

Real-Time GNSS Corrections: Productivity, Profitability, and Practical Considerations



Is It Time To Ditch The Base Station?

This article is part of the blog "Real-Time GNSS Corrections: Productivity, Profitability, and Practical Considerations". The blog discusses important considerations for your GNSS surveying workflows: When should you use a base station? Are you missing the opportunity to gain productivity by including correction services in your workflows? Can differential base-rover RTK benefit from correction services? Reading the full series will not only help you to answer these questions, it will enable you to calculate the cost-savings of a real-time GNSS correction subscription.



Is it time to ditch the base station?

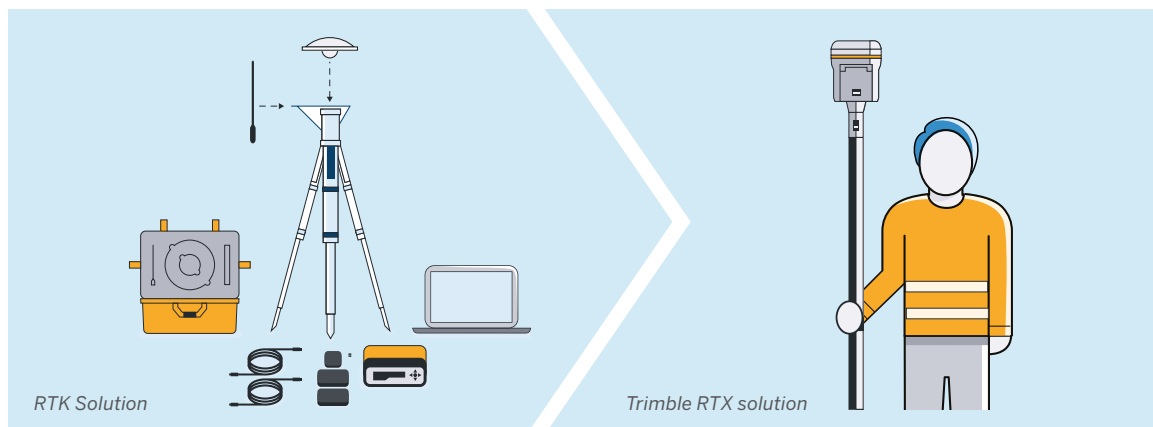
The Legacy

Current Trimble Services

The Case for a Base—or Not

5 MINUTE READ

The ubiquity of real-time networks and globally available GNSS correction services heralds a new era where traditional base-rover workflows may not be part of the surveyors daily work as they once were. There are many situation where differential real-time kinematics (RTK) using a base-rover pair of GNSS receivers may be the best—or only—choice. However, many surveyors have already realized, such instances are becoming fewer, and the alternatives can bring additional time and cost savings. There have been great advances in alternatives to base-rover workflows—networks and correction services—but also in high-precision GNSS technology overall. If you haven't already “gone baseless,” now might be the right time to visit the idea.



THE LEGACY

In the early days of GPS-only, high precision came with a premium on time. For instance, in the pre-real-time era, where postprocessing was the only option, workflows involved many steps—and a lot of waiting; waiting for enough satellites to be in view, waiting for hours of observations, waiting hours or days to do additional sets of long observations, waiting for hours while static data files trickled through a serial cable, waiting days for precise ephemeris availability for download, and waiting to be back in the office to process and adjust. Despite the time required, GPS was an improvement over legacy terrestrial surveying workflows. Then along came real-time differential (DGPS), and real-time kinematics (RTK) with on-the-fly (OTF) initialization giving surveyors and mappers many more options such as those discussed by Gavin Schrock in his article “GPS/GNSS Corrections: The Right One for Your Needs”¹.

1. GPS/GNSS Corrections: The Right One for Your Needs

The first commercial differential RTK base-rover system was released by Trimble in 1994². These RTK systems from the earliest days connected the base and rover via dedicated, and often built-in, radios. By the end of the 1990s, network RTK, like Trimble VRS Now™ was developed, and started spreading rapidly in the form of local, regional, statewide, and nationwide real-time networks (RTN) that provided real-time GNSS corrections. These RTNs have evolved to be referred to as a new form of “utility”³, and in many cases, to also serve as essential geodetic infrastructure.

CURRENT TRIMBLE SERVICES

Developments over the past 20 years have brought even greater availability of real-time correction services that provide adequate accuracy for nearly all surveying tasks including construction site surveying. This includes broad regional commercial RTN, such as Trimble VRS Now service, and global precise point positioning (PPP) correction services, such as Trimble CenterPoint® RTX correction service.

The Trimble VRS Now service delivers instant access to RTK level positioning services using a network of permanent, continuously operating reference stations covering large areas⁴ of North America, Europe, Australia, and New Zealand, and continues to grow with dense networks of reference stations. Precise point positioning (PPP) services, such as Trimble CenterPoint RTX real-time GNSS correction service, are global in scale and offer real-time, centimeter-level corrections almost anywhere on the planet—even in places such as the Australian outback, the American Great Plains, and remote areas of African Rwanda, where there may not be cellular data and internet access.

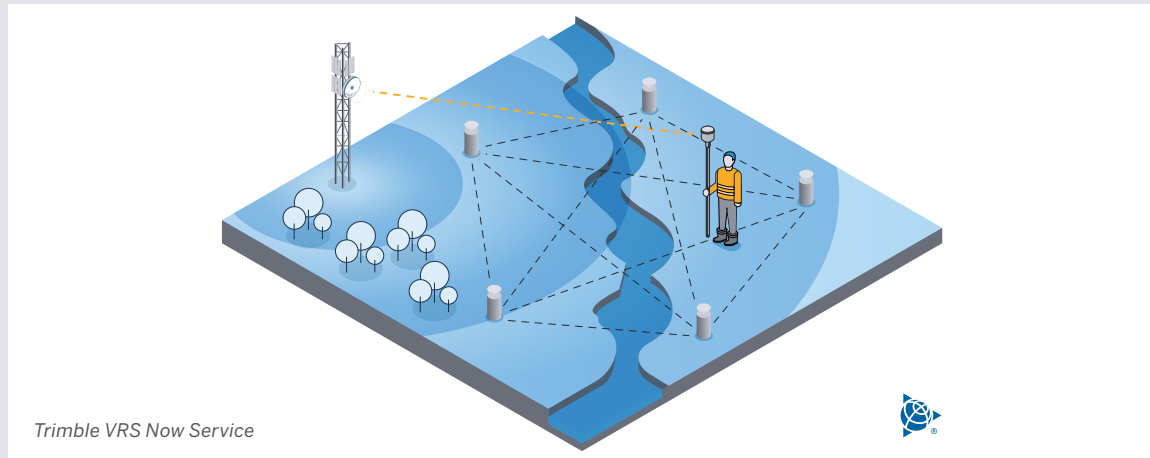
GNSS receivers that leverage correction services have delivered high precision and accuracy at a faster rate, simplified common workflows, and provided instant ties to geodetic reference frameworks. In many instances, surveyors and mappers can start working as soon as they get out of their truck. Correction services can mean less up-front investment as only a single rover is needed, or a base-rover pair can be repurposed as two rovers.

2. The Birthplace of VRS

3. https://archive.amerisurv.com/PDF/TheAmericanSurveyor_Schrock-BirthplaceOfVRS_Vol7No3.pdf

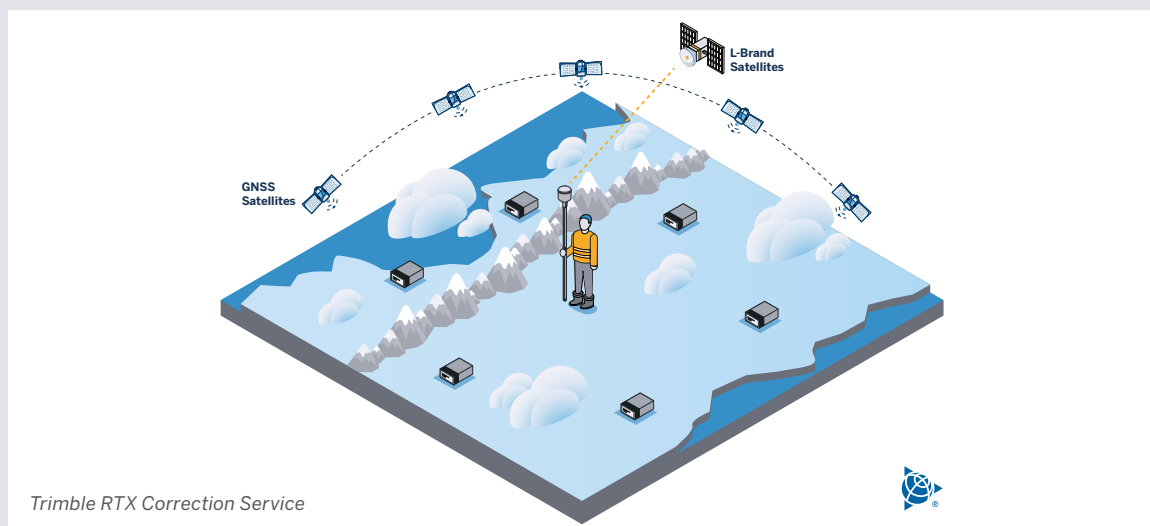
4. Coverage Maps for Trimble Positioning Services

A quick look at Trimble VRS Now and Trimble RTX correction services:



Accuracy: 2 cm (< 1 in) horizontal / 3 cm (< 1.5 in) vertical

- gives instant access to RTK positioning services using a network of permanent, continuously operating reference stations.
- has existed for over 20 years and provides a dependable network RTK correction for the rover receiver.
- Requires a two-way cellular data connection.



Accuracy: 2 cm (< 1 inch) horizontal / 5 cm (< 2 inch) vertical

- advanced PPP technology that provides real-time, centimeter-level positions.
- enables true mobility allowing the work without the constraints of a local base station or VRS network, with high-level accuracy delivered worldwide via satellite or Cellular/IP.
- provides a globally available RTK correction for the rover receiver.

THE CASE FOR A BASE—OR NOT

Let's look at reasons why some surveyors and mappers have been hesitant to go baseless and the Trimble solutions that need to be considered.

CONCERN	CONSIDERATION
<i>I have to set up a base because there is no cell service to use VRS.</i>	<i>Trimble RTX technology makes this point almost moot. A rover can receive corrections from any of the geostationary RTX L-Band satellites—no cell, no worries.</i>
<i>There is spotty cell service.</i>	<i>Losing RTK corrections due to spotty cellular service, and for that matter, spotty radio connections can be a source of frustration. With Trimble xFill® technology, powered by Trimble RTX technology, you can get seamless centimeter-level back-up positioning via satellite if RTK or VRS signals are interrupted. With xFill technology, the RTK and RTX engines are running at the same time, so if RTK/RTN corrections are lost briefly, xFill technology takes over without missing a beat.</i>
<i>I need to set up a base to collect long static to establish control.</i>	<i>Unless there are very stringent requirements for geodetic control, both VRS Now and Trimble RTX can yield survey-grade positions in minutes—measurements that might otherwise have taken many hours for static postprocessing. Subsequent blog posts “Bases, Correction Services, and Control”, and “Postprocessed or Real-Time?” explore this in more detail.</i>
<i>I need the high precision that base/rover provides.</i>	<i>While base-rover RTK can yield slightly higher precision than networks or PPP, this is very conditional: if the baseline length is very short, such as when your jobsite base is less than a kilometer away; if the base receiver and antenna are of equal or better quality than the rover; if the base is in clear sky and free of multipath hazards; and the big one: if the base does not get stolen or disturbed! Even under these conditions, the performance gap has narrowed with recent developments. These include the addition of more satellites and modernized signals, and a new wave of RTK engines, like Trimble ProPoint™ GNSS technology that has been implemented in many Trimble receivers such as the Trimble R12i, Trimble SPS985, and Trimble Catalyst™ DA2.</i>
<i>I need a base for specialized applications.</i>	<i>This applies to certain applications, like certain machine control applications, and for postprocessing drone PPK+IMU data (that works best with a “site base” <1 km from the area being flown). However, there is another option for postprocessing for drones that could eliminate the need for a “site base”: Virtual Rinx data available from many of the Real-Time Networks that are operated with Trimble Pivot™ platform.</i>

There are other elements of GNSS workflows to consider, including: time, equipment costs, the error budget, site control, geodetic references. In subsequent blogs we examine these elements and how the evolution of the technology and the aforementioned services warrant a reexamination of legacy workflows.

A few additional notes to consider: Trimble VRS Now and Trimble RTX services are staffed 24 hours a day, 7 days a week to monitor network performance. Trimble correction services have an uptime rating of 99.99 percent, which is probably an improvement for most work crews, unless they have never forgotten to charge a battery or turn the radio on before driving off (never!). And finally, the number one blunder in GNSS workflows that has remained a constant since the start: the height of the receiver/antenna, especially the base. When receiving a correction, reference station heights have been rigorously measured and remain unchanged. Out in the field, sometimes the measure-ups are miscommunicated or done inconsistently: “Do I measure to the ARP, or bumper? Where is the measure up mark on this one? Where is the note in the field book? Where is the field book?”...

It's sometimes tough to reach the accuracy level of a differential base-rover RTK solution over a short baseline or with great changes in height and therefore potentially great changes in atmospheric conditions. Your base-rover will likely be a dependable tool in your toolbox for years to come, but don't depend on one tool for every job where the potential for cost-savings is evident.

In the next blog post, "The Value Proposition of Going Baseless", we take a closer look at some typical workflows.

Check out the Trimble VRS Now and Trimble RTX **coverage maps**.

Sign up **here** for your Trimble RTX 30-day trial using the promo Code: **FREE30**

THIS ENTRY IS **PART 1 OF 5** IN THE SERIES:

PART 1 : Is it time to ditch the base station?

PART 2 : The value proposition of going baseless

PART 3 : Bases, corrections services, and control

PART 4 : Conventional, postprocessed or real-time?

PART 5 : Site calibrations, bases, and correction services



The Value Proposition Of Going Baseless

This article is part of the blog "Real-Time GNSS Corrections: Productivity, Profitability, and Practical Considerations". The blog discusses important considerations for your GNSS surveying workflows: When should you use a base station? Are you missing the opportunity to gain productivity by including correction services in your workflows? Can differential base-rover RTK benefit from correction services? Reading the full series will not only help you to answer these questions, it will enable you to calculate the cost-savings of a real-time GNSS correction subscription.



The value proposition of going baseless

How much time could you save by using a real-time GNSS correction service as part of your regular survey workflow?

Site Coordination

Base and Rover Setup

Setting Up An External Radio

Breaking It Down

Putting It All Together

5 MINUTE READ

So you're considering taking the leap, and leaving the base in the truck—or even back at the office—in favor of using a real-time correction service? This blog explores how much time and money you can expect to save leaving that base behind. We will review some common workflows and examine how a correction service might work as a replacement for your base, or as a workflow augmentation that could save you time and money. To help you evaluate such options, we've included some tables with example calculations of savings and invite you to use your own values to easily determine return on investment.

Switching to a real-time GNSS correction service will deliver varying ROI depending on the type of work, the project-specific challenges regarding establishing control, and the logistics of setting up a base. For many applications where you set-up one base per day, you could save up to an hour or more daily, as one surveying and engineering firm noted in a case study about pipeline construction staking¹.

SITE COORDINATION

If you're not using a real-time GNSS correction service, you will likely be setting up a GNSS receiver as a base station for traditional base-rover differential real-time kinematic (RTK) surveying, whether measuring points or staking points.

Prior to setting up, you've probably determined which positioning/control approach you will be taking for your specific project:

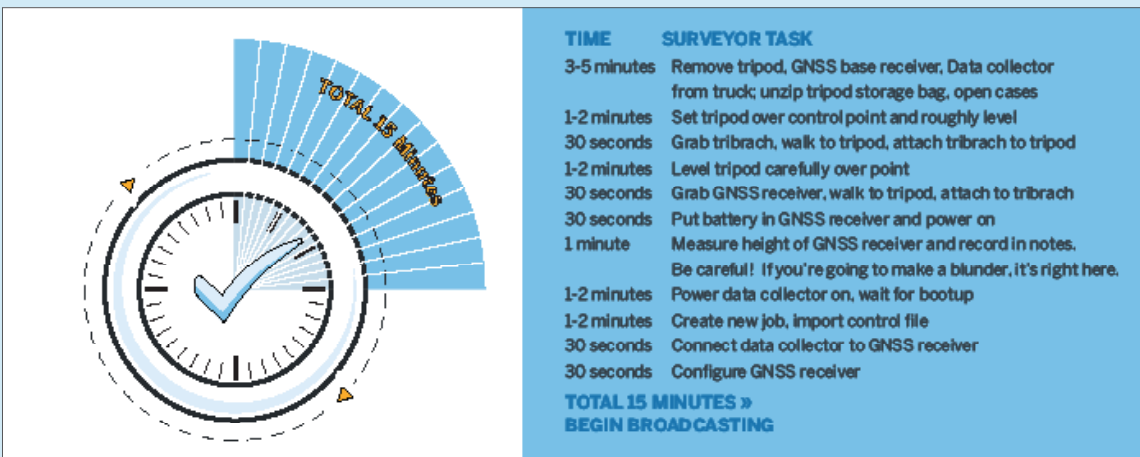
- **Known coordinates** when setting up over an established control mark with published coordinates on a stated geodetic datum. For instance, in the U.S. this might be a National Geodetic Survey (NGS) monument, state or local monument, or setting up over a job site control point that was provided.
- **Unknown coordinates** when you require establishing a control point. Establishing coordinates through long, static observations and postprocessing later with office software like Trimble Business Center, or with online postprocessing services like the NGS Online Positioning User Service (OPUS) in the U.S., Trimble RTX Postprocessing, or other PPP services. Many real-time networks also offer online postprocessing services. Establishing base coordinates using a real-time correction service is also an option.

1. How precise point positioning became a survey crew favorite

- **Unknown coordinates where performing a site calibration is necessary.** Setting up a base somewhere safe where it will not be stolen or disturbed, and then measuring existing control points on the project site for orientation.

Different control approaches require different amounts of time to execute, which we'll examine later in a subsequent blog post: *Bases, Correction Services, and Control*², however no matter which method you use to establish the position of your base, you will have to set it up first, so let's explore what time that requires.

BASE AND ROVER SETUP



Generally these steps would apply to all GNSS receivers that are able to be used as a base station if they have an internal UHF or Spread Spectrum / 900MHz radio. These radios are typically broadcasting at around 1 to 3 watts, which is usually capable of pushing the signal ~1.5 to 3 km (1 to 2 miles), depending on topography, interference from competing signals and obstructions such as trees and buildings.

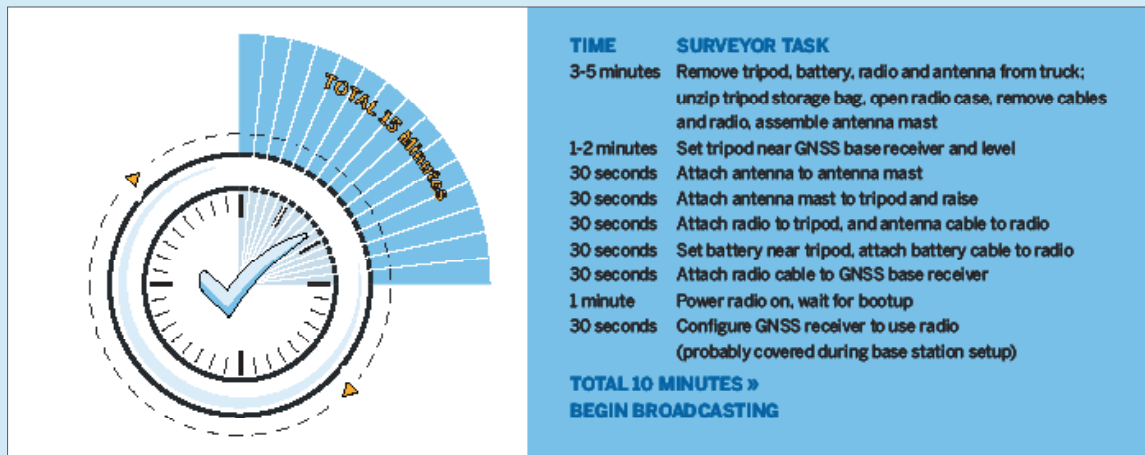
If the site or survey area extends beyond this range, an external radio can be added to increase broadcasting power. For example, in the U.S., these radios tend to be around 35 watts, and while subject to licensing restrictions, are capable of broadcasting ~15 to 30 km (10 to 20 miles). External radios are of subject to the same limitations of topography, interference, and obstructions. Be sure to license your radio to avoid fines levied against pirate broadcasters.

Additionally, you'll need to calculate the probable error at the extents of job site:

- for horizontal error, $8 \text{ mm} + 1 \text{ ppm}$ would result in an error of $8 \text{ mm} + 30 \text{ mm}$ if you were 30 km away from your base (38 mm, or roughly 1 in. or 0.12 ft)
- for vertical error, $15 \text{ mm} + 1 \text{ ppm}$ would result in a vertical error of $15 \text{ mm} + 30 \text{ mm}$ at the same distance (45 mm, or roughly 1 in. or 0.15 ft).

However, as you increase the distance between your base and rover, using network RTK solutions like Trimble VRS Now will generally perform better over similar baseline lengths. After all, this was one of the reasons why network RTK was developed—to overcome the degradation-over-distance of single-base RTK.

SETTING UP AN EXTERNAL RADIO



After you load the empty cases and bags back into your truck, you're 20 to 30 minutes into your day, but you're not ready to be productive just yet. After setting up a GNSS receiver as a base, you will need to set up a second GNSS receiver as a rover, verify that you're receiving the radio correction signal, and perform some checks to make sure that you're working accurately.

If you were using a real-time correction such as the Trimble VRS Now or CenterPoint RTX service, you would already have your rover set up and you would have verified that you are working accurately.

BREAKING IT DOWN

At the end of the day, you'll need to break down your base station and pack it up to go home. Packing up might include stopping the logging of GNSS data, transferring the file to external storage or to the cloud, drying the gear off after a rainy day, or cleaning it off if you're on a muddy or dusty job site. You'll certainly want to coil up cables so that they don't look like tangled Christmas lights when you take them out tomorrow. You'll pull batteries so that you can get them on charge overnight. And you'll close up tripods, disassemble antenna masts, latch the cases, zip the bags, and finally build a protective fortress around your base station control point with indestructible lath and flagging so that you can leave the site knowing that nothing can possibly disturb that point.



PUTTING IT ALL TOGETHER

This table adds a current typical hourly rate to the set-up and tear down times we discussed above, the annualized savings from “ditching the base station” offsets the cost of a real-time correction service.

EXAMPLE CALCULATION					
TASK	TIME	DAYS PER WEEK	HOURLY RATE*	CREW MEMBERS	YEARLY COST
Set up Base	15	5	\$115	2	\$14,950.00
Tear down Base	15	5	\$115	2	\$14,950.00
Set up Radio	10	5	\$115	2	\$9,966.67
Tear down Radio	10	5	\$115	2	\$9,966.67
Postprocess Data	30	1	\$115	1	\$2,990.00
				TOTAL	\$52,823.33

*USD Based on a recent published rate for an "Operating Engineer Heavy/Highway Party Chief" prevailing wage + supplemental for New York State

TRY FILLING IN YOUR OWN VALUES					
TASK	TIME	DAYS PER WEEK	HOURLY RATE	CREW MEMBERS	YEARLY COST
Set up Base					
Tear down Base					
Set up Radio					
Tear down Radio					
Postprocess Data					
				TOTAL	

or use this [Online Calculator](https://tnzmarcom.com/dev/baseless/v4.htm) for your own calculation: tnzmarcom.com/dev/baseless/v4.htm

Completing the table above with your business numbers shows how the time-cost of using a base station adds up over the course of a year.

There are situations where differential RTK using a base and rover make the most sense; however, treating it as the only solution can add up. Additionally, if you're paying someone to guard your base from theft or disturbance, obviously the cost will increase. You may also want to consider travel time to/from the base station, or to a checkpoint, or to conduct base station location reconnaissance. There is also the cost of your broadcasting license (where applicable) if you use external radios. Pirate broadcasting without a license can lead to fines, and those can be calculated back to the start of the project.

Finally, consider the opportunity cost of spending time where you could be saving it. How many points could

you have staked while you were setting up your base station? What other work could the crew member you left to guard the base be doing? How many measurements could you have taken for your as-built survey instead of driving over to your check point? How many other construction site workers and activities were on hold, waiting for you to get set up, so that you could stake their points?

Check out the [Trimble VRS Now and Trimble RTX coverage maps](#).

Sign up [here](#) for your Trimble RTX 30-day trial using the promo Code: **FREE30**

In the next blog post, **Bases, Correction Services, and Control**, we examine another element of the value proposition for going baseless.

THIS ENTRY IS **PART 2 OF 5** IN THE SERIES:

PART 1 : Is it time to ditch the base station?

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PART 3 : Bases, corrections services, and control

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Bases, Correction Services, and Control

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Bases, correction services, and control

With new options for establishing high confidence survey control, the balancing act between “budget” and “error budget” is less of a struggle.

[RTK Base Set Up on a Known Point](#)

[RTK Base Set Up on an Unknown Point](#)

[Online Postprocessing Services to Establish Base Coordinates](#)

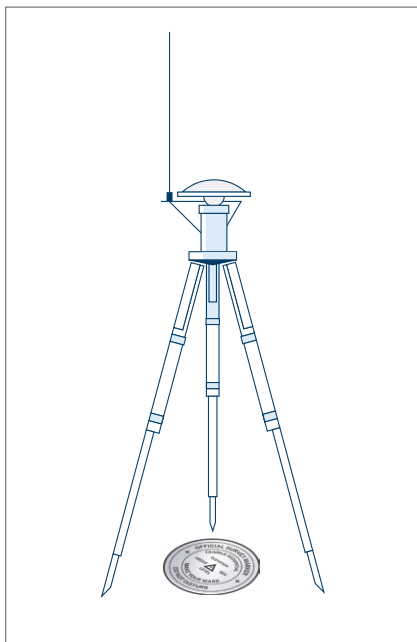
[Using Real-Time Services to Establish Base Coordinates](#)

[Considering Error Budgets](#)

5 MINUTE READ

In a previous blog in this series *The Value Proposition of Going Baseless*¹ we covered the types of control that are likely to be used for setting up bases on your job sites. Each type of control could have one or more workflows, and each workflow would present differing value propositions. Real-time methods not only offer alternatives to costly and time-consuming legacy methods, they meet the precision and accuracy requirements of nearly all field applications.

In this blog we examine common control scenarios and methods for establishing base coordinates, and the considerations for using real-time satellite delivered GNSS corrections.



RTK BASE SET UP ON A KNOWN POINT

This is a common scenario for land surveyors and construction surveyors. Often these pre-established control points have been established by land surveyors through one or more of the following methods.

STATIC GNSS

Static GNSS is often used for “campaign” style surveying, where multiple GNSS receivers collect observations on multiple points simultaneously, with one or more on known points and one or more on control points to be established. These observations are later post-processed together; the baselines are processed and analyzed, and adjustments performed. This is the legacy geodetic method, and it is still the gold standard to achieve high precision GNSS accuracy, but it is a time consuming and costly GNSS surveying method.

CLOSED TRAVERSES AND/OR LEVEL RUNS USING OPTICAL SURVEYING INSTRUMENTS

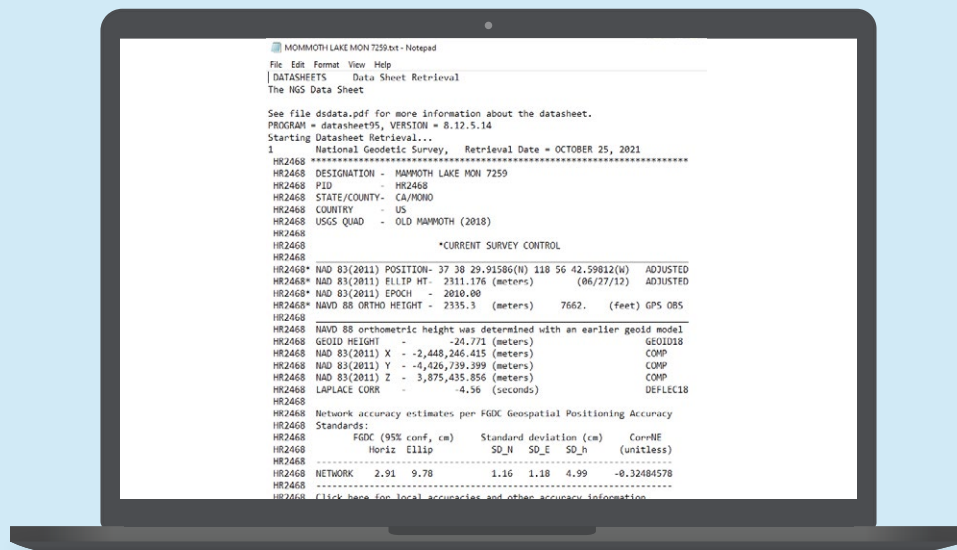
When using closed traverse and/or level runs with optical surveying instruments, measurements begin from one or more known control points, looping through the job site and new control points are established—the measurement loop either ends on other known control points, or on the known points where you started. These methods provide high quality and confidence but can also be very time, labor and equipment intensive..

PUBLISHED CONTROL

A project may require a tie to previously published control, including control established by your clients and other surveyors they have hired, or by either local, state or federal authorities. In essence, using a published value of coordinates is like a site calibration. Using this method can mean there are no other steps involved in setting up your base besides inputting the published coordinates. This can fulfill the requirements of the job, but there may be many factors that have rendered the published values obsolete, such as tectonic plate velocity and subsidence.

Pre-established, known control points are assumed to be accurately measured, and the resulting coordinates are stored in a job file so that they can be assigned to the GNSS receiver you are using as a base. Correct metadata is crucial: units of measure, precision, data format such as NEZD, Cartesian, Lat/Long, reference framework (datum), projection—and don't forget the date and time: surveying, especially if GNSS is used, has the 4th "D" of time dependency. For example, if you're setting up your GNSS receiver as a base over an NGS monument, you would input the values from the NGS data sheet.

Whichever option you choose, you will need to input the known control point coordinates into your base station. This is the fastest method of establishing the location of the base station, as it will only take a few minutes to input the coordinate values or import the control file with control point coordinates to your job file.

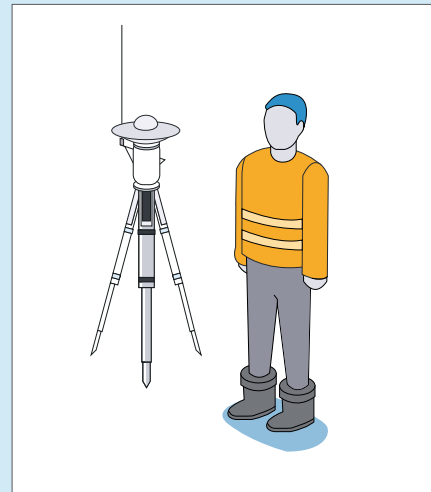


RTK BASE SET UP ON AN UNKNOWN POINT

Another common scenario for setting up a base when coordinates have not been pre-established is on an unknown point. In this case, you need to establish coordinates, which can be accomplished several ways:

STATIC GNSS

Static GNSS is a typical scenario for land surveyors who need to use a national, local, or global datum for their job sites. In this instance, data from the GNSS receiver that was set up as a base station over the unknown control point is logged, and later downloaded to a computer for processing. You can download RINEX files for post-processing. RINEX enables surveyors to use shorter observation times to establish base coordinates. Setting a GNSS receiver up for logging will add a small amount of time to the initial setup, perhaps a minute or two to set the parameters such as logging rate, data format, storage file and type/path. Additional time will also be added to the end of the day when the logging is turned off and the file is transferred from the receiver to external storage such as a USB drive or the computer where the file will be further analyzed.



CLOSED TRAVERSES AND/OR LEVEL RUNS

As in the example above.

TEMPORARY COORDINATES

Input when you set up the base, while also logging static data to postprocess. You can later post-process this static data and apply as updated base coordinates in your field controller, or office software.

USING PPP-BASED ONLINE POSTPROCESSING SERVICES

Discussed below.

USING RTN-BASED ONLINE POST-PROCESSING SERVICES

Many RTN, like those that use Trimble Pivot RTN software and have this enabled, offer online postprocessing. The spacing of the RTN stations is closer than, for instance, the Online Positioning User Service (OPUS), and offers multi-constellation processing.

USING REAL-TIME SERVICES

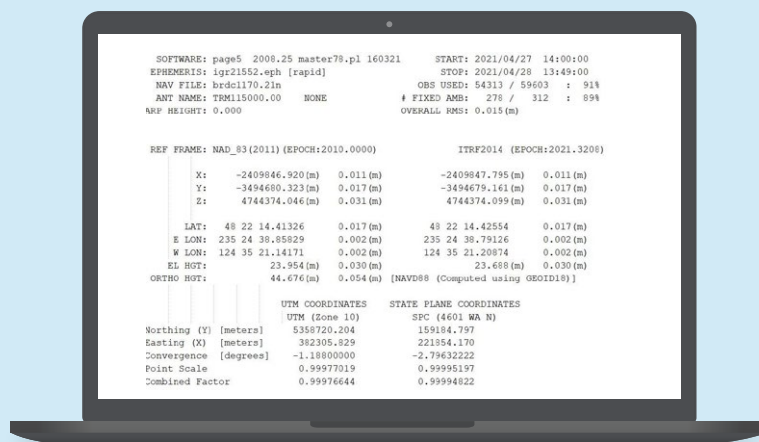
Discussed below.

ONLINE POSTPROCESSING SERVICES TO ESTABLISH BASE COORDINATES

Once static data has been downloaded, it can be sent for online postprocessing. Examples of post-processing services include:

US Based: OPUS¹ provided by NGS: geodesy.noaa.gov/OPUS/, which only provides GPS constellation corrections or the Trimble CenterPoint RTX post-processing service www.trimblertx.com, that provides corrections based on observing all GNSS constellations

Globally: AUSPOS and CSRS-PPP. Like RTX, these are precise point positioning based (PPP), but there may be additional steps to transform to your desired reference framework. RTX will perform many common transformations for you.



SOFTWARE: page5 2008.25 master78.pl 160321				START: 2021/04/27 14:00:00			
EPOCH: 2021/04/28 13:49:00				STOP: 2021/04/28 13:49:00			
NAV FILE: brdc1170.2in				OBS USED: 54313 / 59603 : 91%			
ANT NAME: TRM115000.00 NONE				# FIXED ANTS: 276 / 312 : 89%			
ANT HEIGHT: 0.000				OVERALL RMS: 0.015 (m)			
REF FRAME: NAD_83 (2011) (EPOCH: 2010.0000)				ITRF2014 (EPOCH: 2021.3206)			
X:	-2409646.920 (m)	0.011 (m)		-2409647.795 (m)	0.011 (m)		
Y:	-3494680.323 (m)	0.017 (m)		-3494679.161 (m)	0.017 (m)		
Z:	4744374.046 (m)	0.031 (m)		4744374.059 (m)	0.031 (m)		
LAT:	48 22 14.41326	0.017 (m)		48 22 14.42554	0.017 (m)		
E LON:	235 24 38.85829	0.002 (m)		235 24 38.79126	0.002 (m)		
W LON:	124 35 21.14171	0.002 (m)		124 35 21.20874	0.002 (m)		
EL HT:	23.954 (m)	0.030 (m)		23.688 (m)	0.030 (m)		
ORTHO HT:	44.676 (m)	0.054 (m)		(NAVD88 (Computed using GEOID18))			
UTM COORDINATES				STATE PLANE COORDINATES			
UTM (Zone 10)				SPC (4601 WA N)			
Northing (Y) [meters]	5358720.204			159184.797			
Easting (X) [meters]	382305.829			221354.170			
Convergence [degrees]	-1.18800000			-2.79632222			
Point Scale	0.99977019			0.99995197			
Combined Factor	0.99976644			0.99994822			

A sample report from the NGS online user processing service (OPUS). Note that you should choose the extended report and look at the peak-to-peak accuracy values. You may find that real-time services can match these values with far less time expended.

A multi-constellation GNSS postprocessing service such as CenterPoint RTX service delivers shorter observation times and enables you to work in limited-sky environments.

The time spent using services such as OPUS depends on how long it takes to upload your file—typically a minute or two depending on the size of the file. Once the data has been uploaded, it will be processed, and you will receive an email with the results. In its entirety, the addition of postprocessing an unknown point for use as control for your job site may add up to 30 minutes to your workflow. You can continue working and measuring on your job site while your GNSS receiver you set as a base station logs data, and then reprocess your job file once your final coordinates are known—an option that is better than an extra trip to the job site just to set control.

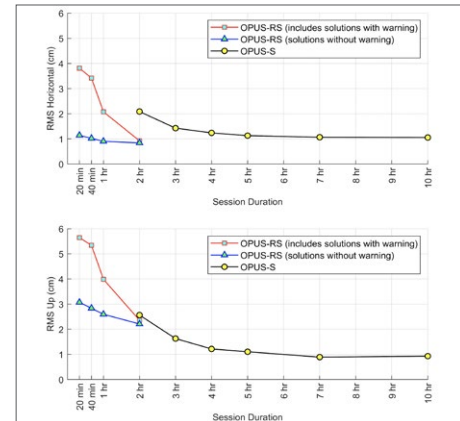
¹: OPUS only processes observations from the GPS constellation so it may require longer observation times, and may not work well in limited-sky environments.

USING REAL-TIME SERVICES TO ESTABLISH BASE COORDINATES

To save time you can use a Trimble correction service to establish a control point coordinate for the GNSS base receiver. This takes less than a minute to connect to the Trimble VRS Now network, obtain a fixed solution, and store a point at 2 cm accuracy (roughly $\frac{3}{4}$ " or 0.066').

Alternatively, you could use CenterPoint RTX real-time correction service, and in under a minute you could converge to a position of 2 cm horizontal and 5 cm vertical and store the point. The National Geodetic Survey (NGS) recommends at least an hour of logged data to reach the same threshold (see figure²).

An advantage of using a PPP-based service over an RTN service is that cellular connection is not required because CenterPoint RTX service provides the correctors via L-Band satellites. Real-time methods are a substantial time saver when compared to legacy postprocessing or optical methods. Surveyors have developed best practices for using real-time methods to establish control. Some guidelines are published by various entities, like state departments of transportation, or developed by individual surveys/firms based on their own testing.



Source: NGS Data

CONSIDERING ERROR BUDGETS

Real-time methods for establishing control have evolved and improved to the point where they can often, but not always, meet the precision and accuracy of legacy static and post-processed methods. You may be strictly required to use legacy methods, however there are many entities that have adopted real-time methods, provided steps are followed that can provide high confidence in results.

These steps may include, for example, multiple 2- or 3-minute real-time sessions, re-initializing, or converging, with time separations between observation sessions to take advantage of the change in satellite constellation geometry. A typical workflow may include multiple observation sessions at the beginning of a work day, and several more at the end as a check.

Using real-time services to establish your base position represents a three-decade leap forward in meeting the twin goals of efficiency and precision. The precision gap between legacy methods and real-time has closed to a point where you no longer face stark trade-offs between the two.

In the next blog, we'll take a closer look at evaluating when to use real-time or postprocessing.

THIS ENTRY IS PART 3 OF 5 IN THE SERIES:

BLOG 1 : Is it time to ditch the base station?

BLOG 2 : The value proposition of going baseless.

BLOG 3 : Bases, corrections services, and control.

BLOG 4 : Conventional, postprocessed or real-time?

BLOG 5 : Site calibrations, bases, and correction services.



Conventional, Post-processed, or Real-Time?

This article is part of the blog "Real-Time GNSS Corrections: Productivity, Profitability, and Practical Considerations". The blog discusses important considerations for your GNSS surveying workflows: When should you use a base station? Are you missing the opportunity to gain productivity by including correction services in your workflows? Can differential base-rover RTK benefit from correction services? Reading the full series will not only help you to answer these questions, it will enable you to calculate the cost-savings of a real-time GNSS correction subscription.



Conventional, post-processed, or real-time?

Selecting the best workflow for site and base coordination based on error budget.

The Known Factor

The Error Budget

The Technologies

Mixed Methods

5 MINUTE READ

THE KNOWN FACTOR

Tools for surveyors have evolved significantly in the last decade, and while working with well-known familiar tools is often preferred, new techniques can provide significant time and cost savings while also meeting precision and accuracy requirements for many applications.

One of the main considerations in determining whether a conventional optical, post-processing or real-time workflow is best for a project is the level of confidence required for the accuracy of measurements. This alone could sway a surveyor from adopting a different technology—due to lack of confidence in the measurements or how to use the technologies to improve efficiency and increase accuracy.

THE ERROR BUDGET

Each project has an error budget that provides insight into the right tool for the job. The level of accuracy required will vary, determining the thresholds and specifications for how rigorously to measure and adjust. For example, the error budget for surveying a property in a dense, urban setting may be much smaller than the error budget for a large farm property due to the required specifications for the survey or, when working on a project to establish first order control, there are specific accuracy requirements that must be met by the surveyor. Some projects may require producing control reports, standards on errors of closure, and confidence of position. But applying these standards to every survey results in more effort than necessary, extra costs, and wasted time.

The following are some examples of desired accuracy, and methods used to achieve these:

A control project that requires vertical accuracy for control of $<1 \text{ cm } 2\sigma$ (95% confidence). You may have no other choice than to perform a closed loop with a digital level. For $<2 \text{ cm } 2\sigma$ you could have more options, and adjusted traverse with your total station, trig leveling, or rigorously constrained long static GNSS, post-processed.

For horizontal accuracy of $<1 \text{ cm horizontal}$, a closed traverse is standard, but you may be able to meet this requirement with rigorously constrained and execute long static GNSS, post-processed.

Pre-design topographic surveys and construction projects are examples of where a slightly lower standard of accuracy may be acceptable. For example, when installing a parking lot and lighting, being half an inch off in the wiring is not going to result in a major difference. Whereas half an inch off vertically for a mile of pavement on a roadway project would be extraordinarily expensive because of additional material and labor costs that would be involved to lay more pavement.

If a specific construction element requires $<1\text{ cm } 2\sigma$, you may be limited to **conventional methods** with total stations and digital levels.

At $<2\text{ cm } 2\sigma$, the options grow. You could easily achieve this with static post-processed, but that is impractical for the collection of the many points needed for a **topographic survey or construction stakeout**. For topographic and most construction tasks, conventional and RTK have become the go-to, provided you set up your instruments or RTK on rigorously established control. Local real-time networks (RTN) or correction services like Trimble VRS Now, or Precise point positioning (PPP) correction services like Trimble CenterPoint RTX can easily meet these requirements in many situations.

There may be accuracy requirements expressed as 3D values (e.g., $<3\text{ cm } 3\text{D } 2\sigma$) or separate values for horizontal and vertical (e.g., $2\text{ cm H}, 4\text{ cm V}$). While dependent on specifics of the site, environment, and other conditions, if properly executed, conventional, post-processed, and real-time can all deliver $3\text{ cm } 3\text{D}$ with high confidence. Many surveyors triage their options by looking at the most time and cost efficient method, determining if it will meet the requirements (which often involves testing at the site), and if it does not, they move on to the next option.

To recap, based on the error budget, the level of accuracy needed, required setups and reporting will determine the right workflow for the job. With the right workflow, efficiency and profitability are maximized.

THE TECHNOLOGIES

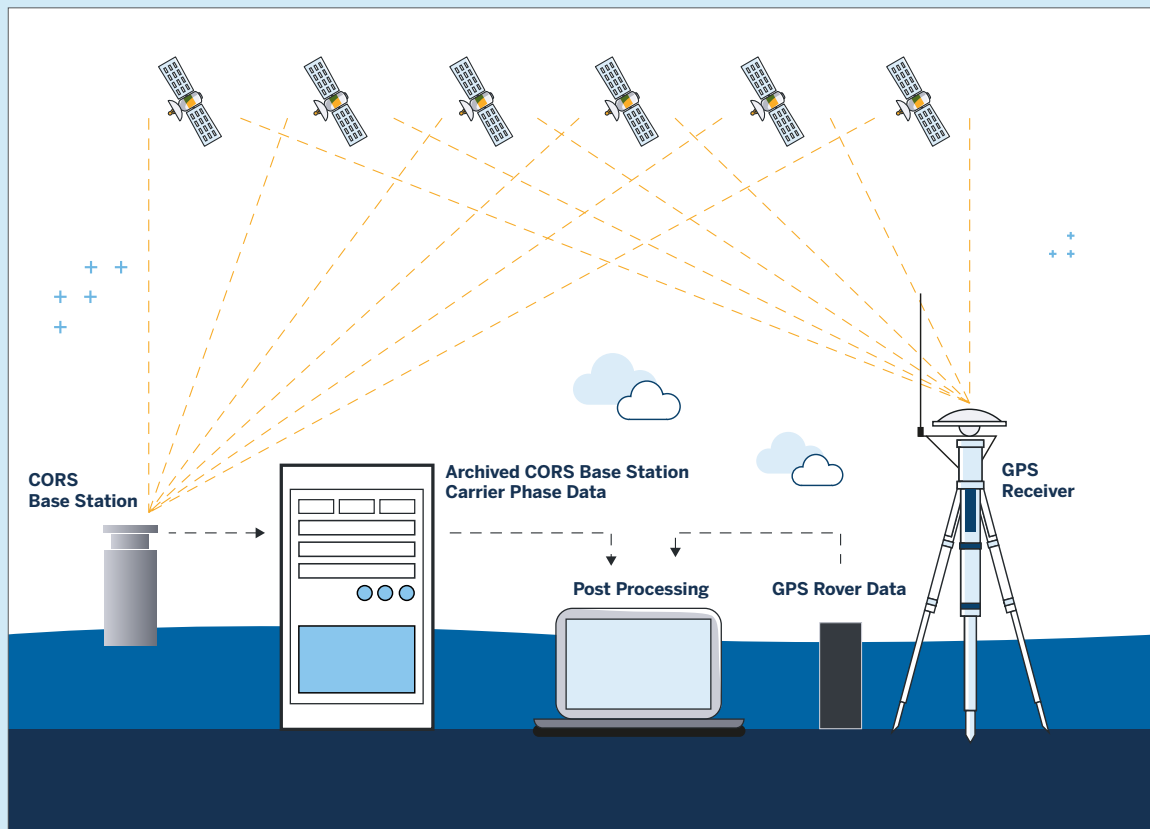
Surveyors have more options today than ever before when selecting hardware, software, and correction services for their jobs. One decision that needs to be made is to take either a post-processed or real-time approach, and the selection that is right for the job should be determined by the error budget and requirements of the job.

POST-PROCESSING

Post-processing data is a well-established method with equipment and services that are tried and true. Measurement accuracy can be proven, meeting the confidence required for static control, design, and topographic and boundary surveys. Benefits of post-processing include:

- It is not susceptible to the communication link drops of real-time options
- Validated positions and adjusted field data, constrained to a geodetic datum
- Correlation of biases
- Inclusion of survey control monuments, when required
- The ability to analyze and remove noisy data from observation sets
- Repairing cycle slips and fixing integer ambiguities
- Least-squares (single baseline) and constrained least-squares (network) adjustments

Post-processing typically comes with increased costs on hardware, software, skill, and labor. By properly setting up and maintaining control points and spending extensive time in the field and the office, this approach provides both proof of confidence in the results and that you have met the error budget.



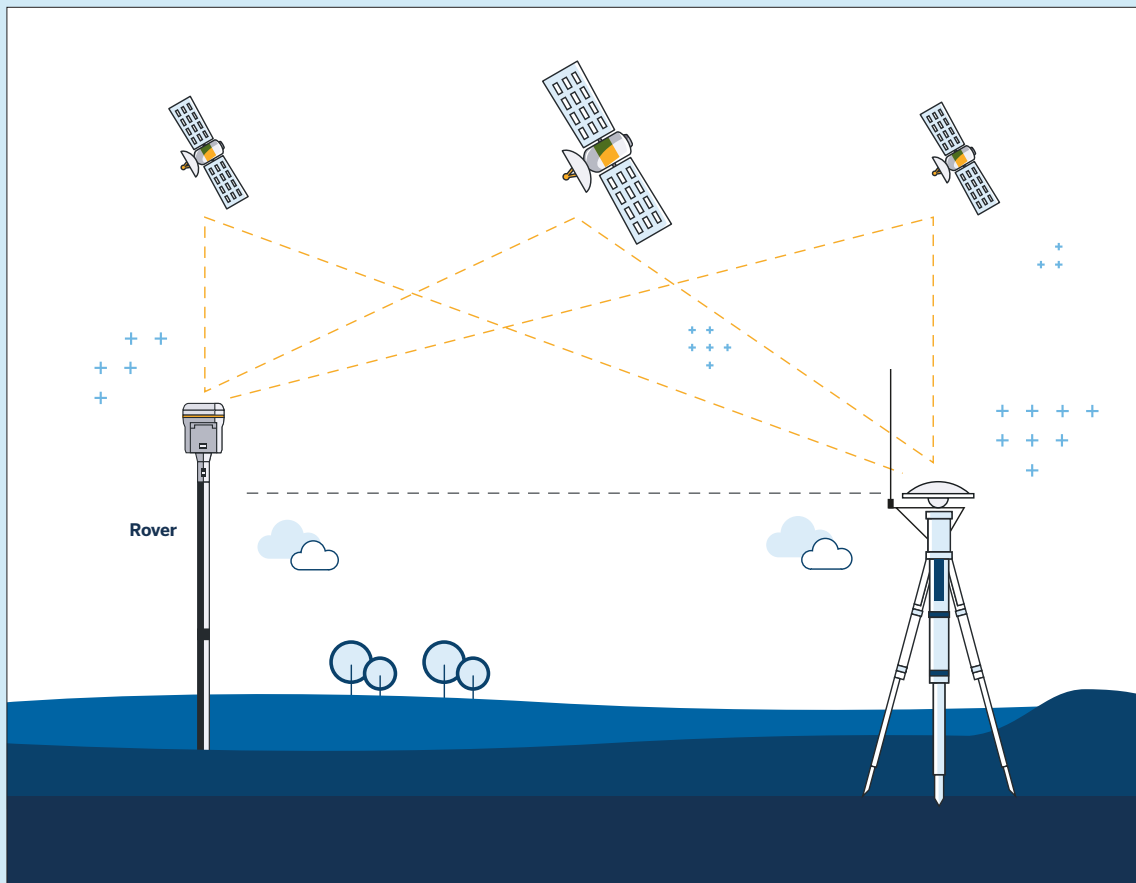
As we examined in the previous blog *[Bases, Correction Services, and Control](#)*¹, online post-processing services provide methods to establish control for setting up a base, new project control, or evaluating the quality of previously established control.

Services provided by federal agencies, like the U.S. National Geodetic Survey (NGS) Online User Positioning Service (OPUS), provide standard reports with quality and accuracy details. There is standard OPUS for observations >2 and <48 hours, and an OPUS-RS for observations >20 and <120 minutes; the user determines which suits their error budget. Many surveyors view services like OPUS as the authoritative answer but fail to look at details like the peak-to-peak values in the extended reports for the few instances where it might not meet your error budget. Still, you must do the same long observations as you would if you did your own post-processing, but there are alternatives.

Commercial services like Trimble CenterPoint RTX Online Post-processing can often deliver the same precision as federal services, but with dramatically shorter observation session times. This is possible due to several factors: improved PPP clock and orbit data and multi-constellation support. Taking this a step further, many regional real-time networks (RTN's), like those using Trimble Pivot software, offer online postprocessing. These leverage improved clock and orbit data to the same kind of baseline processing you would do with your own office software, but the task of processing is greatly automated. The PPP and RTN services provide standard reports with quality and precision data.

REAL-TIME CORRECTIONS

Real-time data was developed as a workflow over the past few decades, as this primer on GNSS correction types examines. For many surveyors, the standard real-time approach has been differential kinematic using a base station and rover(s) with radios. More recently, correction services from Real-time Networks (RTNs) and Precise Point Positioning (PPP), using real-time corrections via satellite or internet data link, have grown in popularity. There remains a high degree of confidence in measurements using real-time corrections, and results are achieved more efficiently than traditional methods, and, when compared to base-rover RTK, eliminate several factors including:



- Need for a base station, receiver, antenna, and radio
- Time spent setting up and breaking down a base station
- Errors in base station setup
- Time spent checking control points to verify base station setup
- Scouting a site and guarding a base station from theft or disturbance
- Radio broadcast license
- Risk of broadcasting UHF signals across international borders
- RTN corrections are not as susceptible to the degradation of solution over distance that long-baseline RTK experiences. Base-rover RTK can yield varied results if you mix baselines of different lengths.

- RTN can be better at modeling changing space weather (ionospheric) and tropospheric conditions over wide areas.
- Satellite-delivered PPP correctors, can go one-better than RTN, eliminating the needed cellular connections.

There are both **survey field** and **survey office** software platforms, like Trimble Access and Trimble Business Center that seamlessly work together to offer the flexibility of choosing post-processing or real-time data depending on the job. For example, office software can automatically download data from a continuously operating reference station (CORS) and perform the calculations required to confirm measurements—analyze and edit observations, process baselines, and perform adjustments.

A real-time workflow either using a CORS network or a satellite delivered service is ideal for projects where error budgets need to be met—which has increasingly become the case—affording the ability to save significant time and costs.

MIXED METHODS

The powerful field and office software platforms also enable the import of vector data from real-time GNSS receivers and vectors from total station surveys, combining these in post-processed network adjustments.

A recent example of the rise in confidence in real-time GNSS correction methods is the development of a standard GNSS vector format (GVX) by the NGS. GVX can be used for submission to the NGS OPUS Projects Beta application for incorporation in Bluebook and GPS-on-Benchmarks processes. The NGS will accept vectors from RTK and RTN surveys from sessions as short as 3 minutes (two 3-minute sessions minimum, separated by at least three hours). This is a huge leap forward from the legacy standard method of observation sessions of 4 hours or more.

Several factors have contributed to this change. One is the proven high quality of RTK/RTN results, and that RTN bases are typically rigorously constrained to fiduciary active control networks (e.g., the nationwide NOAA CORS Network in the U.S. and similar networks in other countries). The reduced observation times are also made possible through the multi-constellation capabilities of RTN and modern base-rover systems. GVX has been incorporated as a standard output in Trimble Business Center and some other office software; the adoption of GVX and formats for other similar modernization initiatives.

Whether manually processing or using an office software to automatically process, time and expense required should be weighed against the error budget.

THE BEST OPTION FOR THE SURVEY

Unless there are specific legal or contractual requirements precluding the use of either post-processed or real-time GNSS correction approaches, both can provide the data required by the survey, assuming they meet the error budget.

We should also not overlook the safety advantages for the surveyor, crews, others on the site, including members of the public. The less time you need to spend doing observations in hazardous environments the better.

After reviewing the factors present in a survey project—communication options, site accessibility, accuracy requirements, crew skills, and tools available—it should become clear whether a postprocessing or real-time workflow is the right option. With advances in both real-time GNSS correction services and hardware, it's important for surveyors to know what's-what in order to make an informed choice. It is worth the effort to consider all options knowing the benefits afforded by each, for the surveyor, and their customer.



THIS ENTRY IS **PART 4 OF 5** IN THE SERIES:

- PART 1 :** Is it time to ditch the base station?
- PART 2 :** The value proposition of going baseless
- PART 3 :** Bases, corrections services, and control
- PART 4 :** Conventional, postprocessed or real-time?
- PART 5 :** Site calibrations, bases, and correction services



Site Calibrations, Bases, and Correction Services

This article is part of the blog "Real-Time GNSS Corrections: Productivity, Profitability, and Practical Considerations". The blog discusses important considerations for your GNSS surveying workflows: When should you use a base station? Are you missing the opportunity to gain productivity by including correction services in your workflows? Can differential base-rover RTK benefit from correction services? Reading the full series will not only help you to answer these questions, it will enable you to calculate the cost-savings of a real-time GNSS correction subscription.



Site calibrations, bases, and correction services

Site calibrations are an essential element of many surveying projects. There are many options on how to approach these.

Fitting the Site Calibration and Site Bases

5 MINUTE READ

In previous blogs, we looked at various aspects of base-rover workflows, contrasting the value proposition of bases vs. corrections services, and contrasting real-time vs. post-processed methods for project control. All of these subjects can come into play when performing site calibrations. There is an old saying among surveyors: “Calibration is not your friend, except when it is”.

For surveyors, site calibration (also referred to as “localization” in some field and office software) is when more than one point is observed, compared, and adjusted to corresponding “known” points. And although site calibration can be essential, it also gets a bad rap.

Some surveyors insist that they will never calibrate because it “adds error”. But is it even possible to never calibrate when the requirements of a job or project cannot be achieved by any other means? After all, setting up a base (or total station) and inputting coordinates is essentially a radial calibration. GPS/GNSS in its raw form is outputting WGS84 values, so when you work in a specific datum that’s transformed in the rover along with any further projection, that is also a form of calibration.

FITTING THE SITE

A properly executed site calibration gets the observed points to “fit” the known points. With this type of calibration applied, any subsequent observed points are adjusted to have high fidelity to the created site reference framework. When a surveyor performs a site calibration they are transforming the geocentric baseline vector components measured by GNSS receiver to local geodetic coordinates that provide a Northing, Easting and Height. This is commonly referred to as “translate, rotate, and scale” so that the points in the plan match the points on the ground.

Using best practices for site calibration, error can be minimized to be close to the full capabilities of the instruments used and within the error budget for the job or project. Therefore, if a calibration is a project requirement, the job of a surveyor is to use best practices to yield the highest accuracy as is practical within the error budget.

Surveying field software like Trimble Access have calibration routines that step you through the process. You can view quality data at each step. For instance, you can see how well the published control points fit each other (residuals) after observing them with GNSS, total station, or digital level—depending on project requirements, you may wish to use combinations of these. Additionally, specific to project requirements, it is not uncommon for surveyors to create a site calibration in office software like Trimble Business Center.

GNSS static observations, real-time vectors exported from rovers, total station vectors, and levelling data can be combined to create the site calibration that can be exported for application in field instruments.

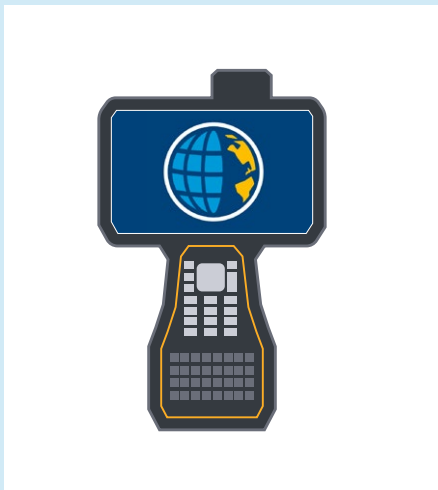
It is optimal when the published control that you are using to create the site calibration comes from one source. Yet it is not uncommon (often to save time/costs, or if the client does not understand the ramifications of doing so) that mixed control is provided. For example, you might be given values for say, two state highway monuments, two more from a local municipal control database, a benchmark from a local utility, etc. The hazard of mixing control is that values may have been established by different entities, different surveys years apart, different methods, and with different accuracy outcomes. Mixed, they may not have relative integrity that would make them good candidates for creating a site calibration. It is more likely that a project general contractor provides points set by a surveyor, tied together with a single survey.

While a surveyor does not need to be completely versed in spatial data analysis and the nature of measurement error sources to step through calibration routines, it is highly recommended that at least some self-study in the subject is undertaken. The software is great at guiding you, but you need to understand what it is telling you. Take in a seminar, take a formal course, or read through a treatise [like this](#).

By the time you create the site calibration you should have a very good idea of the expected accuracy for any work done inside the region of the constraining control points. And remember, the calibration should be viewed as invalid for any area outside that area. Doing additional checks should be viewed as an essential step, even if not otherwise specified as a project requirement.

A site calibration should provide adequate accuracy for the duration of most projects, noting that the actual position of any point on Earth is constantly changing due to tectonic plate drift. Some field and office software deal with changing positions by utilizing time dependent transformations that allow you to transform your measured coordinates to the reference epoch of the datum. Caution would be advised when utilizing a site calibration years after it was created, especially in areas with high tectonic velocity.

CALIBRATION AND SITE BASES



Surveying field software such as Trimble Access™, has calibration routines. Trimble Access software continues to be the leading field software professional surveyors use around the world.

The subject of site calibration would take volumes to cover comprehensively, so let's focus on a common scenario: setting up your GNSS receiver as a base and performing a site calibration.

Performing a site calibration to create a local datum is a common workflow for construction job sites but can also apply to pre-design topographic surveys. In the construction example, you may have a set of plans that has a scale, orientation, and basis of bearing that correspond to points that already exist on the site and match points in your job file.

When performing a site calibration, you would set up your site base, by methods detailed in the previous four blog entries, and then measure three or more (emphasis on more) points on the ground. You can perform additional checks to see how closely the resultant RTK values match the predicted values shown in the rover software.

Five points is recommended, distributed outside the bounds of the project site to form a strong geometry. Putting a long line of control points along a narrow corridor often does not provide good geometry. If control points out wide from the site have not been provided, consider adding more high-quality control. If vertical precision is key for project specifics, consider doing a level loop through all bounding control points to check the relative integrity of the provided values.

Here again we note that you could utilize a correction service to perform the site calibration. With a correction service such as Trimble VRS Now or CenterPoint RTX, you can forego setting up a base to save time, avoid the need to locate a site for your base, guard your base station from theft or disturbance from machines or workers, and to reduce the complexity of your workflow.

Utilizing correction services such as VRS Now or CenterPoint RTX in conjunction with a site calibration may also be useful at various stages of the job as well. For instance, if a site reference station will later be added to support the use of machine control systems, one could utilize a correction service while the area for the permanent base station is cleared and grubbed instead of setting up a base somewhere off the site and having to broadcast corrections over a great distance. If there is no safe and practical place within the site to put a base, some surveyors use an NTRIP client, for instance on a PC in the job shack to access a VRS solution for the center of the site and connect via a serial port to a base radio for re-broadcast.

If your error budget is tighter, doing your own post-processing, or utilizing post-processing services to evaluate the quality of provided control, or establishing new control can be the best choice. There are trade-offs: post-processing can often yield higher precision than real-time, but this comes with the premium of substantially more time needed for field observations and processing. While post-processing services like NGS (National Geodetic Survey in the U.S.) Online User Positioning Service (OPUS) and CenterPoint RTX are free, the time/cost of the longer observations by contrast make the cost of a real-time service subscription seem a bargain. The decision to use any or all of the above is the balancing act you must do in considering the specific error budget of the job or project and time/cost constraints involved. Some considerations may outweigh others, for instance a megabuck construction project may not wish to shut down certain operations (at thousands of dollars per day or hour) while you employ time consuming surveying methods to achieve higher precisions than are warranted.

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BASE STATIONS USED			
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PTRF			23290.3
DE6609 UCLU	UCLUELEY CORS ARP	N485532.281 W1253229.841	93452.5
CLRS			60357.6

A sample data report from an automated online-post processing service (NGS OPUS), from submitted long-static observations. Note that you may be able to meet the same accuracy estimates (shown) with much shorter observation times using real-time correction services.

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PART 1 : Is it time to ditch the base station?

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