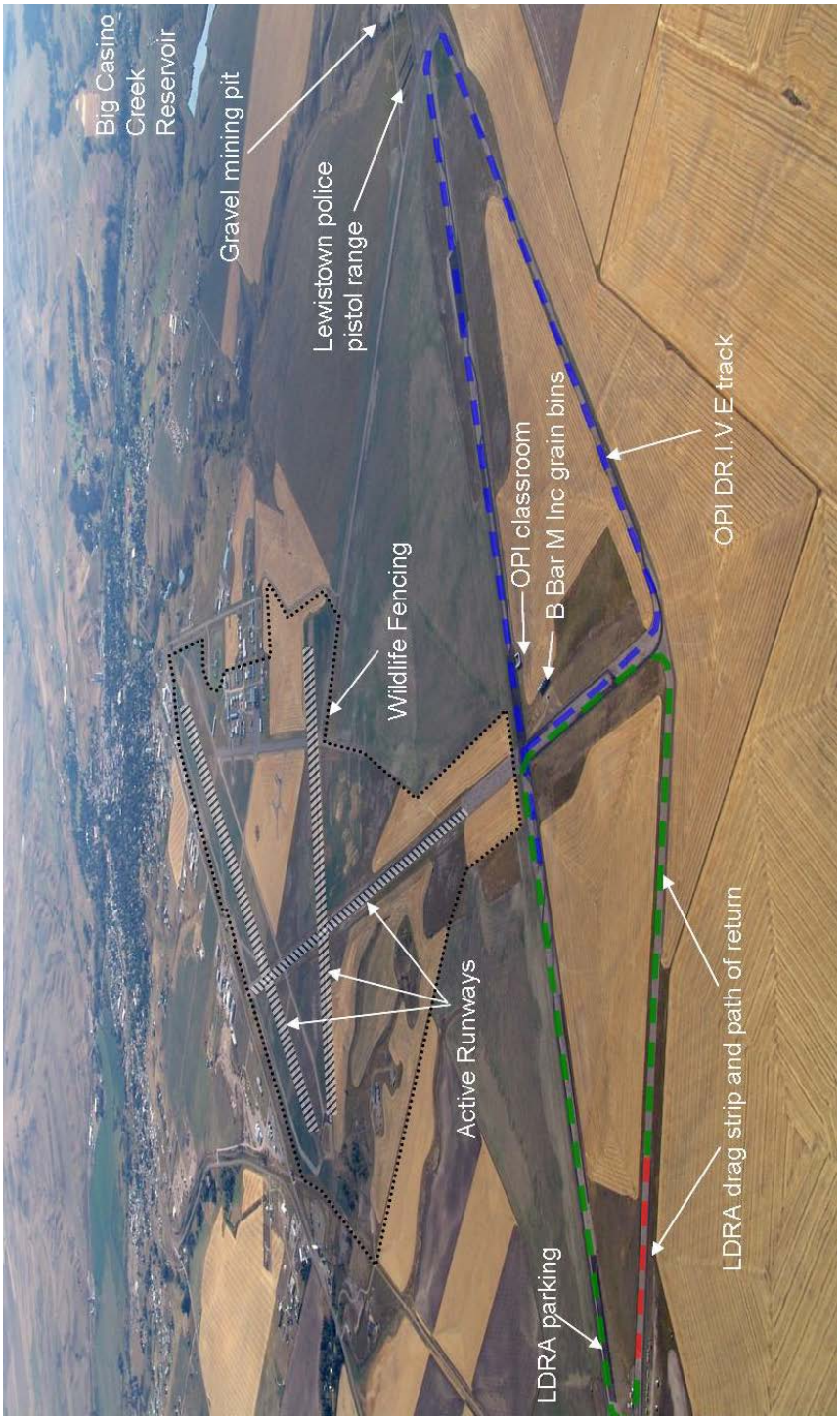
Experiments with L3 automation on Minnesota Highways began in 2003 in a snowplow gang-plowing environment[5], and continued as the Driver Assist System for Transit buses operating on narrow shoulders was developed in Minneapolis in 2009[6]. Protocols taken in those early years conformed to those in the NHTSA guidelines. With lessons learned in those early years, adherence to the NHTSA guidelines can be assured.

TRANSCEND Facility Aerial View.

An aerial view of the Transcend facility is provided in Appendix 1: Aerial View of Transcend.

[5] http://www.cts.umn.edu/Publications/ResearchReports/reportdetail.html?id=1027
[6] http://www.nxtbook.com/ygsreprints/ygs/1-27910831nxtbook/index.php#/0

Appendix 1: Aerial View of Transcend



Existing tracks and facilities at the Lewistown airport.