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# ***RTK Blankets Buckeye State***





# ODOT's Sensational System

Gerald L. McGray, RPLS



It's widely known that the state agencies known as departments of transportation (DOT) have long been in the forefront of surveying innovations, notably with using the Global Positioning System (GPS) for precision surveying. As early as 1990, maybe even earlier, state DOTs were using GPS both to explore the system's capabilities and for actual production. Since those early days, various states have continued to develop new uses and methods for GPS surveying. For example, many state DOTs have set up networks of receiver-occupied permanent control monuments. These stations are typically members of the Continuously Operating Reference Station (CORS) array, logging data 24 hours a day. Some of these networks-within-a-network have been enhanced by internal cross checking methods to ensure the accuracy of the positional data they provide, and by other advanced improvements. As official CORS sites, that data is available to all. Even stations that have not been entered into the CORS database usually make their data available to whomever has a need for it.

An order-of-magnitude increase in the value of that kind of contribution to the surveying community is evidenced by the advent of Ohio's Virtual Reference Station (VRS) network. This assembly of permanent monuments, receivers, radios, computers, and special software enables real-time kinematic (RTK) GPS surveying anywhere in the state without a user-supplied base station. Did you get that? One surveyor with one receiver (suitably configured, including cell phone or other wireless communication) can get centimeter-level precision within seconds anywhere in the state. All by herself (or himself). We've been talking about the data collected by CORS stations and its availability. But with the Ohio DOT's system what's being provided are the real-time ambiguity resolutions, that is, the solutions, that is, finally, the corrected coordinates of the object position! Read all about it in our feature article, "Ohio DOT's VRS Network."

Not to ignore the laudable—and similar—projects now underway in other states, the key thing about the Ohio system is that it's statewide. Smaller pilot programs are underway elsewhere, and many of those will no doubt grow to statewide scope. Of course there are states like Texas and Alaska with vast areas that have little immediate, or even pretty soon, need for instantaneous centimeter positioning. Such states would cover selected areas rather than every square foot of wilderness. In any case, it looks pretty clear from here that VRS systems providing fast RTK positions will be available virtually everywhere they are needed in the nation, within the not-too-distant future.

Pondering such capabilities almost always gets one to the cliché, "Gee, when that capability is available, nobody will need surveyors anymore." Please. Don't we know better than that by now? Haven't we come to understand that there's a whole lot more to it than determining the coordinates of a point? That old lament has been popping up since the Egyptians figured out a new way to knot their measuring ropes. It's a tool, folks. Use it, for Pete's sake, don't cry about it . . . and have a nice day! ♪

Gerald L. McGray, RPLS, Editor

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**President**

Johan Boesjes ([joban.boesjes@gitc.nl](mailto:joban.boesjes@gitc.nl))

**Publisher**

Neil Sandler ([neil@gitcamerica.com](mailto:neil@gitcamerica.com))

**Editor**

Gerald L. McGray, RPLS ([jerry@gitcamerica.com](mailto:jerry@gitcamerica.com))

**Managing Editor**

Patricia A. Smith ([patty@gitcamerica.com](mailto:patty@gitcamerica.com))

**Software Reviewer**

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Contributing Writers can be reached via the Message Center on our Website.

**Administration**

Angie Crum ([angie@gitcamerica.com](mailto:angie@gitcamerica.com))

**Art Director**

Kathy Whyte ([kathy@gitcamerica.com](mailto:kathy@gitcamerica.com))

**Graphic Designer**

Terry Kasmarzyk ([terry@gitcamerica.com](mailto:terry@gitcamerica.com))

**Circulation**

Karen Seldon ([karen@gitcamerica.com](mailto:karen@gitcamerica.com))

**Account Manager/Advertising**

Paul Siegel ([paul@gitcamerica.com](mailto:paul@gitcamerica.com))

**Account Manager/Advertising**

Carol Wright ([carol@gitcamerica.com](mailto:carol@gitcamerica.com))





# Ohio DOT's VRS Network

Steve McGowan

## Introduction

The Ohio Department of Transportation (ODOT) has a tall order as it delivers an annual construction program in excess of \$1.2 billion, including responsibility for the nation's second largest inventory of bridges, third greatest value of truck freight, fourth largest interstate system, and fifth greatest volume of traffic. With spatial attributes governing many transportation-related functions, surveying and other types of positioning are critical functions that must be performed in order to allow ODOT to accomplish the needed work.

## Background

Global Positioning System (GPS) technology has revolutionized positioning and created a tremendous potential for operational improvements in surveying. The Office of Aerial Engineering at ODOT has been using GPS technology for surveying since 1990 as well as working with Continuously Operating Reference Stations (CORS) since 1997 in an effort to improve surveying operations. After attending a National Geodetic Survey (NGS) Convocation in April 2000, Dave Albrecht, Survey Operations Manager at ODOT Aerial Engineering, stated that it had become evident that GPS surveying using CORS stations would continue to provide more and more operational benefits over traditional survey methodologies. Almost immediately, ODOT began to plan a CORS network that could meet ODOT's current and future needs.

## Design

Once ODOT decided to proceed with an improved CORS network, every aspect of the system was designed to prevent past and potential problems in an

attempt to ensure maximum system availability. The new design addressed items such as monument stability, signal quality, security, network connectivity, cabinet layout, continuous power supply, future maintenance, and environmental considerations among others. The result was a CORS station consisting of the following:

- **Monument** – Continuously reinforced concrete; 3' diameter base, 10' deep; 8' tall Washington Monument style structure above ground.
- **Antenna**: Geodetic choke ring
- **Antenna mount**: Machined Delrin with tribrach adapter
- **Antenna Cable**: LMR 400 or LDF-4
- **GPS receiver**: Trimble 5700 CORS
- **Cabinet**: 36" x 36" x 12" steel with lighting and a thermostat controlled cooling fan
- **Computer**: Dell GX 100 with 15" flat panel monitor



ODOT Antenna pillar/monument (CORS Classic) at Sidney, Ohio (first pillar that ODOT set)

- **Network connection**: T1 (typical)
- **Software**: Trimble Reference Station
- **Lightning protection**: ground rod and in-line gas capsule surge suppressor
- **Power**: 120v service with battery backup, backup generator where available

A few minor modifications would later be made, but the majority of the system remained the same.

## Construction

With the design having been completed, ODOT began constructing the system using internal staff collectively known as the CORS Crew. The CORS Crew constructed 17 stations during the first two years. Each of the stations would later be referred to as a "CORS Classic." After the initial learning curve, actual construction of each CORS Classic could be accomplished within three days.

"Constructing the stations ourselves allowed for better quality control," said ODOT Aerial Engineering's Dave Beiter, who managed the construction. "It also provided us with detailed knowledge concerning every aspect of the installations."

## Adding RTK using VRS

Having constructed a high-quality CORS network that could be used to improve GPS data collected in the field, ODOT was pleased—but not finished. As luck would have it, rapid advances in GPS technology had created yet another cost-effective opportunity to improve surveying operations. The opportunity was Real Time Kinematic (RTK) GPS over large geographical areas, enabling users to gain instantaneous centimeter-accuracy positions in the field on a statewide basis. The technology that claimed this was possible was Trimble VRS (Virtual Reference Station).



# Building the Nation's First Statewide RTK GPS Infrastructure

Trimble VRS technology uses RTKNet software. The software utilizes a CORS network to provide a fully modeled RTK solution to rovers. The solution takes into consideration ionospheric and tropospheric factors as well as orbital reporting error to obtain centimeter-level positioning. The primary advantage of VRS is that it allows you to increase the spacing of the CORS stations over conventional RTK, which makes the system more cost effective. The system effectively reduces or eliminates the spatial decorrelation (PPM error) associated with traditional single baseline RTK, thereby allowing for continuous RTK accuracy over a properly designed network.

ODOT constructed a pilot VRS network on the west side of the state. The success of the pilot led ODOT to plan a statewide VRS network. ODOT added 22 more CORS stations to the existing network. These new stations are referred to as "CORS Lite" in order to distinguish them from the CORS Classic.

The primary differences were the antenna mount (3" steel pipe bolted to a building), antenna (Trimble Zephyr Geodetic antenna), and GPS receiver (Trimble NetRS). The antenna mount was changed to provide greater flexibility in site selection, specifically single story masonry structures at existing facilities allowing ODOT to easily meet the spacing requirement. The Zephyr Geodetic antenna was used because it was comparable in quality to the choke ring and was more cost effective. Changing the receiver to a NetRS allowed removal of the computer and provided access to the new L2C signal, which is to be implemented in the near future. The new receiver also allowed ODOT to remove an external Ethernet interface or device server from the system (as needed with the 5700 CORS), potentially eliminating an additional point of failure. The NetRS has a fully integrated Ethernet port, making it ideal for permanent mounting and connection to the state's LAN.



*Kokosing Construction Co surveyors Rex Bogner and Dan McIntire do sign layout using a Trimble 5800 RTK GPS system with the ODOT VRS Network on an I-71 ODOT project.*

Construction of a CORS Lite could be accomplished in one day.

A few additional CORS stations were added via a cooperative arrangement with private and public entities to complement the network at the state borders and other areas where additional stations would be beneficial. The entire CORS network now consists of 52 stations, all of which will soon become part of the NGS National CORS Network.

## Testing

ODOT surveyor Jim Stafa, PS, conducted many of the tests to evaluate the VRS network. He performed extensive testing against High Accuracy Reference Network (HARN) marks (accuracy A or B order) throughout the state. The test points were in the 0-25mm horizontal and 0-4cm vertical range. He also compared the VRS technology with OPUS (NGS's Online Positioning User Service)

in an attempt to identify any systematic errors. Sessions were conducted with 20-25 test points using VRS on each point at different times and varying constellation configurations. The results were in the 3 sigma range, indicating 99 percent of the test points were within 9-15mm horizontally and 15-25mm vertically. "The system is a very powerful tool," said Stafa.

In addition to the testing that ODOT performed, a few other entities who had expressed a desire to use the system during its development were provided access to test and evaluate the system while it was being completed. ODOT's goal was to determine how the new system would perform for various surveying applications across the state.

Kokosing Construction Company, Inc., a general contractor from Fredericktown, Ohio, was interested in trying the system and agreed to assist in testing





*ODOT CORS Construction Manager/Surveyor David Beiter surveys newly constructed sub-grade for US33 Lancaster Bypass project in Lancaster, Ohio. Image courtesy: Chuck Bernthold*

the ODOT VRS system. When performing RTK surveying with one or more of their 12 survey crews, Kokosing would normally set up a Trimble 5700 RTK GPS system as a field base station along with any needed repeaters on construction sites for all survey work.

Kokosing's survey crews used the VRS network on a job site in Columbus for construction staking, topo work, and other GPS work. Crews collected points using both the traditional base station and the VRS network. "They both hit

right on," said Bill Clifford, PS, Kokosing survey manager.

"We now use VRS technology like our regular GPS except we don't have to set up a base station and repeaters," he added. "VRS technology is a huge cost savings for us. You can literally jump out of your truck wherever you are and start your job. It's outstanding."

Woolpert LLP, a design, mapping, and survey firm located in Dayton, Ohio, has 24 offices throughout the nation. Woolpert has been involved with other

geodetic programs in the past, and a few years ago researched the potential for a statewide geodetic control network for the Ohio Geographical Reference Information Program (OGRIP).

Woolpert initially tested the pilot area of the VRS network on a county-wide utility GIS project, providing RTK-level vertical accuracy on water and sewer structures.

"It was important for us to test the system to better understand the technology," said Tom Mochty, PS, Woolpert partner in charge of the Survey/GPS Services division. "Since our teams were on the project for more than three months, we were able to extensively test the VRS system."

Woolpert had previously developed a first-order geodetic control network for the project, including 150 control monument pairs. They checked the VRS system results against their network, as well as experimenting with local and countywide site calibration scenarios.

The results, particularly when they applied the site calibration, were "quite good," said Mochty. "We were consistently able to compute 1-2 cm orthometric heights."

Without site calibration, using the geoid model, results were in the 4-5 cm range. By using the ODOT VRS network, Woolpert saw an estimated 25 percent cost savings, Mochty said. In addition, Woolpert trained the GIS client to use the VRS system with Trimble R8 RTK GPS rovers so they could maintain the GIS themselves. Woolpert also hopes to discuss the use of VRS technology in a workshop at the 2005 Professional Land Surveyors of Ohio (PLSO) convention.

EMH&T, a civil engineering and surveying firm in Columbus, Ohio which maintains 22 survey crews through its three offices in Ohio and Indiana, also participated in testing. EMH&T's Adam Long, PE, PS, used the system on a utility services inventory GIS project. Long utilized a single Trimble 5800 RTK GPS receiver and the ODOT VRS network to collect more than 500 points, including manhole locations, fire hydrants, storm and sanitary structures.

"The beauty of using the VRS network is the ability to achieve survey grade accuracy with a single RTK receiver without setting up a base receiver





## FEATURE



*Kokosing Construction Co surveyors Rex Bogner and Dan McIntire as-built MSE wall footers using Trimble 5800.*

anywhere in the state of Ohio," said Long. "Time is one thing, but our base station security is always in the back of our mind; in fact, we often leave a person at our base station doing nothing but making sure it isn't taken."

"We are constantly striving to complete projects more effectively for our clients and the ODOT VRS network provides us with yet another tool in our toolbox," he said. "The statewide network pushes the industry forward."

### Implementation

The RTK GPS system using VRS has been implemented statewide within ODOT. Cell phones with digital service are currently being used to access the system when working in the field. Alternate telecommunication solutions are being investigated for those areas in Ohio where digital cell phone service is not available. ODOT's goal is to provide high quality service to those who need it and expects to begin accepting applications to use the system by January 1, 2005. There will be a small annual fee for those using the system. The fee will be used to offset a portion of the system maintenance costs.

### Conclusion

"When we began building the CORS network, we never dreamed that we would some day have statewide RTK GPS," said ODOT's John Ray, administrator for the Office of Aerial Engineering. "Now that we have the system, the

day-to-day benefits, as well as the cost savings, will be significant for ODOT's surveying operations, consultant surveying

services, construction work, GIS, and related positioning applications." Ray attributes the success of the ODOT statewide RTK GPS network to the unique capabilities of his staff and ODOT's executive management for providing an environment that fosters innovation and embraces technology to improve operations. ↓

**STEVE MCGOWEN** is a freelance writer specializing in surveying.

**Editor's note:** The following product designations that appear in this article are Trademarks of Trimble Navigation Limited, Sunnyvale, California:

- Trimble VRS (Virtual Reference Station)
- Trimble Zephyr Geodetic (antenna)
- Trimble NetRS (receiver)



*EMH&T surveyor James Pearsall, PS, collects points on the City of Granville, Ohio utilities inventory project using a single Trimble 5800 RTK GPS system with a Nextel cell phone and the ODOT VRS.*