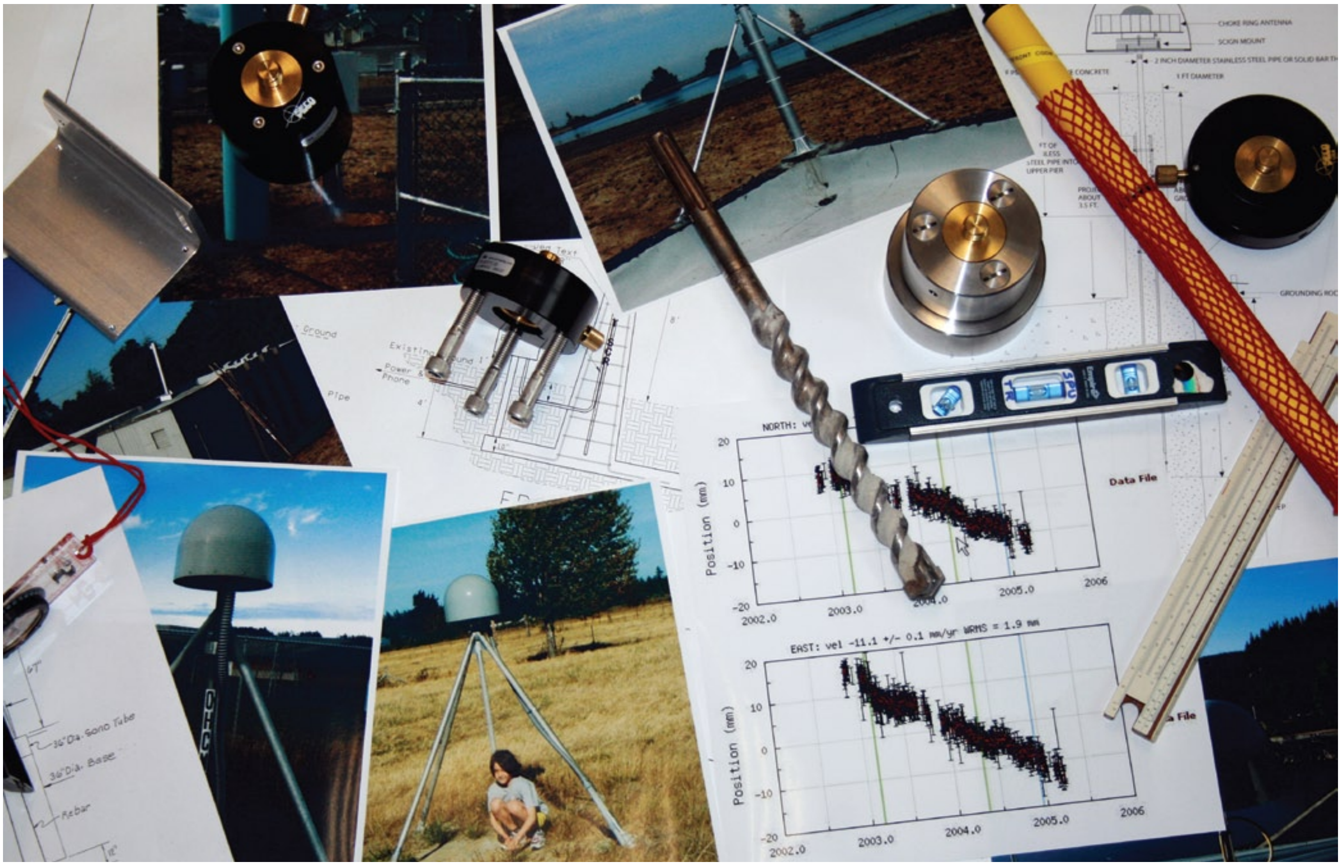


RTN–101:
Mounts Count (Part 13)

"While it is true that an RTN may only be as good as its monuments, it can also be true that the monuments may only be as good as the RTN."

—Some RTN operator in Washington State

>> By Gavin Schrock, LS

Reframing Reference Frameworks

There are few aspects of the subject of RTNs that are not in some way controversial; not uncharacteristic for new ideas. Before we look at mounting and monumentation options (and there are plenty of wonderful guidelines available online), we need to look at the monumentation question from the practical and sometimes controversial perspective of RTNs.

Moving into the world of earth-centered datums is the root of surveyor angst when dealing with space-based positioning; the use thereof requires faith in more than the traditional physical monumentation. It is difficult to reconcile the notion that the satellite constellations could actually be considered as a form of monumentation (though the monitored orbits are reaching levels of precision not previously dreamed of). We are asked to accept such abstractions as reality.

The ground-based component of this new notion of a reference framework takes faith in the ability to track and observe the satellites, to the '*nth*' degree. On the constellation management end, the governments and agencies that operate the constellations must reconcile the orbits, timing, and signal quality to rigid spatial, temporal, and operational norms. The spatial element, in the case of the U.S. Navstar constellation (GPS) is tied, through rigorous tracking by worldwide networks of ground stations. This ground component is further referenced to distant natural celestial "beacons" (do a web search on "Very Long Baseline Interferometry" or "VLBI" to learn more). The results of said tracking are expressed in terms of earth-centered mathematical models like the various ellipsoid conventions (e.g., ITRF, WGS84, NAD83; a separate subject that warrants a treatise all on its own). Are the true "monuments" of these new frameworks distant celestial bodies? This notion is not sitting well with an industry vested in a legacy of physical monumentation.

Not wanting to wade too far into the deep end of the geek pool at this point, a subject closer to the end user (and within the sphere of influence of the end users to some degree) is the immediate RTN ground-based component. This component is the Continuously Operating Reference Stations (CORS); these make up RTNs and sometimes act as the foundation for other reference frameworks. What matters most is the ability of such CORS to observe the constellations with the least amount of error, and to maintain a very high degree of positional integrity with respects to other CORS on the same network. As well, the CORS networks are often tasked to maintain some degree of fidelity to broader regional, national, or global reference frameworks.

To maintain this high level of desired "stasis," there are typically two essential components; a very stable mount *and* rigorous positional integrity monitoring (preferably both). That an RTN may effectively operate with only the tightest of relative positional tolerances means that it serves as its own "canary in a coal mine"–it either works well, or it does not work at all. This reality serves as portent to an ongoing controversy, and indeed the forming of two (almost philosophically opposed) camps on the subject of CORS mounts and monuments. These are the "build for perfection" or "track for perfection" camps.

Two Camps

These are the two camps. Some have characterized these two philosophies as either the strictly specified monument design crowd ("build for perfection"), or the "if-it-don't-move-it-don't-matter" crowd ("track for perfection"). These characterizations do a disservice to the two views of what represents sincere efforts to achieve the same goal. While it could be argued that the movement of any reasonably constructed mount can be monitored to such a degree as to mitigate for inherent movement, or that even the best mount design still requires monitoring, most folks involved in RTNs and CORS for any extended period of time tend to lean towards a reasonable balance of both.

Like other networks of CORS, an RTN can over time become the default physical manifestation of a reference framework. Static campaigns used to rely on setting temporary bases on known monuments, but as individuals and agencies started publishing positions they had established for "permanent" stations (later to carry the moniker of CORS), the end users started relying on an element outside of their immediate control. The need for confidence in such external elements became essential, and periodic re-computation of said values was an early form of continuous integrity monitoring.

The national reference framework has migrated to a nearly exclusively CORS-based system. This "active control" network is constantly monitored and forms the backbone of nearly all of the framework maintenance and adjustments performed by the National Geodetic Survey. The quality is astounding on a national scale; the notion of being able to reconcile any two CORS across the country to the precision of a few centimeters is no small feat. This is wholly sufficient for nearly every positioning need one could think of … except that an RTN requires even tighter tolerances on the local level.

Solid

For an RTN to deliver anything within the realm of sub-centimeter results, each and every CORS must have network accuracy better than the desired result; 10mm across the entire network is the tolerance allowable. The prime consideration in designing a mount is to ensure that it will not move more than a few millimeters. But that depends on how one defines movement; be that acute, localized, chronic, regional, etc.

One would look to various design options to mitigate for each of the movement types, but the first gut reaction is to view the mount as an extension of a traditional monumentation: big, deep and heavy, or attached to something big, deep and heavy. Yes, it is true that the bigger, deeper, and heavier something is, the more it has a tendency to move less than something small, shallow and light. But you cannot apply that maxim to every situation.

One may point with pride to a wonderful-looking pillar mount; reinforced concrete set on a tiered foundation and cites the "several tons of mass." Well, a concrete building may be comprised of several thousand tons of mass, and unless it is weakly constructed or perilously high, it may very well out-perform the other wonderful monument (but I don't want to open up that controversy just yet).

Local Conditions and Design Resources

I hate to rehash the obvious, but even the biggest, deepest and heaviest monument set in unstable soil like a floodplain or alluvial pan is going to shift and/or sink. While there are mounts designed to mitigate for such conditions, unless there is no other choice, look for another site. The same can be said for anything you may want to attach the mount to (e.g., an existing building or foundation); local geophysical conditions warrant upfront research.

There are so many other possible end-users and stakeholders in CORS data that it can be fairly easy to find an ally in researching the site and design for a proposed CORS. Some may have geophysical or geo-technical expertise to lend in scoping out sites. Academic and scientific folks can be a great resource; scout out the nearest university that has a geology, civil engineering, or better still, geodesy department, and you may find out that they may already be hosting a CORS or are involved in a regional or national CORS network. The Unavco-Earthscope Plate Boundary Observatory project has placed 700+ CORS across the western U.S. and Alaska and has some wonderful guidelines online for CORS design and site considerations: http://pboweb.unavco.org (look under "GPS" and "Operations Documents").

The National Geodetic Survey is the shepherd of the largest CORS network in North America (and one of the largest in the world). The NGS may serve as a resource through their state advisor program, particularly if the intention is for a CORS to perhaps become part of the National CORS network. The NGS website has very comprehensive guidelines at: www.ngs.noaa.gov/CORS/Establish_Operate_CORS.html.

[An antenna/mount in an RTN serves as its own "canary in a coal mine"—it must either work well, or it will not work at all.]

Reality in Real-Time

While these various guidelines may be viewed by some as "gold standards," by their well-intended and well-engineered designs, there is a certain irony that there are many CORS serving in "active control" networks locally, regionally, nationally, and globally that have never met such standards. But, through constant integrity monitoring, these sites serve far better than their flawed designs might appear, even to the layperson.

It is not my intention to sully the well-deserved reputation of the authoritative voices in such matters with anecdotal tales of CORS on fence posts, or hanging off the side of antenna towers (oh the temptation), but it needs to be said that certain practicalities tend to rule in the end, even for the bodies authoring such guidelines. One might seek (or be forced into) adherence to such strict criteria that it might completely scuttle an RTN initiative, especially when some criteria may present prohibitive costs with possibly diminishing returns.

An RTN may not just be all about cost-benefit; if it were, then rigid monitoring of "cheesy" mounts alone might do the trick. No, an RTN can (more often than not) become an "active control network" serving as an adjunct to a reference framework, or serving broader needs, like scientific research or public safety. One may want to consider needs beyond those of surveyors.

One answer to this dilemma, which is rapidly becoming quite the norm, is to have some "primary" CORS, or those that serve a fiduciary function with respects to some broader reference framework. For most this might involve the submission of some of their CORS to the NGS National CORS program; these would be monitored by NGS with resultant values having high fidelity to the national reference framework. NGS is also piloting a program where raw data (not correctors) from some national CORS is made available to local RTNs for inclusion in their networks; thus providing these fiduciary stations. The balance of the CORS can be monitored by the RTN itself, and be maintained (in name only) as "secondary" stations. When it comes to the effectiveness of an RTN, there are no 'secondary' stations; they must all in reality pull their own weight.

One not-insignificant glitch in the use of national CORS values for local RTNs (but it is to be noted that these issues are rapidly being resolved) is that some might not meet the tolerances requisite of RTNs. As stated earlier, the national CORS may have amazing network accuracy when viewed on a continental scale, but it is a reality that if one was to perform a rigorous adjustment based on the published values of national CORS, (or some other published array) over a wide area, say a whole state, they might not meet the 10mm threshold. Often, through careful analysis, one must settle on a subset of those CORS to "hold" in tying down an RTN to the national framework. This is not to imply that the other CORS are "bad," or have bad mounts, or that any other particular element is "bad," but if a group of CORS are only monitored to the tolerances of, say, 2cm by 2cm by 4cm (e.g., in NAD83[CORS96]) then those values would not work in an RTN. Many of the same stations are now being monitored to higher tolerances and expressed as ITRF vales of 1cm by 1cm by 2cm; this is perfectly fine for RTNs. The question of whether the surveying industry is ready to move to a purely ITRF world yet is a big old can of worms all on its own (whether we should, but may not be ready to, is to be further examined in later installments). The NAD83 and ITRF worlds are soon to collide, and RTNs may just be the harbinger of things to come.

Monument Nirvana and Pudding

Okay Mr. Cynic, then what is a perfect monument? As stated earlier, there are fine mount designs to be found online that are designed for various site conditions, provide features that help mitigate multi-path, reduce localized movement, take into account climate considerations, and provide easy access to the reference point for other monumentation activities such as digital leveling.

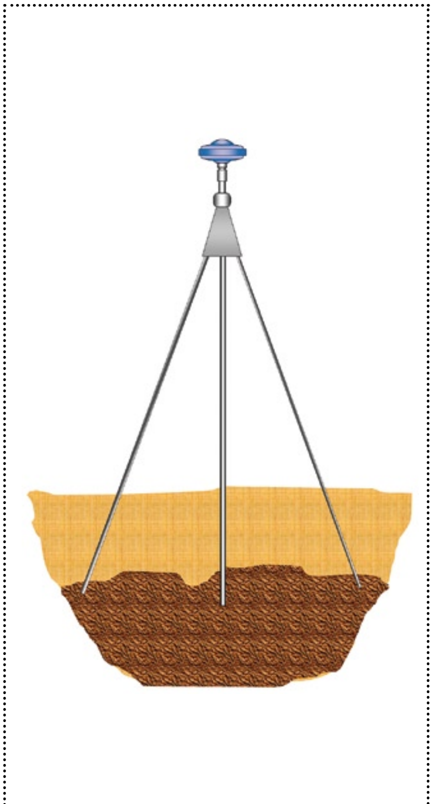
The other component of a perfect monument is how well it performs over time. An RTN (and other applications) can provide you with good "time-series," usually represented as a graph showing the overall trend in movement over long periods of time (quite a bit more evident in regions of tectonic activity) with the short term localized movements shown as tightly spaced undulations.

The proof is in the pudding. A monument, regardless of how carefully designed will definitely let you know if it is not working once plugged into an RTN. And how!

No one is advocating compromising quality just to save a few bucks, but a reasoned balance between well thought-out design, cost, site considerations, and integrity monitoring is not only advisable, but has been the standard M.O. for nearly every successful RTN.

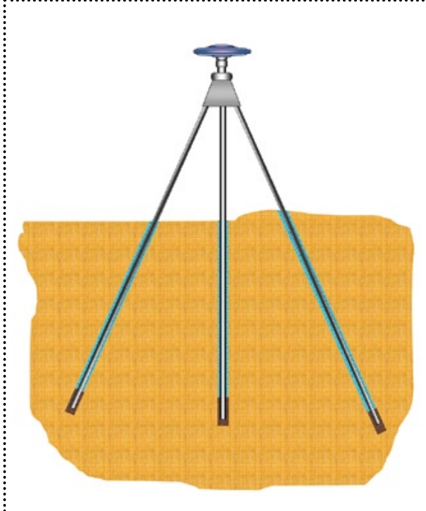
The perfect monuments are great if you can afford them, or if a particular site can accommodate one, otherwise one might need to consider other options or designs, like (gasp) building mounts. What follows is a quick summary of the most common types of mounts found in use on existing (successful) RTNs:

Short Drill Brace



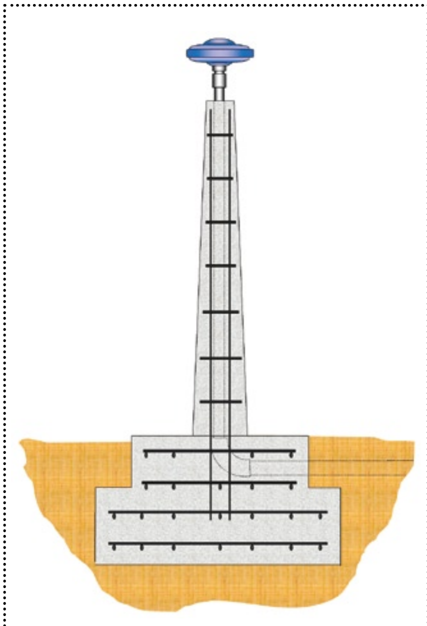
This can be used when the depth to bedrock or other stable surface is less than 10 feet. The stability of a tripod (though most constructed have 4 angled legs plus one vertical under the antenna) is paired with narrow members (to reduce multipath hazards). This is very popular with the scientific community, okay by both Unavco and NGS standards.

Long-Drill Brace



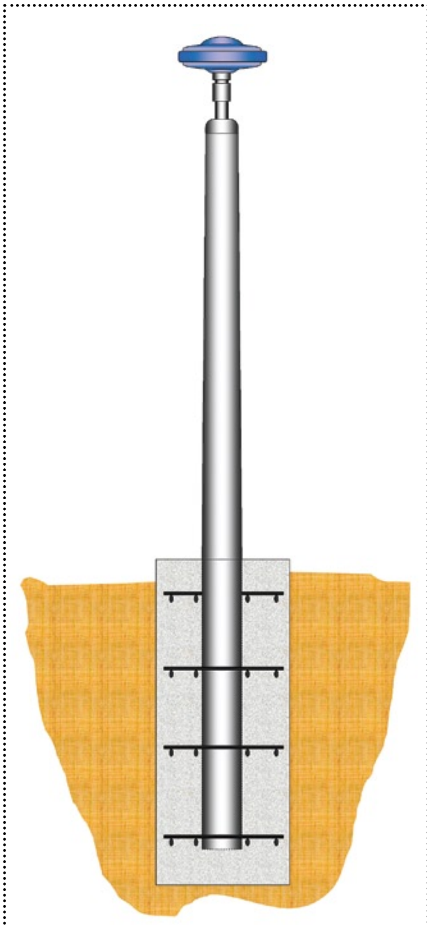
Another tripod, "quad-pod", or "quint-pod" style monument, this one is used where the soil and sub-surface conditions may be less stable. The legs may be drilled up to 40 feet and only cemented into place at the very bottom; the balance of the hole around each leg is filled with an insulating material that will not place drag on the legs in the event of shallow strata shifting or sub-surface expansion-contraction.

Base and Pillar



One of many similar variations. this seeks to provide a heavy-stable base for a pillar. Reinforced concrete provides mass, with a broad base. Some have experimented with low, squat pyramids, but those can present a multi-path hazard; the pillar reduces this. Like other good designs, the antenna mount should be 1.5m above the ground to reduce multi-path hazards.

Pole-in-a-Hole

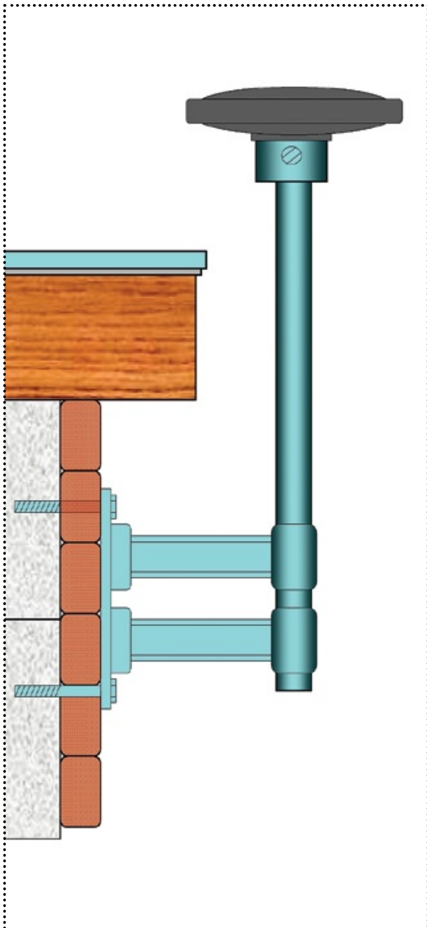


There are several variations on this theme: one involves pounding a pole or "I-beam" down to refusal (or as far as one can afford), another style sets a pole (like a spun-aluminum light standard) down into an augured hole filled with concrete. On some pole type mounts 2-axis tilt-sensors have been added to monitor stability.

Corner-Brace Structure Mount

There are often old foundations or pads available (decommissioned communications sites or old cold-war-era antenna farms often have lots of stable pads), or there may be ground-level concrete utility vaults on which to attach a brace pole. This same type of mount is often used at the corners of load-bearing walls or parapet walls on very stable buildings. How high can one go on a building? There are too many variables to consider, therefore testing is often the best practice.

End-Wall Mount



If there is a sufficiently stable (preferably reinforced concrete) load-bearing wall of a building, perhaps at a roof peak, then this design is preferred by many building owners as it does not penetrate the roof directly. This particular example reaches out around the eaves. A challenge is to get the antenna far enough above the roof to minimize multi-path, but it is to be noted that with many newer antennae, clearances of as little as one foot have worked depending on roof material. Metal roofs can be pure evil.

Mount Hardware

Pretty much any antenna (sold in the U.S.) screws down on standard 5/8"-11 threads (and more than a few home-spun mounts have some all-thread welded on them). Some folks have even stuck a tribrach up on a mount. Those days are over (we hope). In additional to the very well designed and widely used Unavco and SCIGN leveling mounts, there are good solid commercially available mounts. Some are designed to screw onto 1.5-inch, 2-inch or 3-inch threaded pipe, and others with bolt extensions for setting in concrete; most of these designs have leveling screws (some you can set with a coin). Another great feature of some of these commercially produced mounts is a core that can be removed (with antenna still attached to expose the surface on the mount that the Antenna Reference Point (ARP) contacts for access during digital leveling activities.

Integrity Monitoring

RTN software suites include standard integrity monitoring applications utilizing one or more processing engines; some that work in real-time, and others that employ automated post-processing sessions. There are applications that run constant loop closures on every segment of the network, there are others that even use a server side RTK engine to test any rapid motion conditions, others run any number of operator-defined full adjustments on all or parts of a network on daily, weekly, or a monthly basis.

This subject warrants its own treatise in a subsequent article, but in short, an RTN keeps an eye on itself, round-the-clock, to millimeters. An RTN will not tolerate outliers, and can be mighty unforgiving if you try to add a bad monument, and sometimes it is not until you plug a monument into an RTN (or other monitored network) that you find out how good or bad it is.

Gavin Schrock is a surveyor in Washington State where he is the administrator of the regional co-operative real-time network, the Washington State Reference Station Network. He has been in surveying and mapping for more than 25 years and is a regular contributor to this publication.