Leica’s Core Wall Survey Control System for High-Rise Vertical Alignment

A Concrete Contractor’s Review

By Tom Trotter, Baker Concrete Construction, Inc.

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INTRODUCTION

In construction layout, accurate control is crucial.

This is true for any building project but especially in the construction of high-rise buildings.

Before any building can go up, accurate control points must be established on the ground.

The first step is getting the control points or building offset control points. These points serve as the foundation for the control network that will be established on the site.

Once these points are established, the next step is to verify the control network's accuracy, both horizontally and vertically. This includes running a traverse and a bench loop around the site to ensure that the control network covers the building's footprint.

If the given control network does not cover the building site, additional control points must be established. Adjustments may be needed to ensure that the network is as accurate as possible.

Establishing an accurate control network on the ground is a crucial step in the construction process to ensure accuracy and precision.

On buildings that are only a few stories tall, the process is well established and relatively straightforward.

But high-rise construction presents a new challenge, especially as building designs keep getting taller:

How do we effectively maintain survey control as the building structure rises?

CONVENTIONAL CONTROL

The Vertical Laser Method

The vertical laser method involves establishing at least three control points on the ground floor of the building, then using a vertical laser to go up through the floors. This allows you to create an accurate vertical path for the control.

The next step is to put sleeves above these points on every floor, then set up your total station over these points to do your layout.

This approach usually requires two people—one person on the ground, and another person on the working deck marking the points—to ensure the control is properly aligned and ready for use.

The Plumb Bob Method

Another conventional method is to hang a plumb bob down a shaft opening. To reduce lateral movement and provide more accuracy, the plumb bob can be placed in a container of oil.

The plumb bob was used throughout history to provide a vertical line for building measurements. Today, it is generally reserved for plumbing walls and elevator core shafts.

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The 90-Degree Eyepiece

A 90-degree eye piece is an inexpensive and easy-to-use tool that allows us to establish accurate measurements even at great heights.

However, using a 90-degree eye piece requires climbing up and down the building, which can be time-consuming and requires at least two people.

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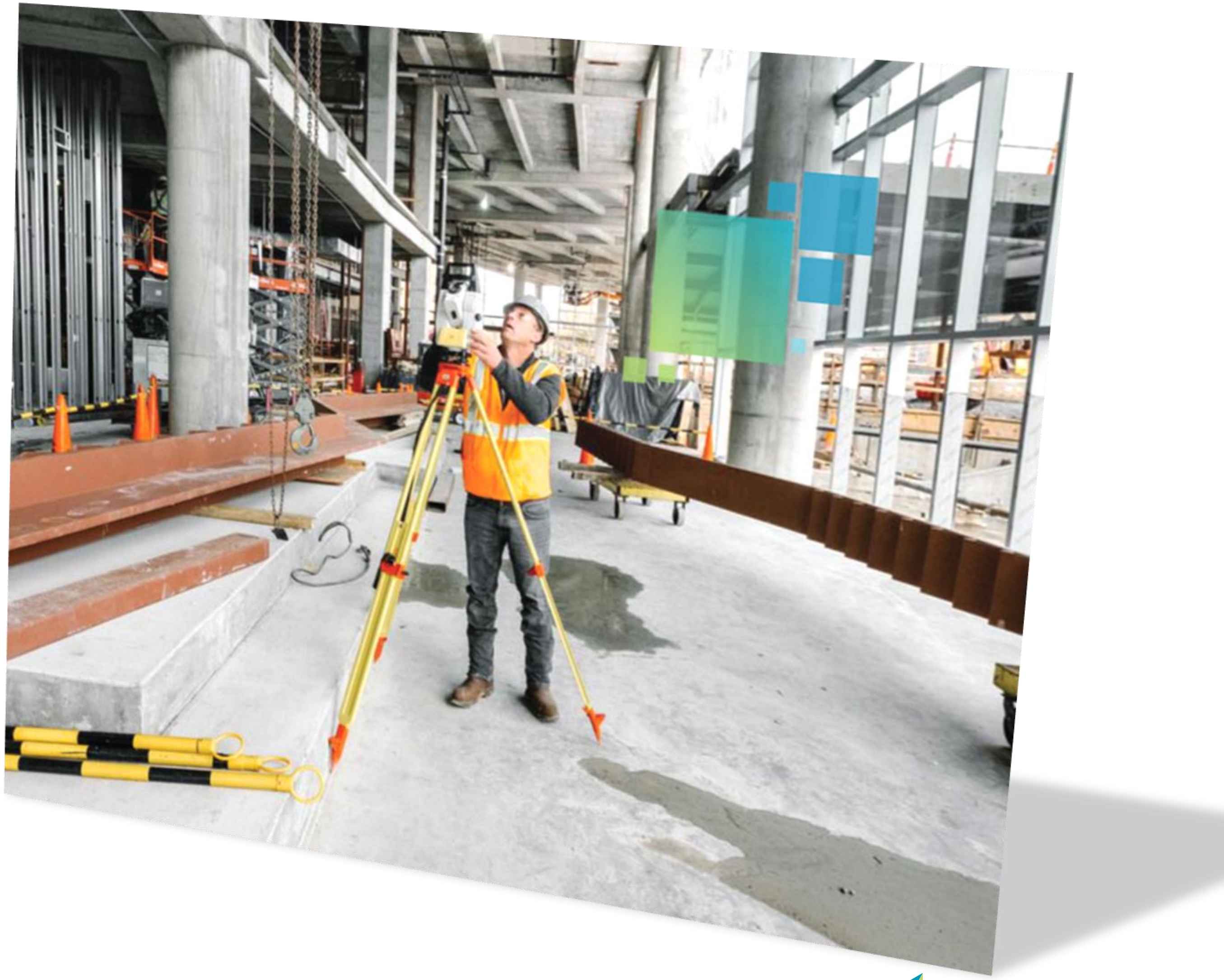
TRADITIONAL WORK PROCESS:

1. Setup a theodolite on known grid lines or ground control points at the street level
2. Raise the alignments with telescope to the upper floor on four sides, or raise the control points from the last floor
3. Average the final intersection axis at the next floor
4. When the street level points are “lost” or too far, use a plumb bob
5. On very high floors, this must be done at night or early morning when the building is “hopefully” in its neutral stage
6. Then form work or steel work layout can start with these grid lines



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THE CHALLENGE OF VERTICALITY

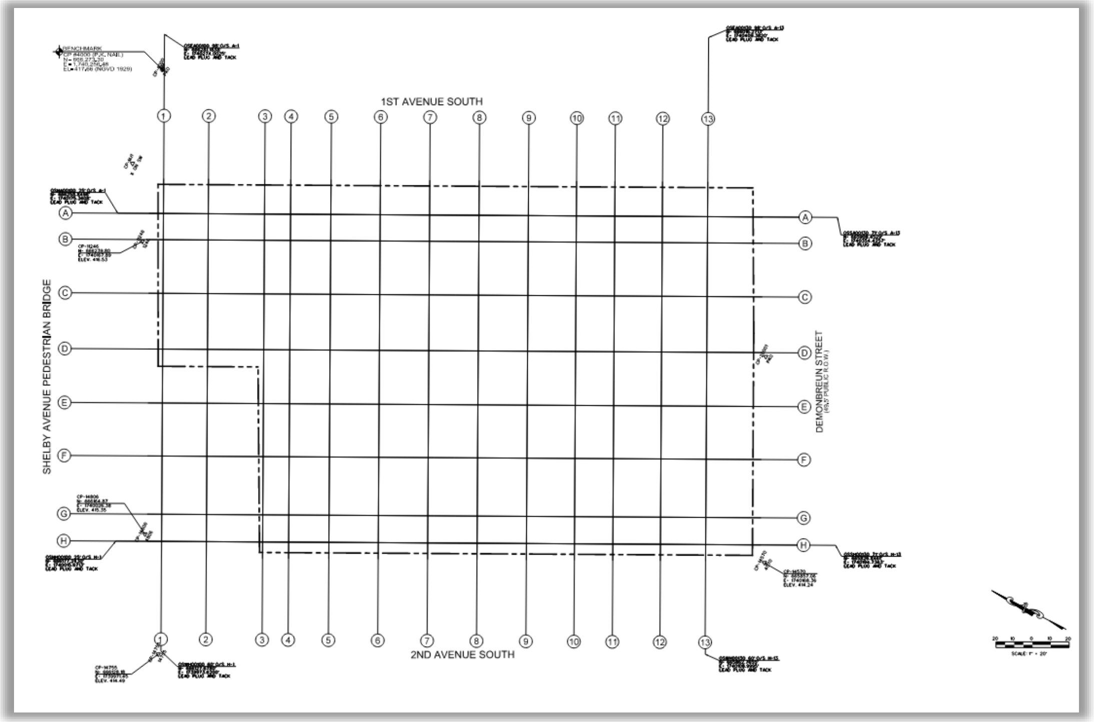
Conventional methods work – but they can't keep pace with today's rapid per-floor construction cycle.

Setting up control points or lines on elevated floors of tall buildings is a challenging task that requires careful planning and execution.

The control points on the ground must be far enough away from the building to avoid any interference from the building itself. In downtown environments where high-rise buildings are usually located, there is usually not enough space to achieve this goal.

As the building grows taller, the traditional methods of establishing control points become too slow and less effective.

New methods must be explored.



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GPS AS A POSSIBLE SOLUTION

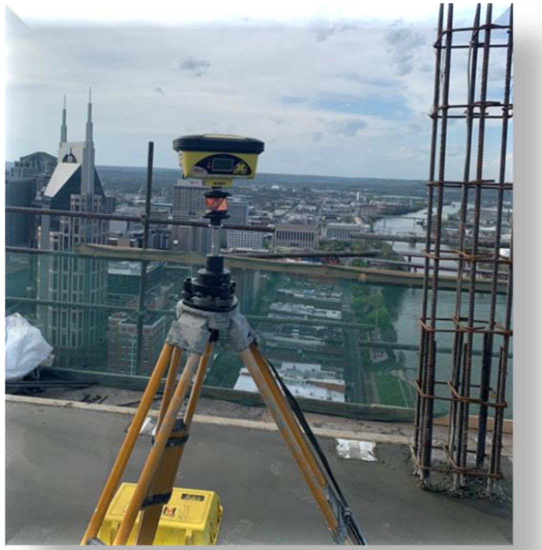
GPS technology provides great accuracy and even greater efficiency in setting up control points for surveys.

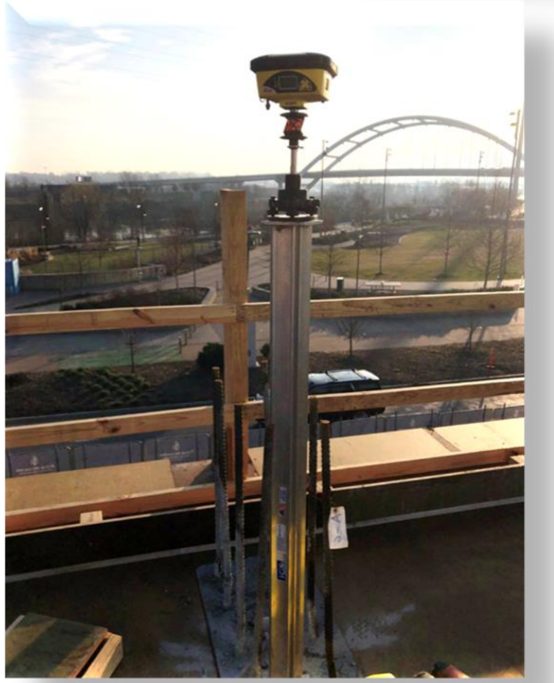
With the use of GPS rovers, we can set up and collect data, and then start working on the day's layout. While the GPS is collecting and averaging data, we can help elsewhere until we are ready to go.

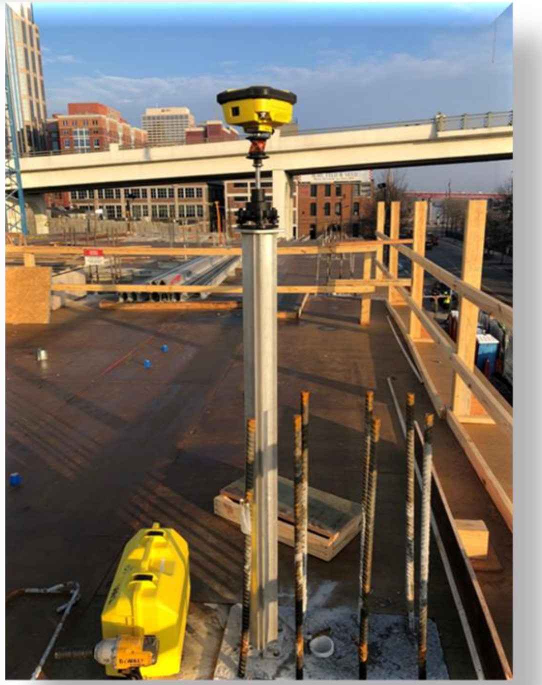
But how would setting up GPS rovers on top of a high-rise building work?

Would it be accurate?

Could new technology help?



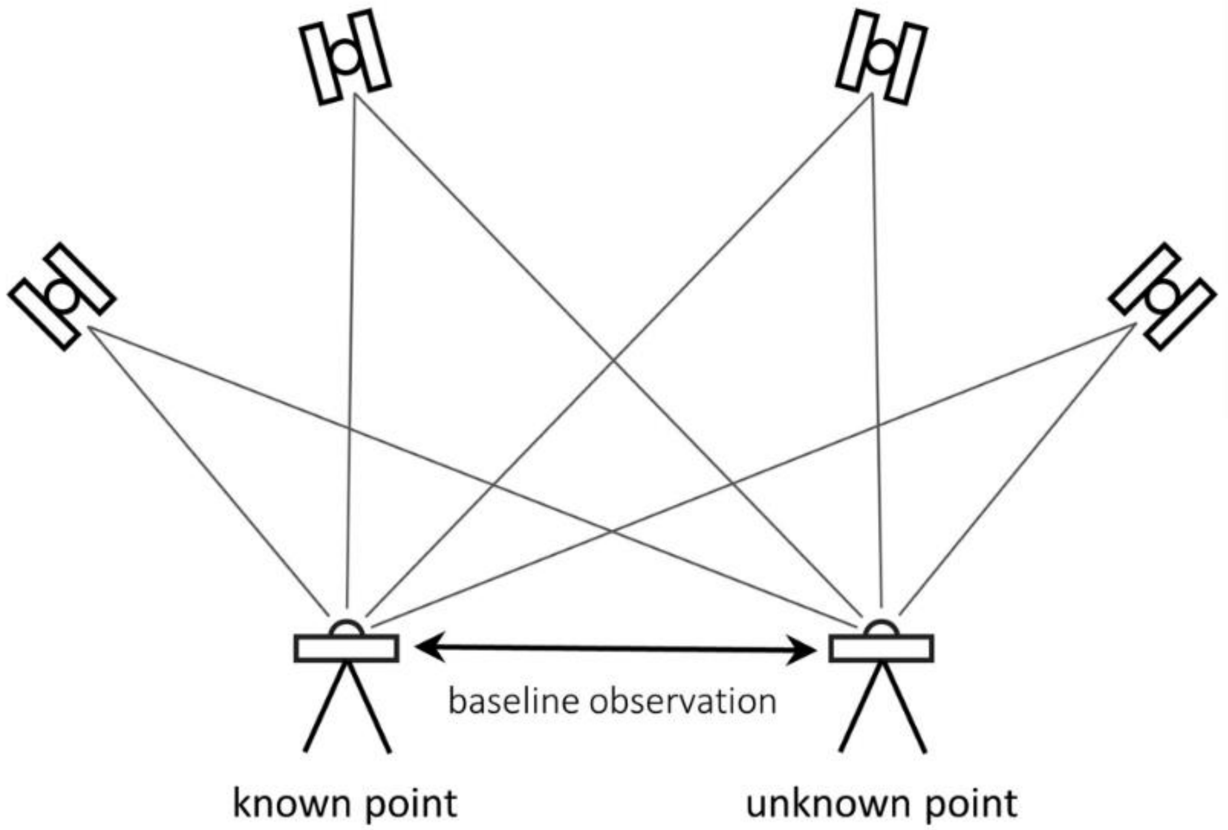




How GPS Works

The Global Navigation Satellite System (GNSS) constellation is a network of satellites orbiting the Earth that provides location and time information to users around the world. Each satellite transmits a signal that can be picked up by a receiver on the ground. One of the most well-known GNSS systems is the Global Positioning System (GPS), which is operated by the United States government.

There are other GNSS systems in operation, such as the Russian GLONASS system and the European Galileo system.

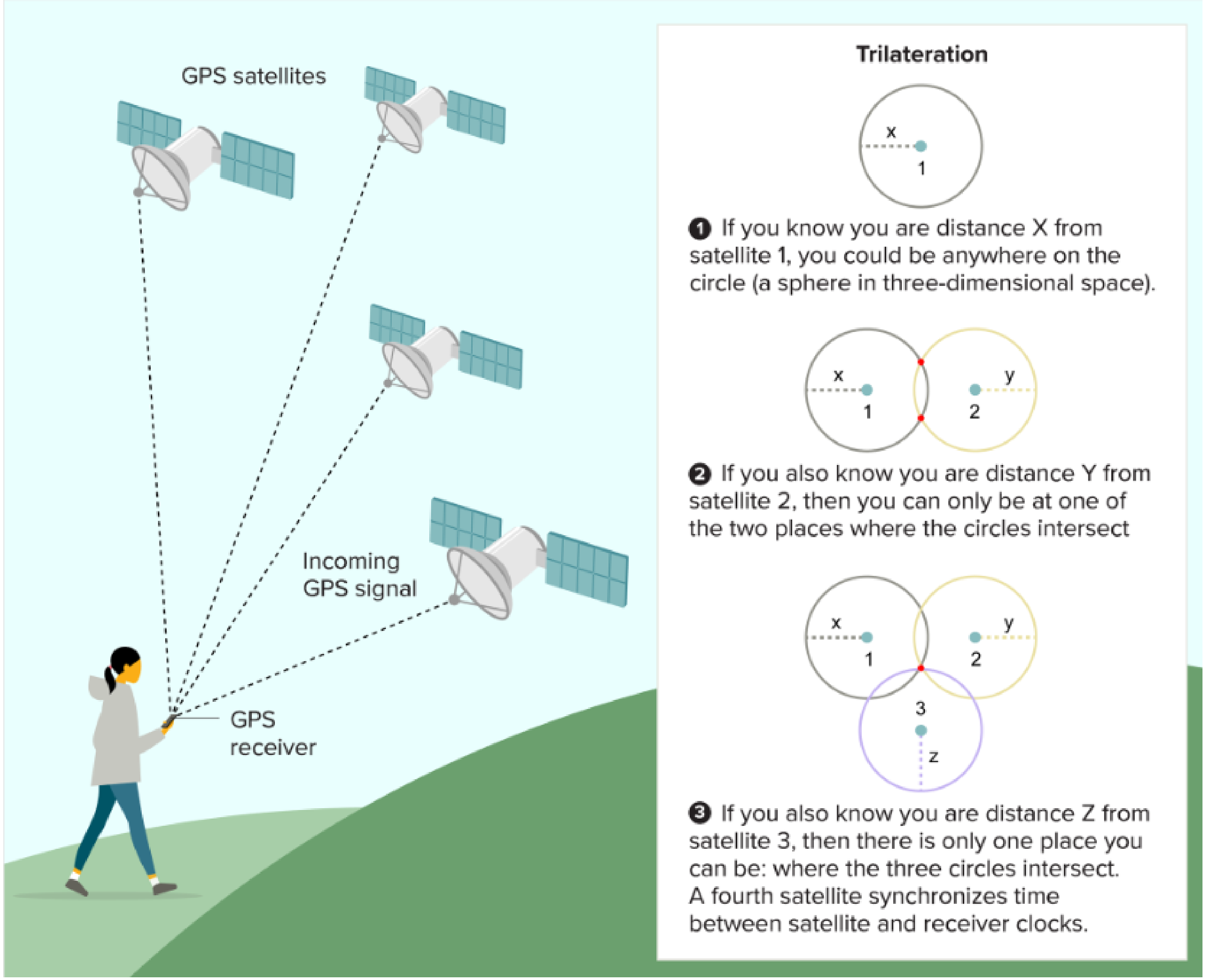


When a user on the ground wants to determine their location, they use a receiver to communicate with the satellites in the GNSS constellation. The receiver compares the time a signal was transmitted by a satellite to the time it was received by the receiver. Because the speed of light is constant, the time delay between transmission and reception can be used to calculate the distance between the satellite and the receiver. By measuring the distance to multiple satellites, the receiver can triangulate its position.

GNSS systems are becoming increasingly important for a variety of applications, from GPS navigation in smartphones to precision farming and self-driving cars.

What about building construction?

A GPS receiver, like the one in your smartphone, pinpoints its location on Earth's surface by analyzing its distance to three GPS satellites; a fourth satellite synchronizes clocks in the receiver and satellites.



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A Healthy Dose of Skepticism

“No way this will work!”

GPS is well accepted in heavy civil construction, where it is used to guide and control heavy machinery for dirt work as well as measure features on a project site to monitor progress and maintain quality control.

It’s not seen as often in building construction, especially for building control on a high rise. It seems unlikely that we could use GPS to stack floors without the building becoming crooked or misaligned.

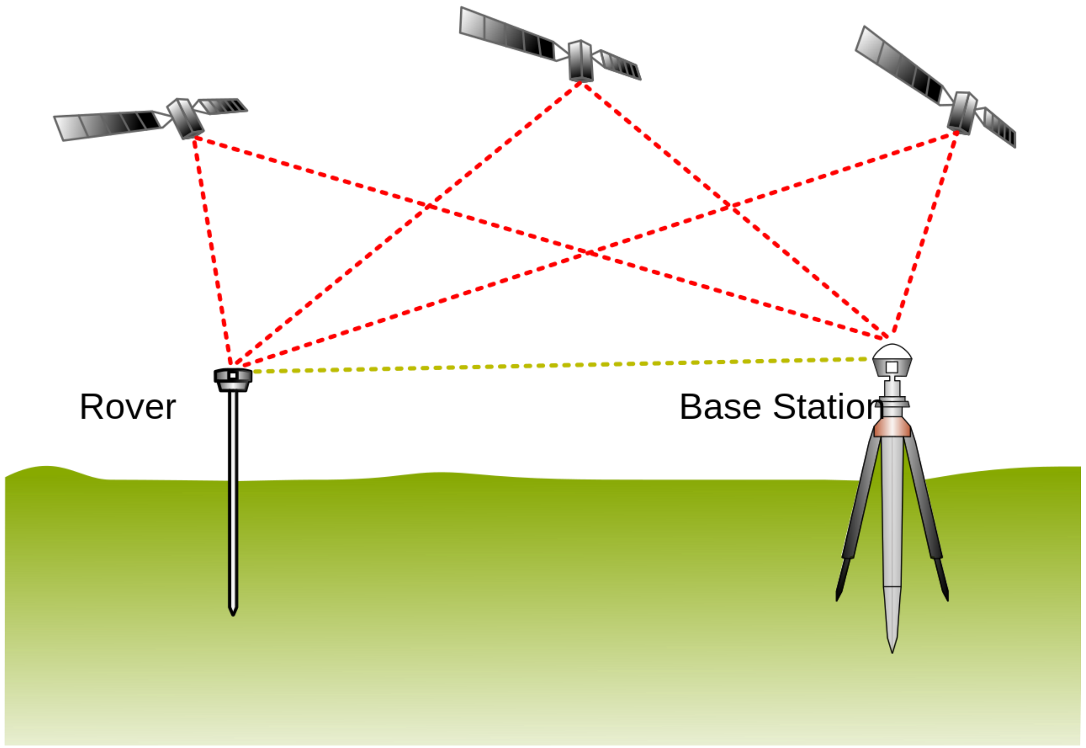
For this approach to be successful, it would need to be able to maintain accuracy for multiple stories.

GPS vs. RTK

The GPS system uses a coded signal from which a receiver derives distance and thus position.

Real-time kinematic (RTK) is a special form of differential GPS that gives about one-hundred times greater accuracy.

GPS/GNSS receivers measure how long it takes for a signal to travel from a satellite to the receiver. Transmitted signals travel through the atmosphere and are slowed down and disturbed on the way. For example, travel time on a cloudy day would be different than in clear sky conditions. That is why it is difficult for a standalone receiver to precisely determine its position. RTK solves this issue.



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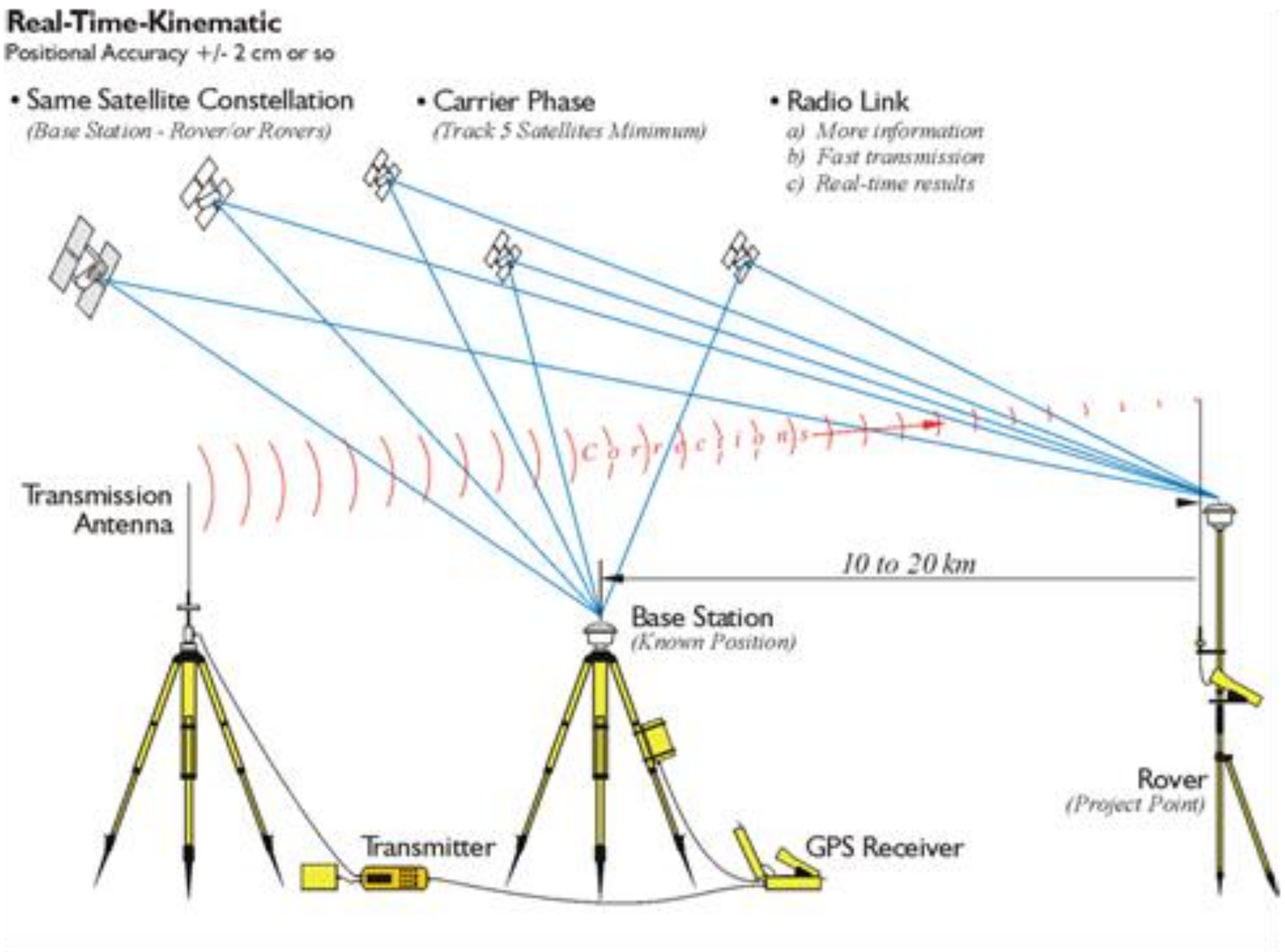
Using RTK to Improve GPS Accuracy

While traditional GPS receivers, like the one in a smartphone, can only determine a position with 2-4 meters accuracy, RTK can give you centimeter accuracy.

It has high real-time precision.

Two receivers are used in RTK. One of them is the base station, which is stationary. The other is the rover, which moves freely.

The base station’s mission is to stay in one place and send corrections to a moving receiver. A rover uses that data to achieve centimeter precise position. Any number of rovers can connect to one base if their input settings match the base's output.



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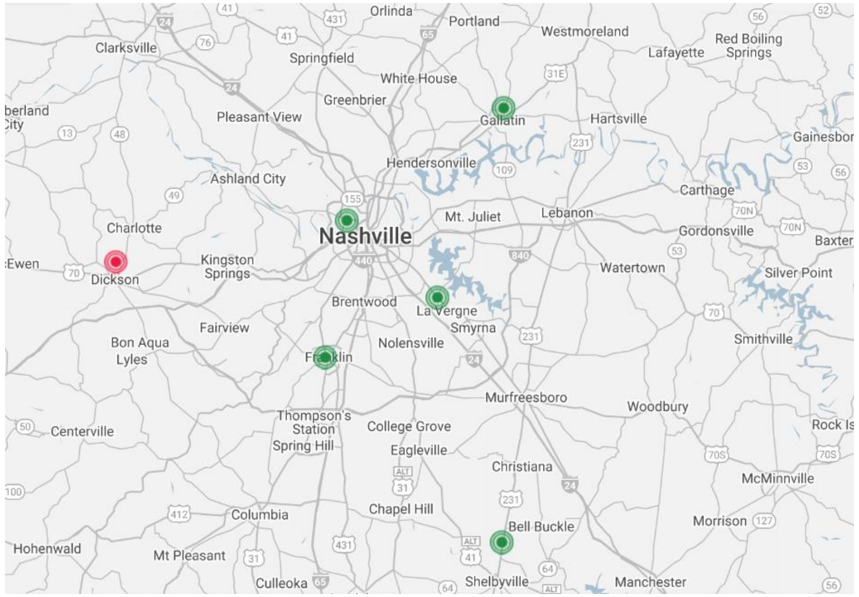
Corrections Over NTRIP

You do not necessarily need a second unit for RTK all the time. Usually, there are local services that share base corrections over the Internet. This technology is called NTRIP.

NTRIP is a good option for areas with strong cell coverage and a vast network of NTRIP bases nearby. In other cases, using the second receiver as a local base station has some advantages

A data SIM card can be used to access these corrections via the Internet. This approach has proven to be viable even when cell coverage is limited.



Station Information - TNNS - W Nashville TN

ONLINE

Site Name:	W Nashville TN	Date Installed:	02/22/2021
Site Code:	TNNS	Prepared By:	Tyler Collier
Date Prepared:	03/12/2021		
Monument Description:	Aluminum Mast - 3 inch	Last Updated:	SA on Dec 3, 2022
Height of Monument:	6.4 m		
Monument Foundation:	Masonry Structure	Site Quality:	Meets Standards
Foundation Depth:	0.75 m	External Site Link:	Open

Additional Information:

The antenna is affixed to a 3" fabricated aluminum mast via a 5/8" stainless steel leveling monument adapter and 5/8" SS bolt. The SS bolt is threaded into a machined 3" solid aluminum plug that is welded into the mast. The mast is fastened to a masonry building via a set of 2 in. slotted strut channel, SS bolts and fabricated aluminum offset arms . The upper and lower strut channel are mounted horizontally and are affixed to the masonry building using SS bolts and 3/4" drop-in hollow set wall anchors. (2) fabricated aluminum offset arms are used to secure the mast to the upper and lower strut channel.

The Role of a GNSS Reference Station Network

Setting a base station requires an unobstructed view of the sky and a constant power supply. This isn’t always possible on a construction jobsite. In some cases, you can pour a temporary concrete column to raise the receiver above any obstructions, but this might not be an option if you’re working in a congested downtown environment.

An alternative to the time-consuming setup and interference concerns of an onsite base station is to use a GNSS reference station network. Subscribing to a service with high precision, availability, and uptime can provide confidence and efficiency in using GPS for control in a high-rise project.

HxGN SmartNet

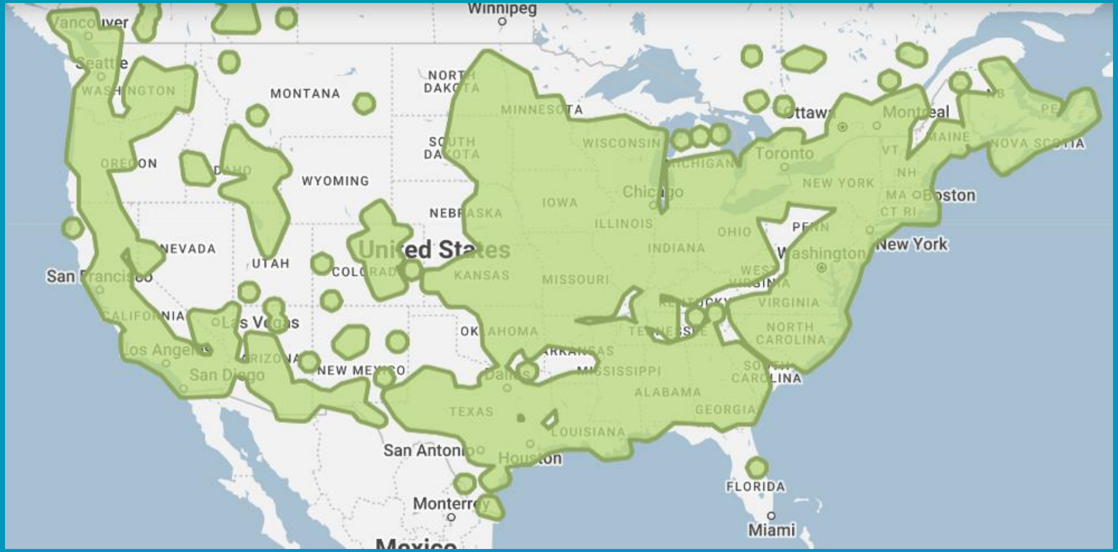
HxGN SmartNet is a GNSS correction service and reference network that has more than 5,300 reference stations worldwide.

It can provide corrections for an onsite base station or can be used as a network base station.

The GNSS satellites broadcast signals, sending data to reference stations and GNSS devices around the globe. Reference stations stream the GNSS data to the SmartNet data centers, which also receive approximate positions of GNSS devices.

This data is then processed, and SmartNet sends network RTK corrections back to GNSS devices over mobile internet. The corrected position is accurate down to the centimeter, providing SmartNet users with high accuracy and precision they can count on.

Users receive correction data in an open standard format (RTCM) by connecting any GNSS-enabled device over the mobile internet. Since SmartNet's open standards work with all GNSS devices, users benefit from one streamlined service across all their GNSS equipment.



Here are some capabilities of the HxGN SmartNet network RTK correction service:

- Horizontal accuracy of 1-3 cm for all sensors / 0.8 cm for Leica Geosystems GS sensors
- Vertical accuracy of 2-5 cm for all sensors / 1.5 cm for Leica Geosystems GS sensors
- Instantaneous convergence and reconvergence
- Delivery via mobile internet

GPS Calibration

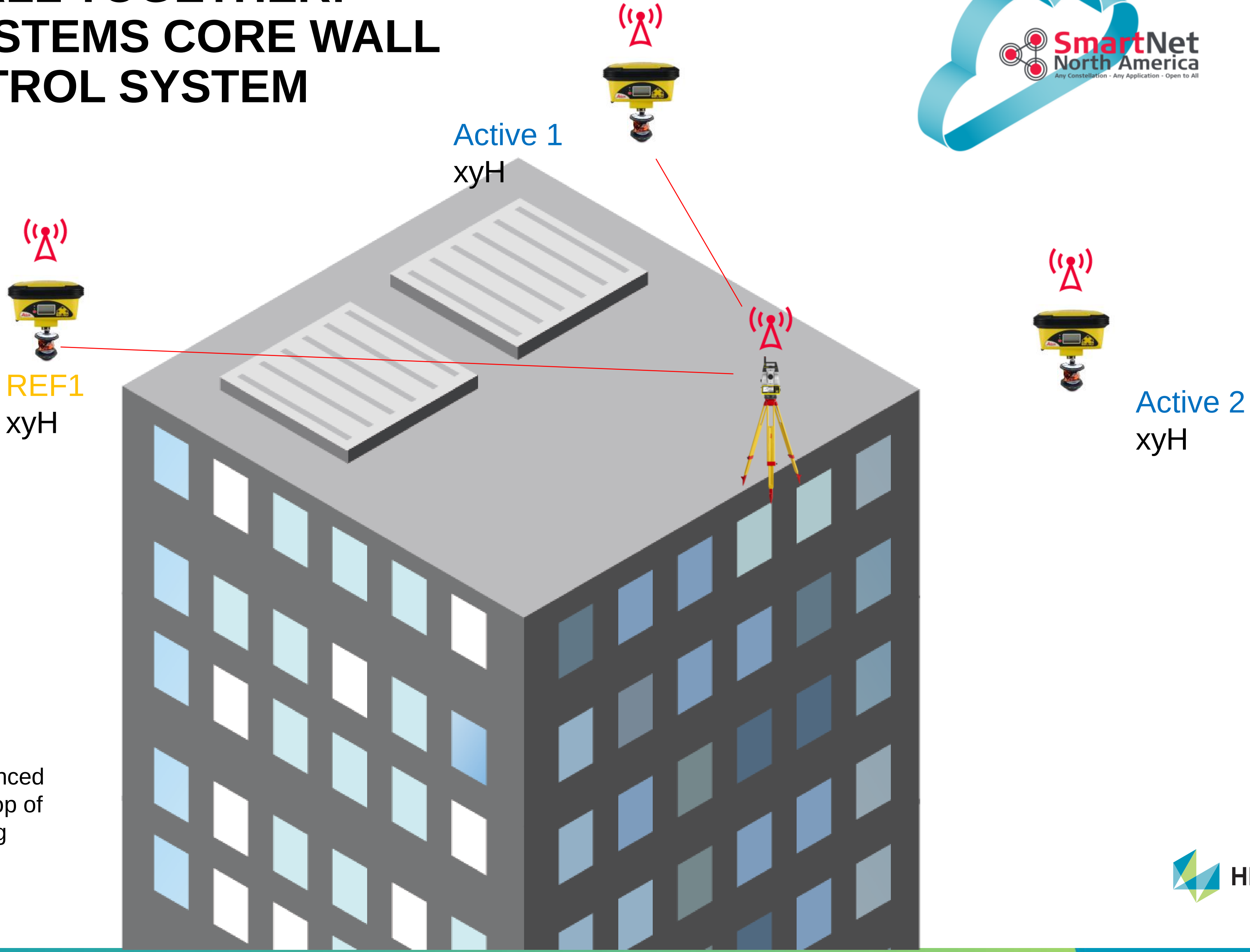
After setting up the control network using traditional equipment, the next step is to perform a GPS calibration.

An essential aspect of this calibration is to have a control network that covers the entire jobsite, thereby reducing errors between the control points for when the GPS rovers are going to be the means of control higher up in the building.

A calibration is a straightforward process that involves setting up a rover on the control points and allowing it to average measurements until it reaches the desired time that you want. Then you can have local or state plane coordinates, whichever you prefer.

The more accurate your calibration, the more accurate your GPS rover control will be.

BRINGING IT ALL TOGETHER: LEICA GEOSYSTEMS CORE WALL SURVEY CONTROL SYSTEM



System Objective

To obtain precise and reliable coordinates that are not influenced by building movement at the top of any building or structure during construction.

SmartNet North America

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A Game Changer for High-Rise Buildings

The **Leica core wall survey control system** is a unique, state of the art system that provides a new way to get control up a high-rise structure. Developed after years of research, the system has been used in some of the most significant construction projects around the world.

The Leica core wall system involves the use of GPS receivers on the building exterior as active control points that move up as floors are completed.

A key advantage of the core wall system is its ability to reduce construction time, which is essential in large-scale construction projects.

The core wall system is also highly adaptable. Your control is where you want it. You can move the GPS rovers to where you need them, depending on the jobsite conditions.

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Can the other methods keep up with pouring every 4-5 days?

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Core Wall Survey Control System: An Impressive Resume

Some noteworthy projects that have used Leica’s core wall system include:

432 Park Ave
NY

Salesforce Tower
CA

Millennium
Tower, MA

One World Trade
NY

220 Central Park
NY

217 West 57th St
NY

The Muse
FL

Real-Time Coordinates with Leica GeoMoS

Once you have everything set up and turned on, you need to get your coordinates. This is achieved with Leica GeoMoS automatic deformation monitoring software.

The GeoMoS program can be installed on a dedicated computer in the office to ensure reliable power and Internet and accessed remotely from the jobsite using phones, tablets, or computers.

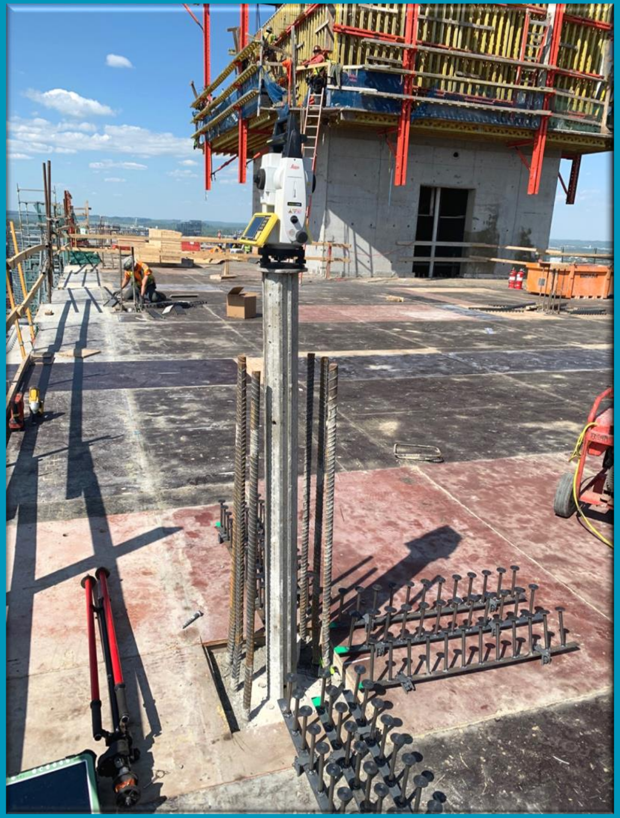
Before you can start running GeoMoS, you have to create a profile for your job. Part of this process involves connecting and assigning your rovers to the system and deciding on how often to receive an email with your coordinates. You should also test your GPS rovers to make sure you don’t have any connection or satellite issues.

GeoMoS can be set up to give you single measurements at set times or averages over time. For example, you can set it up to provide measurement data in 15-minute increments, but it can also give you an average of those 15-minute increments over the last 60 minutes to help you determine the best timing.

We have experimented with 30-minute and 15-minute intervals, and we have found that 15-minute intervals work best for us.

After everything has been set up and tested with a few clicks, you are ready to start the logging process.

- Name,Northing,Easting,Height,Epoch,Type
- ROVER 1,6316.043,4104.623,618.159,01.06.2023 05:00:01.000,Single
- ROVER 2,6386.097,4017.338,618.308,01.06.2023 05:00:01.000,Single
- ROVER 3,6252.367,4102.448,618.214,01.06.2023 05:00:01.000,Single



Control Coordinates Best Practice: Wait for the Second Email

Leica GeoMoS offers the convenience of receiving control coordinates via email, but you shouldn't use the coordinates in the first email to start layout. If the emails are set up to send in 15-minute increments, you might have just turned on your first rover when the first email is generated. It's best to wait until the data from all the rovers is included, which is usually by the second email.

After receiving the second email, you can use the first email to compare the coordinate values. Big differences might be an indication that something is wrong or needs to be investigated. Perhaps someone bumped the rover or tripod legs. The rover could also be in a bad location, maybe under the tower crane or under an overhead load from the tower crane.

It is always a good practice to pay attention to the results.

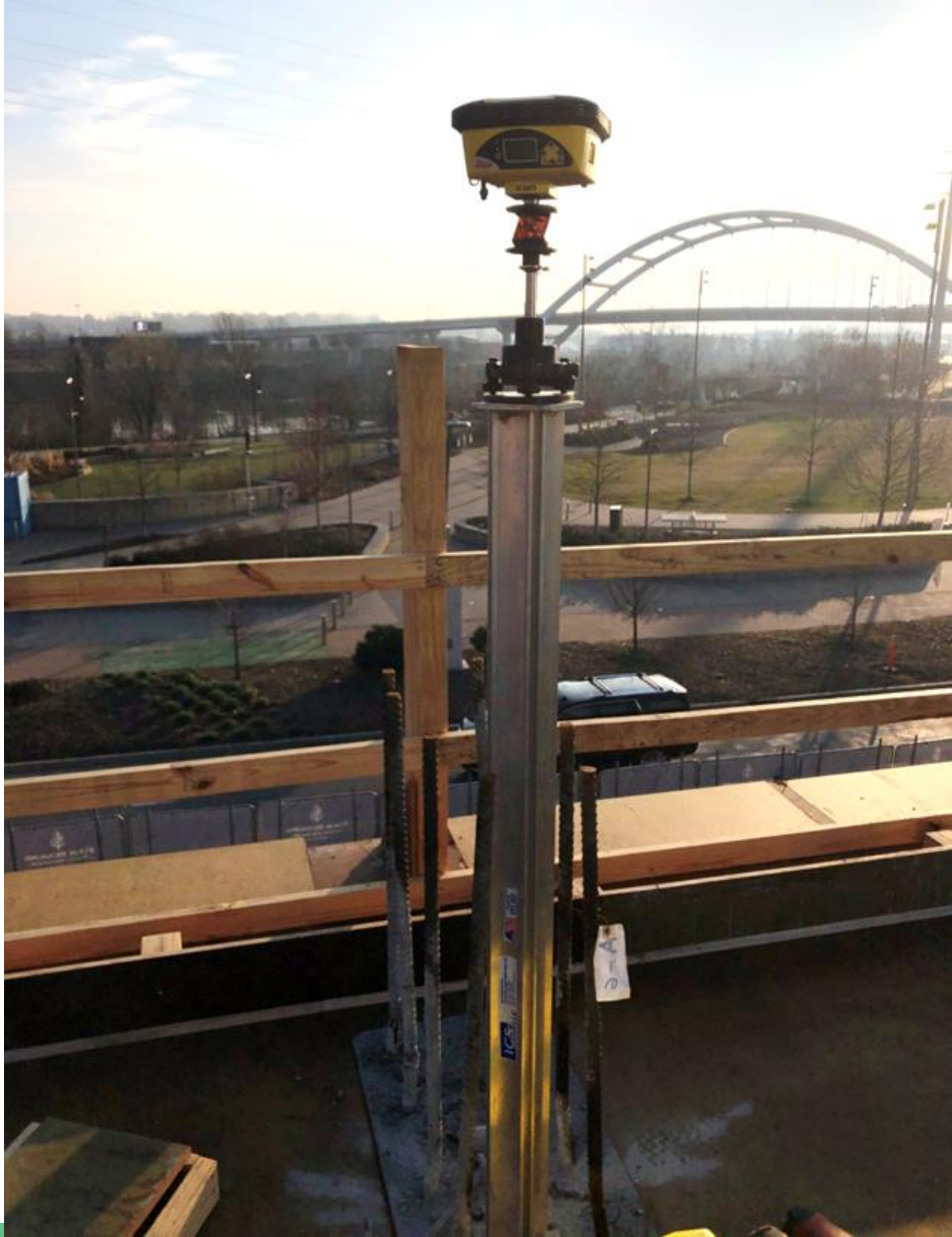
THE PROOF: ACCURATE RESULTS EVERY TIME

Does it really work? Can GPS rovers be used as control points on high-rise buildings?

Initially, I was skeptical of this new method. We constantly cross-checked with our existing layout. We would lay out using our control that was mounted around the jobsite and initially used for the first few floors. Then we would set up the GPS rovers, do a resection from them, and go around and check our layout.

After doing this for a few floors, we saw that nothing ever changed. The layout was the same.

"The Leica Core Wall System consistently delivered highly precise data every day, and it quickly won me over."



Our team has implemented the Leica core wall system on two projects so far.

The first project was a 42-story building standing 538 feet tall.

The second project comprised two 35-story towers each measuring 459 feet in height.

Laying out control points and control lines for the MEP trades was accurate. Their sleeves and penetrations stacked and posed no issues. The core wall system made the process effortless.

The general contractor had their own surveyors come in to verify our control, but we never encountered any discrepancies or problems with others inspecting our work.

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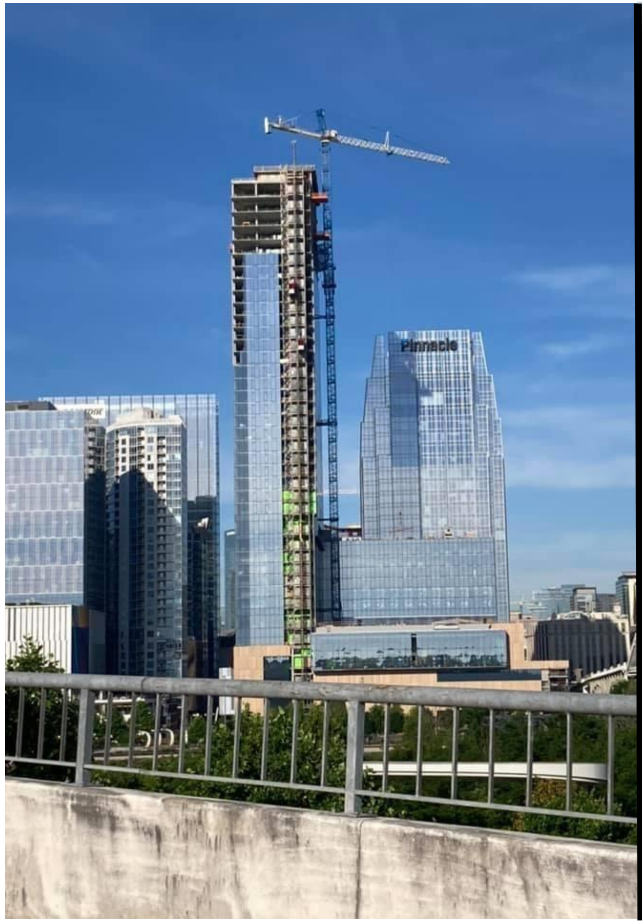

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Precision of the slab edges was crucial for fitting the glass systems and precast.

The building stacked up floor after floor, and we encountered no issues. Everything met ACI tolerances for being plumb.

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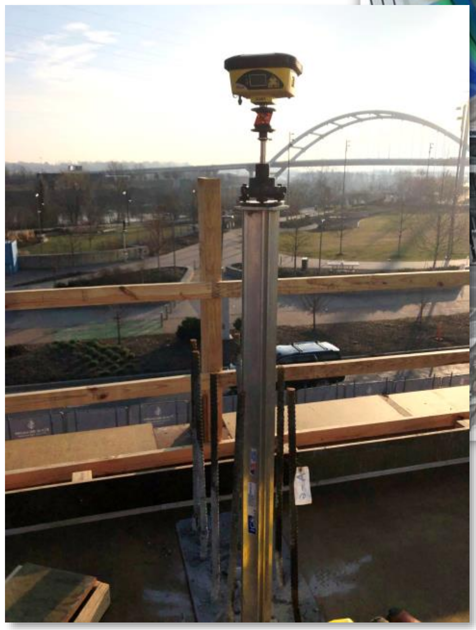

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Coming out of the ground, we would start with fixed prisms for the initial floors and then switch to three rovers that were repeatedly moved once these prisms became too low. The two different means and methods for control matched. There was also no difference in floors when this switch of control happened.

“The Leica core wall system proved reliable, delivering accurate results every time. We saved considerable time and money by not having to go to the street every time we needed new control at the top of the building. The speed and accuracy of the system are unparalleled.”

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Best Practices for Core Wall System Setup and Use

On days we pour concrete slabs, we typically begin setting up the GPS rovers when the concrete starts getting burned in and we can walk on it. We might only use one or two rovers at this time. We turn them on and start the GeoMoS program.

Once the slab is burned in more and we can get a good 90-degree resection and some good distances, we set up the third rover. After we get the control coordinates email with data from all the rovers, we start laying out the walls and columns.

Once the layout is done, we as-built our slab edges. We usually start by moving one rover and doing two setups with the robotic total station. After the first resection has been established, we move the other rovers. That way, when it's time to move the robot, the GPS rovers have already been collecting and averaging the data so there is no extra wait time.

To lay out the slab edges and slab openings on the plywood decks, we often come in a little earlier than the carpenters and bolt temporary posts to the concrete column from below. This process ensures our layout crew is ready to go when it's time to get started.

This layout is all typically done in one day.

Best practices include:

- Maximize the distances between the robot and the rovers
- Find good 90-degree angles for resections
- Set up on solid, stable surfaces
- Understand when and where to set up the rovers

These steps will help you achieve optimum results.

BUILDING A BETTER HIGH-RISE

For the past four years, we have relied on Leica Geosystems core wall survey control system to establish vertical control, and I cannot envision using any other approach.

The ability to set up a GPS rover with a 360-prism attached to it almost makes it too easy. What used to take a good portion of the day with at least two people can now be done in a fraction of the time with just one person.

The core wall system provides precise three-point resection setups every day. With the time saved from not having to repeatedly go down to the ground level and back up to the top, we have more time to look into the drawings or double check our work. It keeps us ahead of the carpenters so the concrete pours can stay on track.

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The core wall system allows us to work effectively and efficiently, no matter how high the building may be.

Setting control points on a busy deck or newly poured concrete slab has never been simpler. In just 30 minutes, we can have control points with averaged measurements emailed to us so we can start our layout.

If we need to relocate our setups, it's not a problem. We simply move them around while keeping an eye on the sky and find a suitable location. With three rovers in strategic locations around the deck, it’s easy to achieve a good setup.

As long as we take the time to set up the control before we begin the vertical phase, the system provides exceptional accuracy. Being able to constantly save time by not having to spend so much time establishing control from the ground, we are able to build and lay out a better product.

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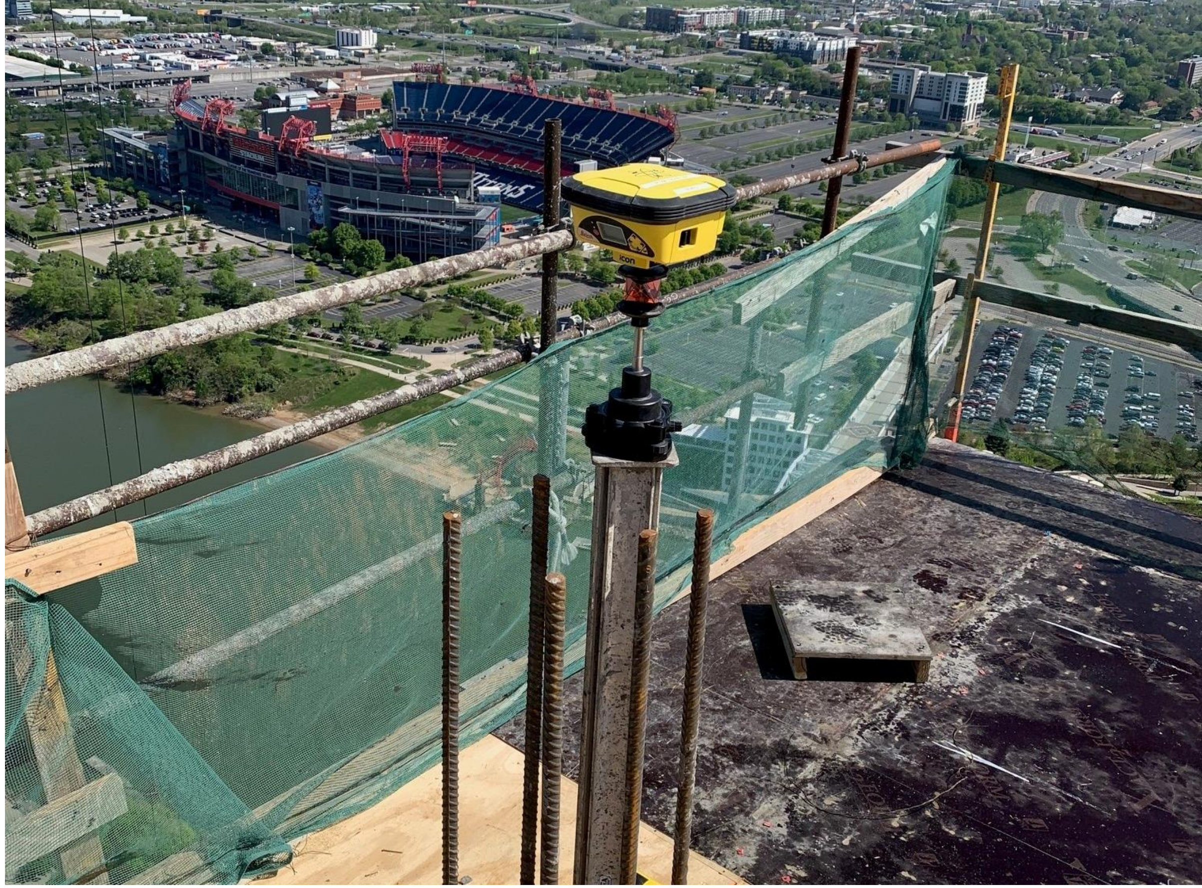
The implementation of Leica's core wall system has significantly impacted our approach to constructing high-rise buildings.

The core wall system has paid for itself and is now our go-to for high rise structures. It helps us keep up with the pace and demands of the job. Our initial planning now includes incorporating this system into our control strategy, which ultimately saves us time and money.



"With the Leica core wall system, we are able to streamline our procedures and increase efficiency. This is a positive outcome for both our company and our clients."

ABOUT THE AUTHOR

Tom Trotter started land surveying in 1997 at the age of 16 and began using GPS in the early 2000s for rough layout and elevations for dirt work. “The rule of thumb was that anything we laid out was going to be plus or minus a tenth,” he says. “For anything that needed to be more accurate, we would use the total station or the robot.”

In 2010 Tom started doing layout for concrete companies, focusing on warehouses, commercial and residential buildings, refineries, and plant work along the Gulf Coast. He joined Baker Concrete Construction, Inc., in 2019, where he has worked mostly on high-rise buildings in Nashville, Tenn. He currently serves as the Line and Grade Manager for Baker Concrete Construction.

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ABOUT BAKER CONCRETE CONSTRUCTION, INC.

Baker Concrete Construction, Inc. is one of the nation's largest specialty contractors. Founded 1968 by three brothers in southwest Ohio, Baker Concrete has been engaged to build stadiums, high rises, steel plants, petro-chemical plants, nuclear facilities and Habitat for Humanity homes. Our greatest achievement is to be able to name numerous co-workers who have grown with Baker for 40+ years. Our dedication, loyalty and long-range focus on customer value have enabled us to succeed together. Family-owned and family-oriented "small company" feel looking for professionals who want to make a difference. Please go to www.bakerconcrete.com for more company information.

ABOUT HEXAGON AND LEICA GEOSYSTEMS

Hexagon is a global leader in sensors, software and autonomous solutions. We are putting data to work to boost efficiency, productivity, and quality across industrial, manufacturing, infrastructure, safety, and mobility applications. Our technologies are shaping urban and production ecosystems to become increasingly connected and autonomous – ensuring a scalable, sustainable future. Hexagon's Building Solutions empower companies to effortlessly utilize BIM to improve productivity and reduce costs across the entire life cycle of the building. Learn more.

Leica Geosystems, part of Hexagon, has been revolutionizing the world of measurement and survey for nearly 200 years. We provide powerful software, efficient workflows, and experienced support for a complete construction technology solution. Our products give you the tools needed to increase safety, facilitate quick documentation, save money, and substantially reduce the probability of errors. Together we provide maximum productivity and exceptional results, no matter how complex the task at hand. With precise and accurate instruments, sophisticated software, and trusted services, Leica Geosystems delivers value every day to those shaping the future of our world. Learn more.