Instant access: this local surveyor in Nissen Japan demonstrated the ease of accessing corrections from the national 1200 station array via one of two commercial providers. Corrections are available by a number of means, including cellular, radio, and wireless.

RTN–101:

An Introduction to Network Corrected Real-Time GPS/GNSS (Part 1)

>> By Gavin Schrock, LS

What is RTN?

Real-Time Networks, Network Corrected Real-Time, Network RTK, take your pick. Satellite-based positioning, using ground sensors (*a.k.a.* base stations, reference stations, CORS) to improve the precision of said positioning, real-time corrections, even network corrected real-time (especially overseas and in a growing number of U.S. regions) are nothing new.

There are more than 200 RTN worldwide, some encompassing entire countries. The U.S. is a relative newcomer to this utility, but the growth has been astounding; in the latter half of 2005 there were approximately 18 in service in the U.S., and as of this writing there were more than 40 representing state, local, and regional initiatives in both public and private sectors.

For all of us, to some degree, this is the first day school on a subject that can (and already has) had a tremendous impact on our industry (and others); that includes folks who already have access to an existing network, and those planning or proposing development of a network in their vicinities or regions. Even those geniuses that develop the applications and hardware are like wide-eyed kids with respects to the feedback from the actual users and seeing the fruits of their labor.

The good news is, that RTN can, and do (if properly implemented) provide consistent, verifiable, and rapid results; a suite of solutions that can (if properly executed) be applied to nearly every positioning aspect of the surveying industry. Of equal importance is the news that these networks for the most part are providing solutions that are non-proprietary and in industry-standard formats.

While there are few who would be qualified to speak to every aspect of this subject (and I definitely could not) there are plenty of resources and experts that could fill volumes. One could delve into any of the respective aspects at a level of dizzying complexity. What is needed for the rest of us is a fundamental understanding that will enable us to put this new utility to effective use.

Welcome to RTN-101, an introduction to the very subject. In this and subsequent articles, we hope to address some of the most important aspects, drawing upon the expertise of those best qualified. This introductory summary itself must be presented in two parts, this and in the next issue. The following may seem an oversimplification to some, and techno-babble to others; but we hope that you may be armed with a level of understanding that will make it easier to step into this subject, and more importantly, to be able to educate (or convince) others as to its utility (particularly those who may be bankrolling your operations).

Rover's-eye view: with a quick calibration to local references, work can begin within minutes of arriving at a site. Grand Coulee in north-central Washington.

Hype—Fear—Hope

Remember when electronic distance measurement devices first hit the ground? Remember the panel of dials and settings one would have to deal with? Remember when we were so nervous about the results that we visited the calibration baselines more frequently that most folks do now (if at all… for shame, for shame).

Not that you should just trust this thing blindly and go off running, for you are still a surveyor and are obligated to be able to stand behind your results. We have witnessed some of the biggest, curmudgeoniest, grumpiest nay sayers cave in and admit this is cool after only a few hours of use. New tools, new ideas; if you give a new tool to surveyors, they will by nature figure out the right way to utilize it.

While no one would ever suggest that RTN can take the place of a closed traverse, or digital level run, or l-o-o-o-n-g period post-processed GPS; repeatability of observation is defendable (you can even export your RTN results as vectors to any post-processing package if you need to show your analysis, which is a common practice for folks who use RTN for cadastral work).

There is a lot of information coming from manufacturers; this is of course a growth industry. To some degree all (think of it as "healthy competition"), yes *all* of our gear providers are inadvertently (or perhaps "vertently") taking advantage of our collective lack of understanding of this subject. The jockeying for position in this battle over networks and network-compatible field gear sometimes highlights subtle differences and some pseudo-scientific hair-splitting that border on laughable.

While it is very *likely* that a solution from any given manufacturer, if properly implemented, will yield excellent results, it is *highly unlikely* that one might provide some magically wonderful especially terrific results that the others cannot. The devil is of course in the details. Because there are few published completely impartial tests or studies, the best tester is yourself (*i.e.*, if it can do what you want it to, that is all that counts).

Beware the "signal-to-noise" ratio on some of this. Have you ever watched British Parliament sessions on cable? Well, the otherwise reputed-to-be-stuffy Brits get into some real cat-calling-hooting-hollering-snippy-smarmy-sarcasm-ridden debates. I find the current vendor wars equally disturbing but amusing. Nuff said.

RTN Utility—Beyond Surveying

The utility of RTN goes far beyond that of surveying and has the potential to foster a climate of collaboration between fields that would otherwise share no common interests. Satellite-based positioning falls under a generalized category of space-based commerce, and with respects to the GPS and GNSS satellite constellations, can be further divided into the fields of position, navigation and timing (PNT). Many aspects of this expanded utility for the satellites were cited in making the case for the original satellites; uses beyond military were anticipated and realized.

An example of forward thinking at the federal level with respects to this anticipated expanded utility was the formation of the National Space-Based Positioning, Navigation, and Timing (PNT) Executive Committee. PNT was established by presidential directive in 2004 to advise and coordinate federal departments and agencies on matters concerning the global positioning system

Semantics-Antics

Folks have cited *acrospeak* as the evolving vocabulary of acronyms that grows faster than we can forget the old ones. *GPS* (Global Positioning System) generally refers to the original U.S. Navstar constellation. Now the updated term is *GNSS* (Global Navigation Satellite Systems) that includes the Russian GLONASS system and the European Galileo constellation. Others on the near horizon include a planned successor for the Chinese Beidou system, and the Japanese QZSS. Old habits die hard, so for purposes of these articles, the terms are interchangeable.

and related systems (*www.pnt.gov*). But while there is a heightened awareness of PNT as a whole, the utility and potential of RTN is a relatively new subject to many, even at the federal level.

The potential beneficiaries and stakeholders in RTN are broad. In many cases it was interests beyond surveying that established the early infrastructure that would eventually morph into current RTN, and in some cases there are non-surveyors establishing and operating these services. (See sidebar for a list of RTN elements that will be discussed in greater detail in future installments.)

There is an old Zen saying "*Sit still and spring will come, the grass will grow anyhow*." With the implementation of these networks moving beyond the "early-adopters" phase, it would behoove surveyors to get involved in a manner to ensure that these networks are established and operated to the exacting standards of our industry.

Longer baselines: this site near Steamboat Rock in central Washington is 50 kilometers from each of the adjacent RTN reference stations; consistent and reliable corrections availalble on-demand 24/7

Theory—How Does It Work?

Satellite-based positioning is susceptible to many of the same sources of error we are familiar with in terrestrial-based positioning (such as setup, calibration, data management), which we can mitigate through proper procedures. There are also the sources of error inherent to satellite based-positioning which we have thus far dealt with by sheer volume of observations and post-processing.

The general populace is readily familiar with "Low Precision-GNSS" in the form of consumer type products like handheld recreational GNSS receivers, or car navigation systems; these generally refer to systems capable of precisions in the order of 1-10 meters. 'High Precision -GNSS' is engineering and surveying grade GPS in the order of 1-5 centimeters. High Precision -GNSS utilizes not only the satellite constellations, but also networks of "earth-sensors," or Continuously Operating Reference Stations (CORS).

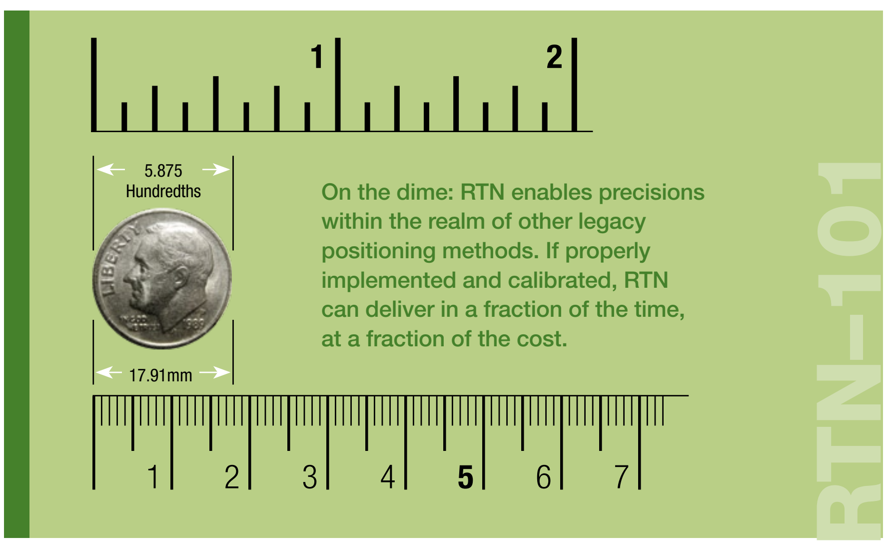
Reference stations, working together as a network, can address directly several of the largest sources of error, and do this in real-time; positional integrity of the reference stations (*i.e.*, these stations do not move very much, and if they do this movement is accounted for through constant monitoring), orbits (*i.e.*, by introduction of higher-precision orbit data at the time of observation), and signal delays (*i.e.*, delays and ambiguities with respects to the signals passing through the ionosphere and troposphere… this is the big one!)

An RTN can generate corrections for any given location or region of a network, or gather data for client-side processing, and pass them in real-time to the field by a variety of means.

In summary (and this may be an oversimplification) the legacy method to achieve "High Precision - GNSS" results (namely post-processing) was to take many observations over a long period of time, cull out unsuitable data, and then spread residual error around. With real-time an effort is made to gather a small amount of good data upfront. Only a well-designed, implemented, and monitored network can do this.

Geodesy—Absolutely Relative

A new user of an RTN usually comes to a hasty conclusion as to the accuracy of the solution "this real-time thing misses my monument by *xyz*!" Granted, it probably does miss the value that the user has as a



On the dime: RTN enables precisions within the realm of other legacy positioning methods. If properly implemented and calibrated, RTN can deliver in a fraction of the time, at a fraction of the cost.

The following RTN elements will be covered in greater detail in future installments:

- Land Surveying
- Construction Surveying
- Machine Control
- Automation of Grading
- Heavy Construction
- Structural Assembly
- Construction Inspection
- Compliance Inspection
- Grade Checking
- Engineering Studies
- Disaster Preparedness
- Utility Location and Clearances
- GIS - Resource Mapping
- Preliminary Engineering
- Asset Inventory
- Physical Plant
- Infrastructure Inventory
- Structural Integrity Monitoring
- Dams, Bridges, Buildings, Plant
- Environmental Mapping
- Geophysical Studies
- Tectonic Plate Movement
- Tsunami Response Planning
- Landslide Studies
- Geological Deformation
- Atmospheric Data
- Ionospheric &Tropospheric Modeling
- Precise Navigation
- Snowplow Guidance
- Maritime Portage
- Hazard Clearances
- Rail Operations
- Intelligent Transportation
- Route Delineation
- Emergency Response
- Incident Mapping
- Post-Event Analysis
- Recovery & Reconstruction
- Precise Guidance
- Forensics
- Scene Investigation
- Archaeology
- Restoration
- Control Monumentation
- Monument Preservation
- Robotics
- Timing

RTN–101

The reference station at the University of Washington research lab in the San Juan Islands between NW Washington and British Columbia serves scientific and positioning needs on both sides of the border.

reference coordinate for said monument, but it did not "miss" the monument. In terms of repeatability, subsequent shots would likely fall within a centimeter (at least horizontally).

So, what missed what?

The bulk of surveying is done in a relative manner; a closed traverse through knowns, a level loop through knowns, RTK with a field base station set at a known. The big questions are "what is the known?", "how was it established?", "what, if any wider reference framework was utilized?".

All that satellite positioning can do for you is provide you with a tie to a consistent reference framework, or more specifically, a mathematical ellipsoid roughly approximating the shape of this big blue marble. The satellite positions are with respects to this ellipsoid, the axis of this ellipsoid is "calibrated" as it were to distant celestial bodies that "appear" to not be moving (this is known as the VLBI or Very Long Baseline Interferometry… Google it!).

At any rate, this consistent reference framework acts as a kind of live monument that you can access from anywhere you can see the sky, and (if all the pieces are in place and proper procedures are followed) will give you the same values any time you observe the same point.

Yes, the earth moves, plates move, and ground monumentation has been established over many eras utilizing the best resources available at that time, but that cloud of disparate references should not prevent the user from leveraging this ellipsoid-based framework in a relative manner. An analogy to electronic distance measurement is often used to describe this relationship: a pair of GPS observations yields a pair of coordinates; a vector… the EDM does the same.

This is the most misunderstood and argued aspect of satellite-based positioning of them all, but should not be. Calibration is the answer; pre-define the local relationship between the reference system you are trying to use and that of the reference stations that make up the RTN (and whatever system they are on). The RTN reference stations need not necessarily be on any particular system to be useful, they need only maintain positional integrity to each other (and the respective RTN software does this to the millimeter). In some respects it might be better if RTN stations were on a completely assumed system (that would force folks to calibrate like they should).

For the most part, these networks aspire to maintain fidelity to national reference frameworks like the NGS NAD83 CORS-based framework (and to that end may have one or more stations included in a national framework like NGS CORS or NGS Cooperative CORS, both a good step in the right direction). This does to some extent provide an external check for positional integrity and lets users obtain an uncalibrated position which may serve as-is for less stringent needs (*e.g.,* resource mapping).

> **"It was new — It was singular — It was simple. It must succeed!"**
>
> **— Lord Horation Nelson**

But what happens when the tectonic plates move or there is an earthquake? The short answer is a combination of date-stamping your work (for example, have you ever had to deal with a compass-based description and had to figure in the changes in magnetic declination over time?) and re-calibrating… remember, all things are relative… but we'll cover that at another time.

Reference Stations—Components & Controversy

What are the basics for a good reference station? Are there standards? What aspects are important with respects to and RTN? Which camp should I follow in the controversy over mounts: the "if-it-doesn't-move-it-doesn't-matter" camp (remember that these networks monitor their relative locations constantly and very precisely), or the "build-a-monolith" camp (are these becoming defacto monuments?), or how about a reasonable combination of both? And good news: no one has a monopoly on the manufacture of good reliable receivers suitable for use as a reference station (yes, the devil is in the details, but few are make-or-break with respects to inclusion in an RTN).

Cost-Benefit—No Bucks, No Buck Rogers

You'd be shocked to find out that a number of RTN were developed completely without a formal cost-benefit analysis; those involved knew that an RTN would not only save on the crew level, but solved many more issues. But that sort of anecdote does not convince any of the folks holding our purse strings, so a number of successful analyses will be examined.

Network Design—Practicalities Rule

It is one thing to determine the limitations of the network solution with respects to theoretical spacing of reference stations, and then it is another to deal with the realities of site selection, permitting, communications, politics, and more communications issues. The good news is that because of the exacting standards for data input into these sophisticated RTN applications, and the all-too-frank feedback from users, the limitations of network geometry become readily apparent.

Upcoming in Part Two:

- Space Weather: The "I" in the Sky
- Satellites: Ours, Theirs, and the Others
- Rovers: L1, L2, Old and New
- Operations: RTN Do Not Run Themselves
- Troubleshooting: What Trouble?
- Communications (or Lack Thereof)
- Innovation: Pop-Tart Blowtorches
- Future: Everything Better except the Coffee

Stay tuned…

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