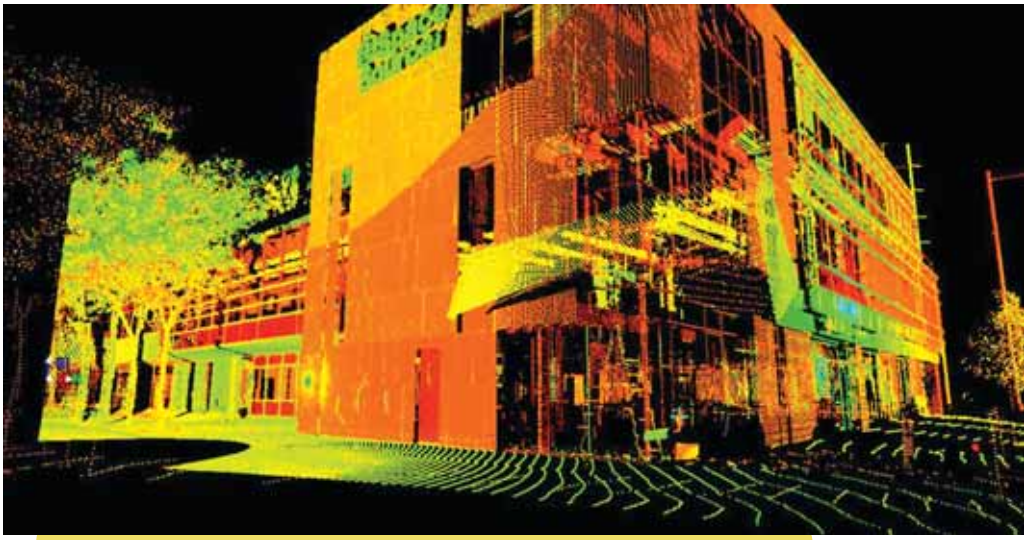
Using Multiple Laser Scanners on Projects

Most organizations still don't own their first laser scanner, yet there's already a strong trend emerging among many that do: using multiple scanners on a single project. This article describes what's behind this trend, with a focus on how progressive users are using different types of scanners for different parts of a project.



▲ A short-range, phase-based scanner and a long range, high-accuracy, pulsed scanner were used simultaneously on this condo conversion survey for optimum productivity—*Image courtesy: Nederveld, Inc.*

Three Groups of Laser Scanners for Surveying

Today, vendor offerings of laser scanners used for surveying tend to fall into three groups. Here I list them in order of maximum practical range:

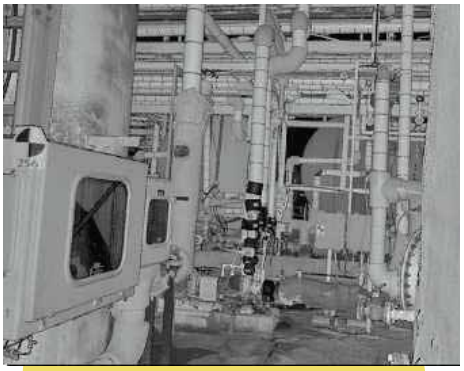
- Short-range, ultra high-speed, "phase-based" scanners
- Long range, high-accuracy, "pulsed" scanners
- Very long range, lower accuracy, "pulsed" scanners

Each of the above three groups has applications for which it is best suited.

The terms "phase-based" and "pulsed" refer to a scanner's method for determining the distance to any surface that has been scanned. These are the exact same, basic techniques used in total stations for measuring distance.

The phase-based method measures a shift in a continuously emitted and returned phase (sine wave) of the laser. The instrument computes a distance to the measured surface based on the magnitude of the phase shift.

Pulsed scanners are also known as time-of-flight or ToF scanners. The pulsed method measures the time it takes a pulse or short burst of laser energy to "fly" from its source to a surface and return to a detector at the source instrument, hence the term time-of-flight. The distance to the measured surface is computed by multiplying the time it takes for the whole flight of each pulse by the speed of light and then dividing by two to account for two flights (to the measured surface and back to the instrument).



▲ Realistic looking, gray-scale scan images of plant interiors are characteristic results from phase-based scanners—*Image courtesy: BE&K*

Today, pulsed scanners can measure much farther distances, while phase-based scanners can scan faster.

Short-range, Ultra High-speed, Phase-based Scanners

Although around commercially since 1998, it's only been within the last couple of years that phase-based scanners have started to become popular within the surveying community. With scanning speeds of ~100,000 to 500,000 points/sec, these scanners are blazingly fast—very attractive for field productivity. This is especially true for conducting "full dome" scans with high point density in a practical amount of time. For example, in just 3 ½ minutes such a scanner can blanket a basic, vacant room and ceiling with ¼" point-to-point spacing at a 30' distance from the scanner!

A few drawbacks had limited their popularity in the earlier days of this technology. Drawbacks included a too-short range, issues with noisy data, and challenges in dealing with the large amount of data collected. Over time, however, these shortcomings have been addressed steadily by vendors; today, these scanners are commonly used for certain applications.

Today, specified ranges are up to ~250', with practical ranges of ~125' to vertical surfaces and ~70' for horizontal surfaces. For some models, ¼" accuracy is achievable for each scan point out to a range of ~80'. All models have a full dome field-of-view. On the office side, software and computing power have improved such that storing and processing the mega-data sets are manageable for regular practitioners.

One other challenge of using this type of scanner has been targeting. These scanners don't have dual-axis tilt compensation, so surveyors cannot use tra-

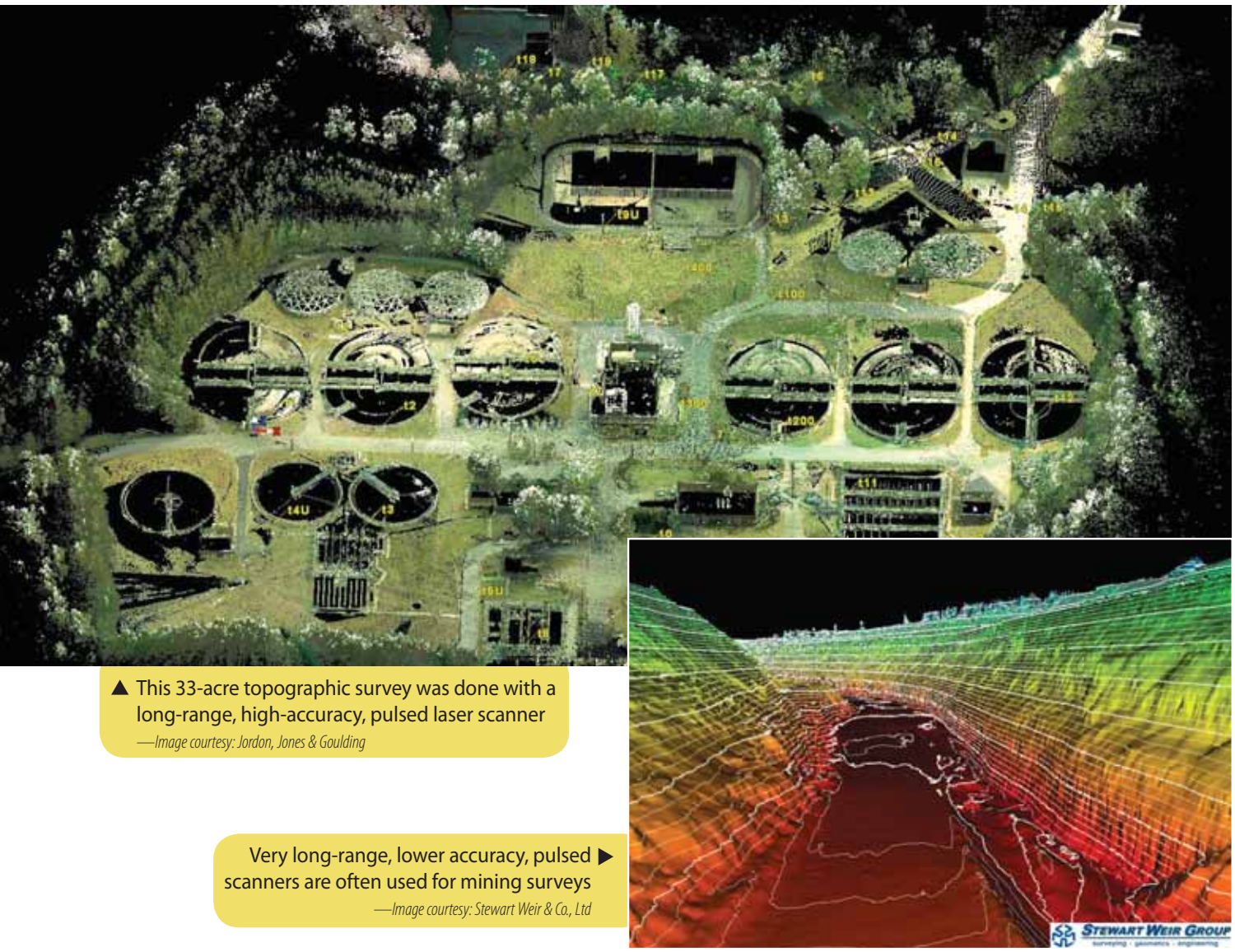
verse, resection, and backsight methods. Instead, special scan targets are used to geo-reference scans and accurately tie scans to each other. Moreover, because of their short range capability, targets must be close to the scanner (within ~50' or so). This leads to many target set-ups, and great care must be taken when surveying such close-in targets, as target network geometry is not as good as being able to use targets much farther away. Cloud-to-cloud registration techniques can also be used, provided there's good three dimensional variation within overlapping scans. Experienced users today have mastered these aspects of field targeting, scan registration, and geo-referencing for phase-based scanners.

Based on the above, phase-based scanners have become popular for high-definition surveys of industrial plants, buildings interiors, tunnels, small intersections and bridges, heritage projects, and forensics.

Long Range, High-accuracy Pulsed Scanners

This type of scanner is the most popular among surveyors due to its versatility for a wide variety of projects. Since day one, models have been available that can achieve ¼" accuracy out to ~175' for each scan point. Today, they feature specified ranges up to ~900' to 1,000' with practical ranges for high-accuracy work up to ~500' for vertical surfaces and ~250' for roads (farther with tall tripods). Some models can scan at exceptionally high density out to 500' or more. In addition, some models in this group feature automatic, full dome field-of-view scanning, plus dual-axis tilt compensation that allows traverse, resection, and backsighting workflows.

These scanners had long been in the 1,000 to 10,000 points/sec scan speed range, but recent advances have extended this to specified speeds of 50,000 points/sec. Fewer instrument set-ups and targets are needed for this type of scanner thanks to their longer range, their ability to accurately capture target coordinates out to ~500', and their ability to be used in traverse, resection, and



▲ This 33-acre topographic survey was done with a long-range, high-accuracy, pulsed laser scanner
—Image courtesy: Jordon, Jones & Goulding

Very long-range, lower accuracy, pulsed ▶ scanners are often used for mining surveys
—Image courtesy: Stewart Weir & Co., Ltd

backsight modes that minimize the use of targets altogether.

These scanners are cost-effectively used for high-definition surveys of industrial plants, topographic sites up to hundreds of acres, building interiors and exteriors, roads and highways, toll plazas, bridges, intersections, tunnels, rail, ships, cell and power distribution towers, forensics, heritage archive, rock faces, small mining sites, and more.

Very Long Range, Lower Accuracy, Pulsed Scanners

This group of scanners often serves applications that benefit from an ability to scan surfaces at a distance of 1,500' to 3,000' or longer. What they give up is accuracy, both in distance measurement and in vertical and horizontal angle accuracies. Point spacing (too far apart) and spot size (too big) can also become problematic at longer ranges. At the extent of their range, single scan point accuracies can be in the several inches-to-one foot or larger band. Scan speeds vary from 250 points/sec to ~10,000 points/second. Today, none of these models is capable of automatic, full dome scanning (i.e., scan 360° horizontally and at least 270° vertically without intervening with the scanner). A couple of models in this group today have tilt compensation, but compensation accuracy is not survey-grade.

These scanners tend to be used heavily in large mining operations or for large terrain and pile/quantity survey applications. They can also be used in certain civil, architectural, heritage, and forensic applications if accuracy requirements are not stringent. This type of scanner is rarely used in high-definition surveys of plant, piping, structural, or other applications in which the as-built information is to be used for parts fabrication and construction. Since high-accuracy applications comprise a large portion of the use of survey laser scanners today, the population of very long range scanners in the marketplace today is much smaller than that of higher-accuracy systems. Nevertheless, this is an important group and mining surveyors, in particular, are adopting these types of systems at a rapid pace.

No Single Type of Scanner Excels at Everything

Each group of scanners has its strengths and its shortcomings. This is unlike total stations. With total stations, you can buy one type that is essentially fully loaded with everything—highest accuracy, longest range, etc. With scanners, you have to pick the type that best suits the kinds of projects you'll want to use it for. If you're doing only huge mine sites, then a very long range scanner is the way to go. If you're surveying only highly congested plant areas, then a phase-based scanner may be the best route. If your organization addresses multiple types of applications, then a long range, high-accuracy system is often the best bet.

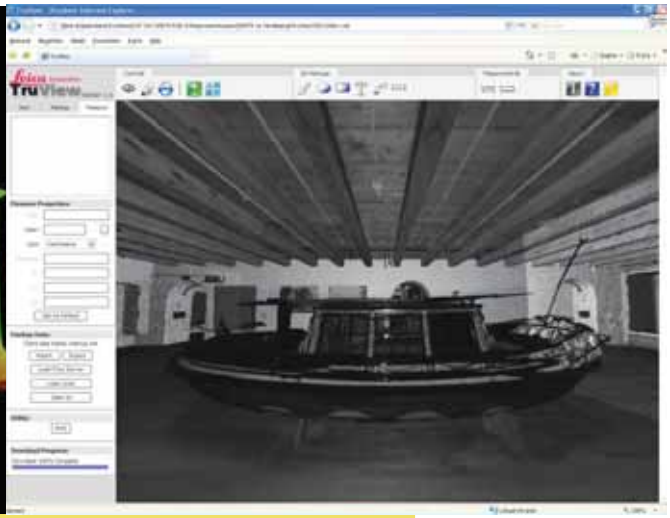
Using More than One of the Same Type of Scanner on a Project

The size of projects in which high-definition surveying is used has steadily grown over time. To meet demanding schedules, many organizations use two or more of the same type of scanner on a single project. The largest simultaneous use of which I am aware is four scanners for one project. This was for a large industrial plant in which four different areas of the plant had to be captured quickly.

I'm also aware of organizations using multiple scanners of the same type for surveys of large building interiors and for road and bridge surveys. For example, Nevada DOT recently used both of

▲ Nevada DOT recently used two, long-range, high-accuracy pulsed scanners simultaneously to efficiently survey a dozen overpass structures

—Image courtesy: Nevada DOT



▲ Fugro Inpark used their high-accuracy pulsed scanner to capture the exterior of this maritime museum and their phase-based scanner to capture interior rooms and museum objects—*Image courtesy: Fugro Inpark*

their long range, high-accuracy scanners simultaneously to capture a dozen highway overpass structures. Originally estimating a project timeline of seven weeks using one scanner, Nevada DOT shaved the actual time to three weeks by using both in tandem: one covering northbound and the other southbound lanes. Crews were able to take advantage of common target setups for northbound and southbound instrument setups.

BE&K used their high-accuracy pulsed scanner to capture these storage tank exterior structures, while using their phase-based scanner to capture dense interior plant areas ▶
—*Image courtesy: BE&K*

Using Different Types of Scanners on the Same Project

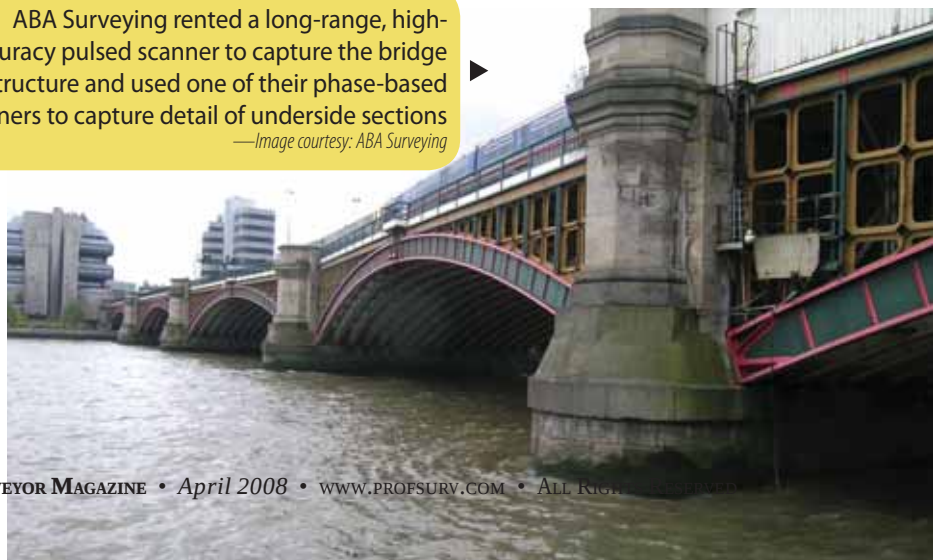
This is where things are getting interesting. Organizations are increasingly mixing and matching their use of scanner types on individual projects. Examples are below.

Buildings: Many users are today using short-range, phase-based scanners for building interiors and long range, high-accuracy scanners for building exteriors and building sites.

Manufacturing Plants and Power Plants: Many users are deploying phase-based scanners for congested areas inside a plant and using long range, high-accuracy scanners to capture geometry of tall distillation columns or long piping runs.

Bridges: Some users are deploying phase-based scanners in tight areas/bays under the main deck and using long range, high-accuracy scanners to

ABA Surveying rented a long-range, high-accuracy pulsed scanner to capture the bridge superstructure and used one of their phase-based scanners to capture detail of underside sections ▶
—*Image courtesy: ABA Surveying*



capture the main road surface and/or the superstructure.

Ships: A long range, high-accuracy scanner is ideal for capturing the hull and mast/tower sections, while phase-based scanners are used for interior rooms.

Heritage: A long range, high-accuracy scanner may be used to capture geometry of estate grounds and towers, while a phase-based scanner is used for interior structures and rooms.

Other factors to consider are:

- Users can today source different types of scanners from a single vendor.
- One software can run different types of scanners and also efficiently process data from each type.
- Scanners are becoming increasingly available on a rental basis.
- As fleets of laser scanners grow in size, more organizations are adding, for example, a phase-based scanner to their fleet of long range, high-accuracy scanners. This gives organizations more flexibility in taking on a wider variety of projects and in being able to execute entire projects more efficiently.

I'm unaware of projects where users have mixed and matched high-accuracy scanners and very long range, lower accuracy scanners but there is little doubt that someone has.

As the number of organizations owning or renting multiple scanners has grown, users are increasingly applying multiple types of scanners on single projects, taking advantage of the specific strengths of each type of scanner. The most common scenario is to use a long range, high-accuracy scanner on the same project as a phase-based scanner, letting each provide optimal productivity for the overall project.

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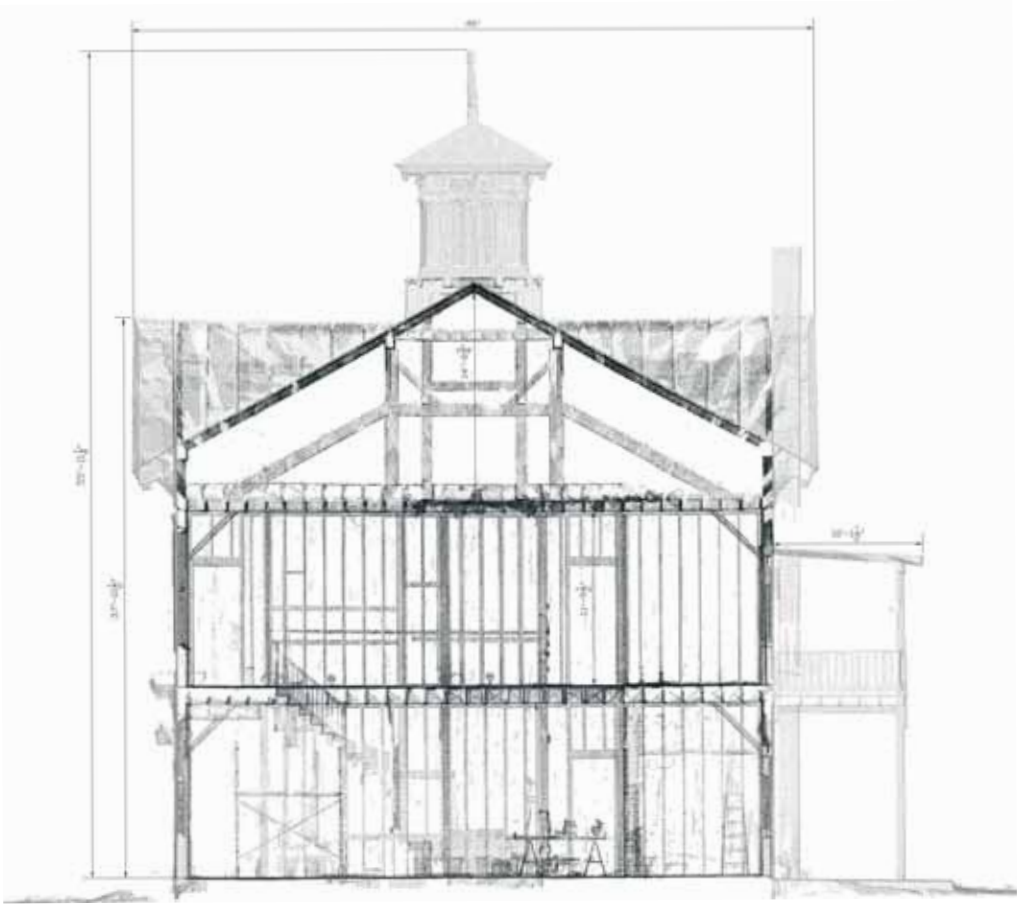

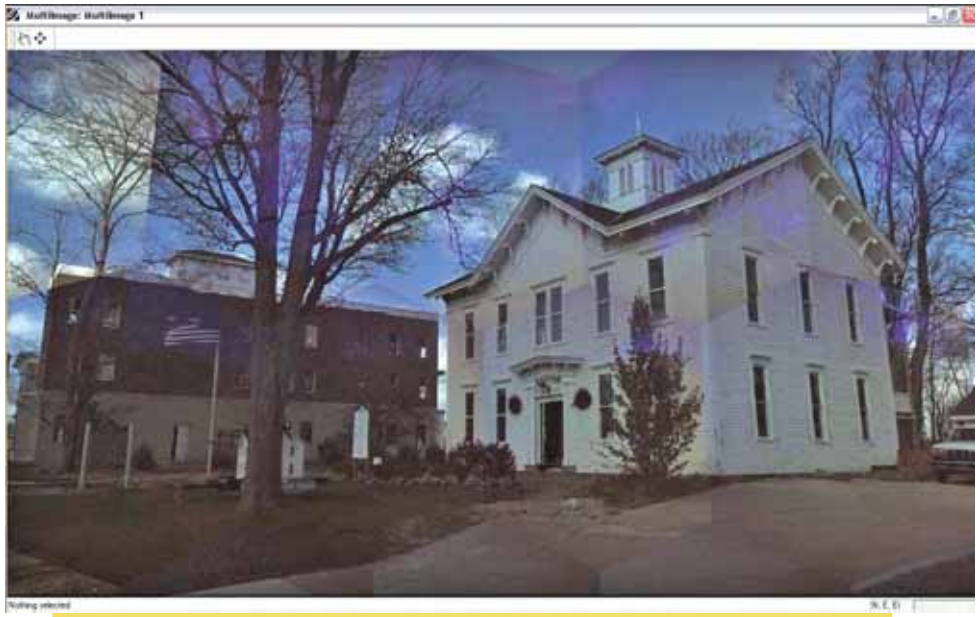

▲ In one day Nederveld used their high-accuracy pulsed scanner to capture the exteriors and site of these two school buildings and used their phase-based scanner to capture the detailed interiors of the 1800s white heritage schoolhouse—*Image courtesy: Nederveld, Inc.*