AASHTO Innovation Initiative

[Proposed] Nomination of Innovation Ready for Implementation

Sponsor

Nominations must be submitted by an AASHTO member DOT willing to help promote the innovation. If selected, the sponsoring DOT will be asked to promote the innovation to other states by participating on a Lead States Team supported by the AASHTO Innovation Initiative.

1. Sponsoring DOT (State): Vermont Agency of Transportation

2. Name and Title: Mary Haley, Right of Way/Survey GIS Professional & VTrans Static Terrestrial LiDAR Team Lead

Organization: Vermont Agency of Transportation

Street Address: 219 N. Main Street

City: Barre City

State: Vermont

Zip Code: 05641

Email: mary.haley@vermont.gov

Phone: 802-279-9233

Fax: N/A

Innovation Description (10 points)

The term “innovation” may include processes, products, techniques, procedures, and practices.

3. Name of the innovation:

Static Terrestrial Light Detection and Ranging (LiDAR) Projects

4. Please describe the innovation.

LiDAR is a remote sensing technology that utilizes light to measure distances for 3D Modeling. LiDAR instruments or scanners assign XYZ coordinates in a common reference system using the location and orientation of the scanner, the angle of the scan mirror, and the slant range to the object. The collection of returns is called a point cloud and creates a 3D model of the scanned surface. There are two major LiDAR systems, airborne and terrestrial; two common types of terrestrial instruments include mobile and static scanners. VTrans utilizes Static Terrestrial LiDAR Scanning (STLS) in conjunction with conventional surveying techniques, allowing for incredibly detailed data collection at the ground level of man-made and natural features. STLS is a cost-effective technology that reduces overall project labor costs and improves the safety of field personnel and the traveling public. In-house staff process the point cloud data, seamlessly incorporating it into design files that support pre- and post-construction activities. Scan requests at VTrans include at-risk roadway asset monitoring, historical preservation, as-built and existing structural assessment, pavement surface analysis, and material volume calculation services.

5. What is the existing baseline practice that the innovation intends to replace/improve?

The existing baseline practice being improved is conventional route surveying.

6. What problems associated with the baseline practice does the innovation propose to solve?

Each phase of a transportation project relies on route surveying activities. Survey data provides critical, preliminary information needed to support project decision-making in research, design, and construction phases. Within each of these phases, the different VTrans sections may have unique survey requests. One may only require a stakeout of utility locations, while another may need a survey of a roadway surface to understand existing damage and coordinate the remediation efforts. In some instances, multiple survey requests are made for the same project, which requires survey technicians to conduct redundant site visits to the same location. STLS technology can be a cost-effective alternative for survey data collection by reducing redundant site visits that unnecessarily increase project labor costs, especially if additional traffic control measures and personnel must be on site. These requests and most conventional survey practices require multiple survey personnel to be onsite operating equipment in and near Vermont's busy roadways creating a potentially hazardous environment for the field staff and the traveling public. A major benefit to STLS is that technicians can collect data at safer distances that sometimes can reduce the need for traffic control measures that put more staff in the roadway. Conventional surveying can also be limited in capturing finely detailed visible surfaces. This could include historical structures with masonry or petroglyph carvings that should be preserved or even the details of a roadside rock cut that is likely to become a hazard after a major weather event. Providing highly accurate and detailed survey data using STLS technology leverages VTrans' ability to efficiently coordinate efforts across the sections and plan future transportation projects.

7. Briefly describe the history of its development.

In 2016, the VTrans Survey section received a request to survey three culverts and measure the exact size of the pipe. Using the dimensions, designers could estimate the maximum liner size to install within each culvert. Terrestrial LiDAR systems were already being employed at local universities and by some external consultants. This request provided VTrans the opportunity to explore developing in-house procedures with 3D scanning technology. After conducting training and tests with different STLS instruments, a Trimble TX8 3D Scanner was purchased in 2016 to support the conventional surveying efforts at VTrans. To determine the best applications of the new scanner, technicians worked with several groups within VTrans to test the scanner's capabilities and the in-house processing software, Trimble RealWorks.

8. What resources—such as technical specifications, training materials, and user guides—have you developed to assist with the deployment effort? If appropriate, please attach or provide weblinks to reports, videos, photographs, diagrams, or other images illustrating the appearance or functionality of the innovation (if electronic, please provide a separate file). Please list your attachments or weblinks here.

Training Materials:

These operational procedures and workflows were developed to organize and standardize scan projects and processing. Specific analysis workflows continue to be developed.

http://files.vtrans.vermont.gov/rowviewer/lidar/VTransSTLSTrainingMaterials.zip

Project Fly Through Videos:

When scan processing is complete, a visual "Fly Through" of the project is developed to display the segmented cloud. These can be used for promotional purposes for the project or just to visualize the extent of the scan area.

http://files.vtrans.vermont.gov/rowviewer/lidar/ProjectFlyThroughs.zip

Georgia Culvert Clearance Volume Estimate

Technicians analyzed the scan of a shotcrete arch culvert in Georgia, VT to estimated volume of the area between the tunnel surface and precast culvert liner. The report heat map shows the distance of clearance in inches and the total volume of the clearance area.

http://files.vtrans.vermont.gov/rowviewer/lidar/Georgia_11b218_LiDAR%20Tunnel%20Clearance%20Map.pdf

Plymouth Slope Monitoring Project

This STLS project monitors the movement of a roadside slope in Plymouth, VT. The slope was part of an embankment stabilization project but there has been movement and settling that has occurred since then. This report visualizes the measured change from the initial scan in 2018.

https://storymaps.arcgis.com/stories/5b1b0e27c08745699b3cf1a1bb67b33a

Berlin I-89N Ledge Removed Material Volume Calculation Report

Technicians were asked to determine the overall material removed from rock ledge along I-89 in Berlin, VT. This project allowed technicians to test the capabilities of the scanner itself as well as the processing software. Initial scans were performed prior to removal activities to create the baseline original surface. After construction activities, another scan was performed to create the comparison surface. A surface inspection was performed on the ledge and a Fill volume estimated for the material removed.

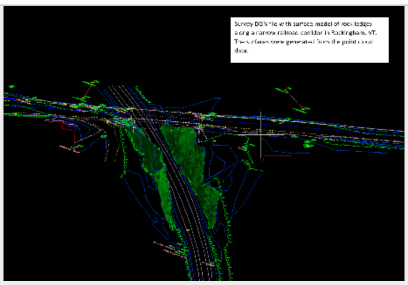
http://files.vtrans.vermont.gov/rowviewer/lidar/Berlin_13a364_MaterialVolumeInspection.pdf

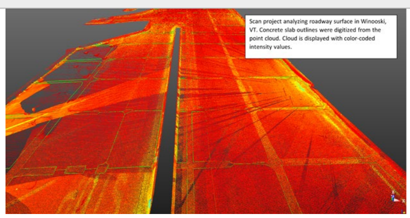
STLS Processing Form – ArcSurvey123

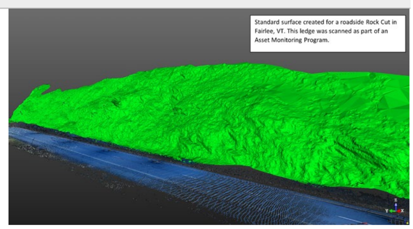
Using the ArcSurvey123 tools and resources, technicians have created a feature class organizing all pertinent attributes related to the scanning and processing of STLS requests. The information from the form is linked to a web layer that displays each scan location across the state. This form replaces the antiquated organizational process of recording requests in a static Excel document allowing for easy queries of geospatial data. The link provided shows a PDF of the Form questions that are required for each scan project request.

http://files.vtrans.vermont.gov/rowviewer/lidar/STLSProcessingForm.pdf

Attach photographs, diagrams, or other images here. If images are of larger resolution size, please provide as separate files.







State of Development (40 points)

Innovations must be successfully deployed in at least one State DOT. The AII selection process will favor innovations that have advanced beyond the research stage, at least to the pilot deployment stage, and preferably into routine use.

9. How ready is this innovation for implementation in an operational environment? Please select from the following options. Please describe.

☐ Prototype is fully functional and yet to be piloted

☐ Prototype has been piloted successfully in an operational environment

☒ Technology has been deployed multiple times in an operational environment

☐ Technology is ready for full-scale implementation

Since the initial purchase of the STLS instrument, equipment, and processing software in 2016, VTrans Survey has performed upwards of 117 terrestrial scans around the state. Most STLS scans are performed upon request in coordination with survey staff; however, STLS can be quickly employed in response to emergency requests. As a standard requirement, all scan data is referenced into Vermont State Plane (US Survey Feet) to be compatible with survey CAD files. For monitoring projects, survey technicians establish permanent control at monitoring locations to ensure stability for future scans or projects. STLS technicians continue adapting STLS protocol and processing procedures. In 2019, VTrans Survey and the Geotechnical sections created a joint asset monitoring federal work program. The objective of this work program is to safely provide rapid and accurate pre-construction, post-construction, and asset inventory monitoring services. Deliverables of assets such as, but not limited to, rock cuts, soil slopes, embankments, bridges, culverts, walls, buildings, and roadways will be shared and easily accessible for transparency and collaboration. Expert staff and consultants will use this data to understand failure mechanisms and triggering factors to implement hazard and risk assessment procedures. Monitoring also allows stakeholders to evaluate the movement rate and aid in determining the safety of the roadway and surrounding areas given the conditions in the field. Geotechnical staff identified 30 out of 200+ roadside rock cuts as preliminary candidates for STLS and/or frequent monitoring. As of Spring 2021, all 30 rock cuts were scanned at least once, if not multiple times over the Spring and Fall seasons. Scans for these ledges provide baseline point cloud data that can be used in future project planning. This federal work program was recently approved for a second year. VTrans Survey will continue to collect baseline STLS data for other identified roadside assets.

10. What additional development is necessary to enable implementation of the innovation for routine use?

No development is necessary to implement this technology. VTrans Survey could benefit from exploring new software and working with specialized consultants to improve project processing times. A standard rule of thumb is that it takes roughly 3-4 times as long to process point cloud data to deliverables as it takes to perform the scan. Some projects covering large areas or containing heavy vegetation can take upwards of 6 times as long to process. For this reason, the development of automated algorithms to assist in point cloud classification could help improve processing time.

11. Are other organizations using, currently developing, or have they shown interest in this innovation or of similar technology?? ☒ Yes ☐ No

If so, please list organization names and contacts. Please identify the source of this information.

Organization	Name	Phone	Email
University of Vermont College of Engineering and Mathematical Sciences	Dr. Jeff Folik	Click or tap here to enter text.	jfrolik@uvm.edu
Click or tap here to enter text.	Click or tap here to enter text.	Click or tap here to enter text.	Click or tap here to enter text.
Click or tap here to enter text.	Click or tap here to enter text.	Click or tap here to enter text.	Click or tap here to enter text.

Potential Payoff (30 points)

Payoff is defined as the combination of broad applicability and significant benefit or advantage over baseline practice.

12. How does the innovation meet customer or stakeholder needs in your State DOT or other organizations that have used it?

Although assigning immediate ROI values to STLS can sometimes be challenging, VTrans' implementation of STLS meets our stakeholder needs in data quality and planning efforts, which ultimately reflects lower project costs. Point cloud data and models can be used in most phases of a project's lifecycle, supporting different needs, especially in the design phase. The accurate and detailed data collected with STLS provides a level of assurance in design that allows project managers to make sound decisions and avoid expensive change orders that impact the rest of the project's timeline. Projects that involve a railroad can benefit from employing STLS. It reduces the need for and expensive cost of a railroad flagger, which must be scheduled well in advance of any site work. The technology uses minimal labor to deliver more value in less time in a much safer way. The equipment can perform surveys in hazardous environments without sacrificing the safety of field and maintenance staff or the traveling public. Though the value of safety is hard to quantify, it is real and may result in fewer vehicle accidents or injuries. Sometimes the benefits to STLS can only be realized after an emergency event occurs. Performing a terrestrial LiDAR scan on a structure post-construction creates a record of existence at a known time. If a major weather event occurs, like Hurricane Irene in 2011, wipes out the structure, the STLS data can aid in quickly assessing the damage and improving response in replacement efforts. Similarly, scanning historical structures, like Vermont's many covered bridges, for preservation purposes, can ensure the integrity and characteristics of the structure are maintained. STLS project data is archived and always available to be remined if later requests are made. Additional costs associated to outsourcing processing and analysis of STLS data can be avoided by ensuring appropriate training and resources are available to internal staff.

13. Identify the top three benefit types your DOT has realized from using this innovation. Describe the type and scale of benefits of using this innovation over baseline practice. Provide additional information, if available, using quantitative metrics, to describe the benefits.

Benefit Types	Please describe:
Improved Safety	Employing STLS for roadway analyses has significantly improved the safety of field personnel and the traveling public. In 2020, a request was received to scan a 3+ mile section of one of Vermont's busiest roadways (Shelburne Road, US7) to survey features in the two barrels between the edge of pavement. This project would have required multiple days of lane closures and maintenance staff on-site, putting additional hazards in an already busy area. Although the STLS project included multiple days of data collection, it allowed technicians to safely collect data out of the roadway and harm's way. Numerous STLS projects have been performed without technicians or equipment on the road.
Improved Quality	STLS data can be collected with very high accuracy and high resolutions. This allows for the point clouds and models to be sampled at any resolution upon request. Some deliverables, such as a roadway surface may not require sampling past 1.0ft resolution, while others, like a surface model of a rock face, may need detail captured at a higher resolution. Standard conventional surveying practices typically aren't efficient at capturing fine details without increasing time in the field. h
Cost Savings	Quantifiable labor cost savings of deploying STLS are observed in the different phases of a transportation project. A minimum of two technicians are needed to conduct most scans that don't require additional traffic control measures and one technician is required to process the data. If processing can be performed in-house, there is additional cost-saving. Outsourcing point cloud segmenting and classification to consultants can double or triple labor costs for point cloud processing.

Provide any additional description, if necessary:

Click or tap here to enter text.

14 How broadly might this innovation be deployed for other applications. in the transportation industry (including other disciplines of a DOT, other transportation modes, and private industry)?

Other VTrans sections and state agencies currently employ airborne and mobile LiDAR systems for various purposes. Many Vermont universities and colleges are using UAS systems as remote sensing technologies grow in popularity. Larger transportation consulting businesses have been exploring the use of static terrestrial LiDAR systems for transportation-related projects. Most of these consultants have experience with various software to processes point cloud data VTrans produces.

Market Readiness (20 points)

The AII selection process will favor innovations that can be adopted with a reasonable amount of effort and cost, commensurate with the payoff potential.

15. What specific actions would another organization need to take along each of the following dimensions to adopt this innovation?

Check boxes that apply	Dimensions	Please describe:
☐	Gaining executive leadership support	Click or tap here to enter text.
☐	Communicating benefits	Click or tap here to enter text.
☒	Overcoming funding constraints	There is a significant initial investment for the scanning instrument and equipment. Similarly, computer software can also come at a high cost.
☒	Acquiring in-house capabilities	Ensure staff is properly trained on multiple types of STLS projects to perform data collection/field procedures and software/processing to standards.
☐	Addressing legal issues (if applicable) (e.g., liability and intellectual property)	Click or tap here to enter text.
☐	Resolving conflicts with existing national/state regulations and standards	Click or tap here to enter text.
☐	Other challenges	Click or tap here to enter text.

16. Please provide details of cost, effort, and length of time expended to deploy the innovation in your organization.

Cost: The estimated initial investment to purchase the necessary equipment and software for a static terrestrial LiDAR system similar to what VTrans employs is $70,000 to $100,000 plus labor costs associated with fieldwork and processing.

Level of Effort: VTrans employs two full staff members that typically perform 30-50 scans throughout the year in addition to other job duties. A 2–3-person survey field crew establishes the survey control needed for georeferencing the LiDAR scans. VTrans has developed an Operations Manual and Processing Procedures to aid with the deployment of STLS.

Time: A typical STLS project will take less than 8 hours for data collection in the field and anywhere from 16-32 hours for processing. Most of the efforts associated with the deployment of STLS are from the training of staff. Staff must be trained to operate the scanning equipment and to understand how best to perform the scan and collect data. Because each project is different, scanning culverts is very different from scanning roadways, staff must be trained to make appropriate decisions in the field that could affect the point cloud data. Similarly, there is a learning curve to efficiently work in the processing software. Developing tutorials or training materials will be critical for successful deployment.

17. To what extent might implementation of this innovation require the involvement of third parties, including vendors, contractors, and consultants? If so, please describe. List the type of expertise required for implementation.

Point cloud processing and detailed analysis is the most common service VTrans outsources to consultants regarding STLS. Using consultants for processing will depend on their familiarity working with point cloud data.