



The Super-Information Highway

*Virginia Tech acquires new data-collection technology to assist Virginia DOT's public-private highway asset maintenance partnerships—by **Don Talend***

Think of roads, and your mind's eye conjures an image of asphalt. But that image would miss the many other features that make roadways into intelligent integrated systems: signs, traffic signals, lighting, drainage structures, guardrails, to name just a few. Transportation departments like that of Virginia, however, keep a very close eye on these assets. They're vital for protecting the safety of the motorist.

Yet, just because there is a good reason to have quality highways does not mean that the labor-intensive task of maintaining them is easy to justify, especially now that state budgets are being squeezed by declining tax revenues. Undaunted, the Virginia Department of Transportation (VDOT) has decided to improve the management of roadway assets through a partnership with Virginia Tech in Blacksburg, Va.

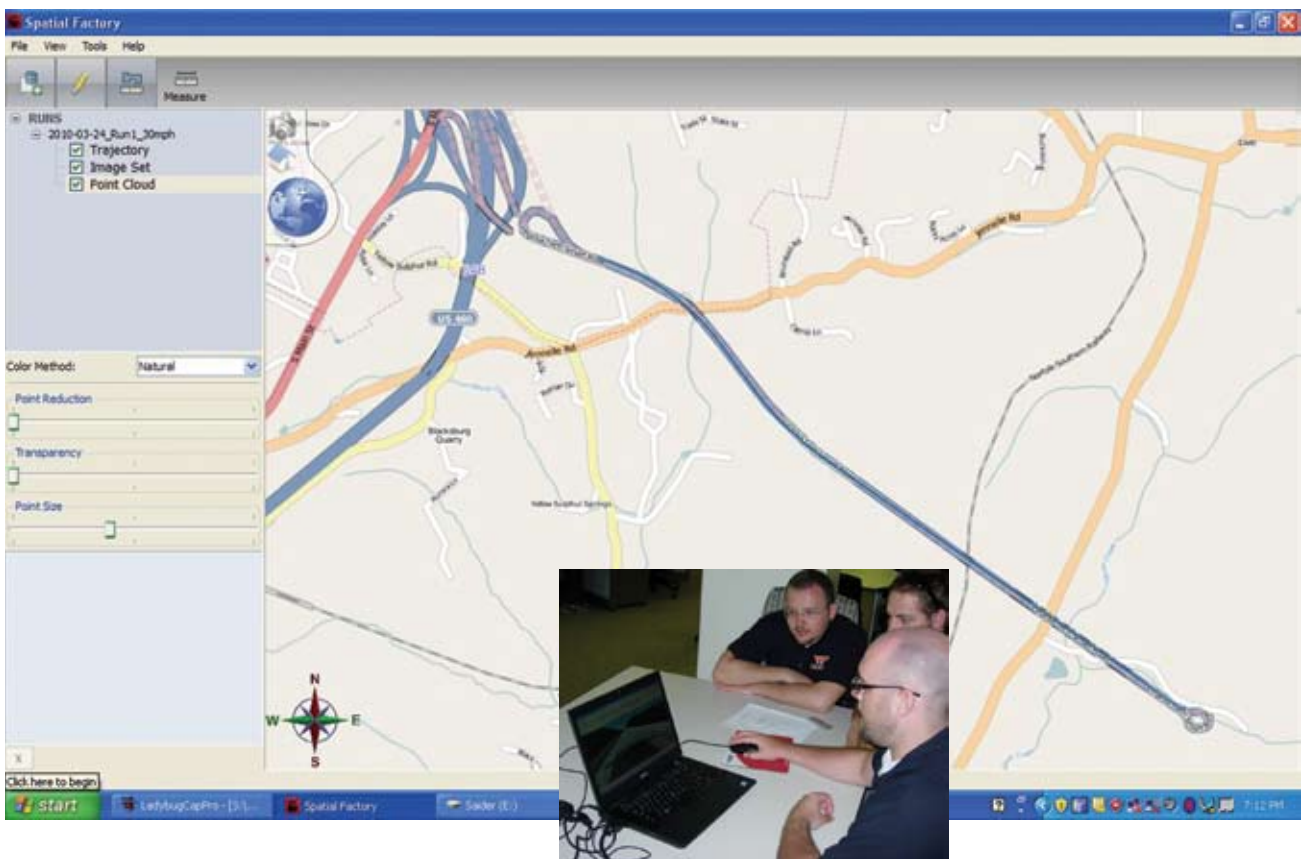
The Smart Road partnership project

Virginia Tech, which is developing a powerful new roadside asset-assessment technology, was the right choice for the private-public partnership initiated. The research is

sponsored by the Center for Highway Asset Management Programs (CHAMPS), and Topcon Positioning Systems has contributed the system's key tool, the new IP-S2 mobile mapping system (see sidebar on p. 46).

Research on the monitoring system has been progressing fast. By spring 2010, Dr. Jesus M. de la Garza, the Vecellio Professor in Civil and Environmental Engineering, and graduate students Grant Howerton, Dimitris Sideris, and Berk Uslu of Virginia Tech's Vecellio Construction Engineering & Management Program, had laid the groundwork for the effort. The monitoring would be done using Topcon's IP-S2 mounted on a vehicle driving along the highways and collecting data for evaluation back at the office—a much more efficient way than having crews evaluate asset condition on foot.

"We have had a close relationship with VDOT for 22 years—since I've been here," said de la Garza. The university has provided continuing education for VDOT personnel for years, and de la Garza planted the seeds for CHAMPS more than 10 years ago, after kicking around the idea with VDOT leadership over dinner during a workshop.



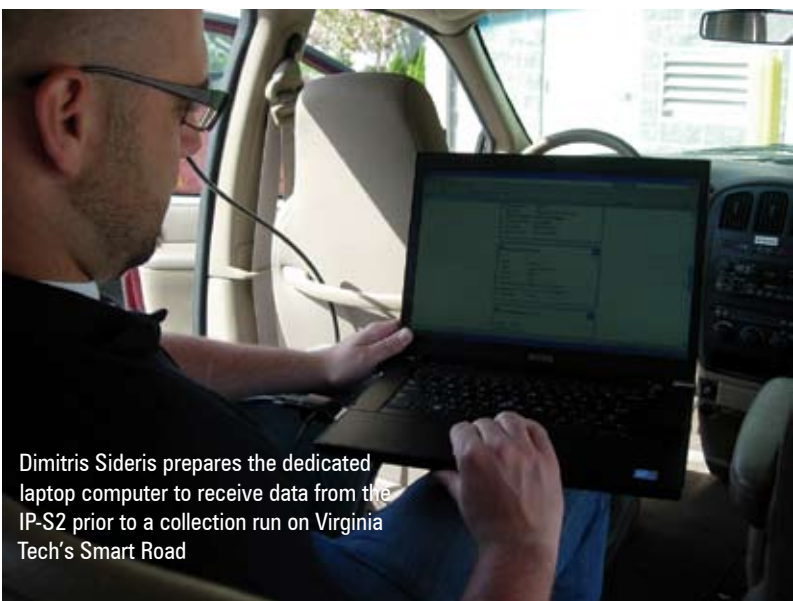
The Virginia Smart Road, as the project came to be known, is a full-scale, closed test-bed research facility managed by the Virginia Tech Transportation Institute (VTI)—the school’s largest university-level research center—and is owned and maintained by VDOT.

The facility is consists of a two-lane, 2.2-mile-long section of pavement, an infrastructure equipped with 400 electronic sensors, and a fiber-optic backbone. Both faculty and students conduct research on the Smart Road, a portion of which is equipped with 75 weather-making towers that produce rain, snow, fog, and even ice. The facility also boasts road surveillance, a signalized intersection, a mechanism for reproducing various lighting situations, 14 experimental pavements, and 600 pavement designs. From a computer-equipped control center, researchers can observe highway traffic and driver performance. Studies have been conducted on new pavement markings, new road signs, pedestrian safety, and new vehicle head lamps.

“The Smart Road is really a 2.2-mile laboratory,” de la Garza observed. “Instead of having a room with microscopes and machines that slice DNA, this lab happens to be a 2.2-mile road.”

Legislation: A boon to partnerships

The VDOT–Virginia Tech partnership benefited from the enactment, in 1995, of the Public–Private Transportation Act, which allows private entities to enter into agreements with state agencies to construct, improve, maintain, and operate on state transportation facilities. Three months after the bill was signed into law, Virginia Maintenance Services



Dimitris Sideris prepares the dedicated laptop computer to receive data from the IP-S2 prior to a collection run on Virginia Tech’s Smart Road

(VMS) was awarded a contract to administer and maintain about 250 miles (or about 20 percent) of Virginia’s interstate highways for five years, renewable for another five.

“That was a radical, 180-degree shift from the way VDOT had maintained the interstates,” said de la Garza. “VDOT was not going to tell us what to do, how to do it, let alone when to do it. The only thing they gave us were the performance targets that they wanted us to attain. The rest was up to us—we’re expected to be innovative.”



Topcon's IP-S2 uses high-accuracy GPS, an inertial measurement unit, 360-degree digital imaging, and a laser scanner to collect data for geospatial information systems.

After ten years, the Secretary of Transportation, assisted by Virginia's Attorney General, drafted updated guidelines in accordance with amendments enacted by the 2005 General Assembly, and VDOT established the Turnkey Asset Maintenance Services (TAMS) program. Currently, the entire interstate system in Virginia is being managed under performance-based contracting. Another consequence is the addition of about 1,000 miles to the 250-mile VDOT-Virginia Tech pilot project.

To ensure impartial oversight of contractors, CHAMPS was tasked to act as third-party administrator of performance assessment. In the past five years, interstate assets in 13 regions of Virginia have received full roadway asset inventory and condition assessment. Virginia Tech developed a method for tracking the achievement of performance goals by contractors. "It's basically a report card," de la Garza chuckles. "We're a university, so, naturally, we keep grades."

The need to evaluate contractors' performance inspired the use of mobile condition assessment system technology. Between 2001 and 2009, CHAMPS researchers produced numerous GIS-based reports on the condition of highway

assets—with faculty and surveyors having to drive to the various regions and often collecting data on foot.

"This method was labor-intensive as well as unsafe," said de la Garza. "We thought it need not be so. If we could demonstrate that we can collect zillions of gigabytes of data with the IP-S2 mapping system attached to a vehicle driving at 65 miles an hour, and then clean up and analyze the data in the office using a semi-automated process, we would make the work more efficient and less costly."

The work is in two phases. "The first step is when technicians identify roadside assets and features recorded by the IP-S2 on a film. In phase two, computer programs, such as "machine vision," are used to find signs and other road features and evaluate their condition."

The future

Two of the original three members of the "Smart Road crew" at Virginia Tech—Howerton and Sideris—received masters degrees in May and have since moved on to careers in construction management and civil engineering. It's the third graduate student, Uslu, who will continue the research while he studies for his Ph.D.

Howerton's contribution to the Smart Road project was research which compared traditional data-collection methods with the IP-S2 mapping method, both in terms of accuracy and time consumed.

Like Sideris, Howerton was very interested in the management of low-capital highway assets. "We did some literature review and found that low-capital assets have been overlooked," said Sideris. "Most contractors and DOTs try to make sure that the pavement is in good condition and bridges are strong enough to withstand heavy traffic—which makes sense. You want to have a safe highway. But low-capital assets are important for safety too. If a road sign is not where it should be, this can cause many problems. The highway is one system, and everything affects everything else. Everything is important."

Uslu, who came to Virginia Tech via the State University of New York and the Technical University in Istanbul, Turkey, will focus his research on automating the collection of highway asset data and their monitoring. "I plan to come up with algorithms which would make sense of the laser data collected by the IP-S2," said Uslu. "I want to have an algorithm which will detect an asset and evaluate its condition. There should also be an algorithm for detecting the presence of signs and failing them if they are damaged." VDOT personnel will be notified when the asset meets, or falls short of, predetermined working condition parameters. Uslu will likely collaborate with researchers at the Center for Human-Computer Interaction in developing these algorithms.

Viewing assets in a 360-degree radius from the vehicle carrying the IP-S2 system



Fine asset details and dimensions from point cloud data



An automated assessment system will result in “a huge cost savings for VDOT because 70 to 80 percent of the cost of highway maintenance programs is in sending people out to collect data,” said Uslu. “Not only is this way of doing business labor intensive, but mistakes can be made during the collection.”

The Center for Highway Asset Management Programs received the IP-S2 in the fall of 2009. Richard Rybka, Topcon’s mobile mapping specialist, provided support via phone and e-mail during its set up. A van was rented from the Fleet Services Department at the university, and a special roof rack was built to mount the IP-S2. The mapping unit also has a custom-designed hood, which is required to comply with Virginia Tech’s security regulations.

From data to a model

By the end of May, more than 20 asset data collections were performed. Moving along a highway, the IP-S2 maps data in a 360-degree radius, at a distance of 10, 20, or 30 meters. The progress of the IP-S2 is monitored on a laptop. The computer uses a Web browser to communicate with the IP-S2 via an Ethernet cable. According to the students, “the real fun” begins when data from different system components are integrated in one system for “geocleaning.”

Five operations are performed in Geoclean. These include processing the IP-S2 raw data for subsequent operations; conducting inertial post-processing to create a geospatial vehicle trajectory; generating a LiDAR (Light Detection and Ranging) point cloud; converting compressed image files from a Ladybug camera into GIS maps; and registering the digital image sets to the trajectory and point cloud.

While Sideris performs the sequential upload to a GIS model, Howerton explains that in order to get the best map view one can change the settings of the Ladybug CapPro viewer using software from Point Grey Research, the camera’s manufacturer. “The settings we use are 18 frames for every tenth of a mile,” he said. A key software program used to view, analyze, and extract features from the processed data is Spatial Factory which merges imagery with point cloud data layers.

“Do you see these bubbles?” Sideris asks. “They are the raster data from the Ladybug.” He clicks on one of the bubbles and up pops an image of a Smart Road section on the screen. He then pans the image in a 360-degree radius around the van, virtually putting himself back on the Smart Road. Clicking on a LiDAR point on the model reveals the X, Y and Z coordinates collected by GPS.

The point-cloud layer makes it possible to incorporate such data as topography and the reflectivity of pavement markings into the GIS model. This additional information is revealed on top of the underlying image. “If you have an excavation, a cut-and-fill project, you can get the dimensions of the area, upload the data to any computer-aided

design software that can process point cloud data, compare the visualization with a map you already have, and then you can get the cut and fill done quite accurately,” said Uslu with considerable satisfaction.

[Photo credit: Unless otherwise stated, all photos are courtesy of Don Talend.]

Sidebar Like Digital Flypaper

The mobile mapping system that Virginia Tech’s Center for Highway Asset Management Programs is using to help the Virginia Department of Transportation monitor low-capital highway asset works like flypaper with five different adhesives—except that it snags the geospatial data and images of everything near it, not the physical objects themselves.

Topcon Positioning Systems’ IP-S2 incorporates three redundant positioning technologies with 360-degree digital imaging and laser scanners. The system consists of a dual-frequency, dual-constellation Global Navigation Satellite System (GNSS) receiver which establishes the geospatial position of the vehicle; an inertial measurement unit (IMU) which tracks vehicle attitude (pose); and external wheel encoders the captured odometry data from the vehicle. Integration of these technologies creates a three-dimensional position for the vehicle and provides accurate tracking in challenging or denied GNSS environments. A high-resolution digital camera provides 360-degree images. The system records and time-stamps inputs at the rate of 15 nanoseconds. The IP-S2 also uses 3D laser scanners with an effective range of 30 meters. Every second, the scanners collect 45,000 x, y, and z points which are used to obtain accurate geospatial positions for assets. Traditionally, LiDAR data have been collected from the air; because this system collects the data from ground level, it provides critical data that cannot be obtained from aerial surveys.