MTSRN FAQ

What is RTN?

The RTN is a real time positioning network that provides less than a cm accuracy in latitude, longitude, and 2-5 cm accuracy in ellipsoid height at any given time (barring geomagnetic storm/solar flare).

Montana RTN is called Montana State Reference Network (MTSRN) (www.mtsrn.org).

How does it work?

It is a network of base stations or in other words, Continuously Operating Reference Stations (CORS) connected with a Central Processing Center (CPC) through NTRIP (Network Transport of RTCM via Internet Protocol). CORS receive real time GNSS observations and send to CPC. CPC processes the data, calculates real time solutions of all the stations and compares with control coordinates and computes errors. CPC then provides corrections via NTRIP to the roving receivers. Rovers located within bounds of the network need internet connection to receive MTSRN corrections.

What is the datum used in MTSRN?

NAD 83(2011), 2010.0. It is called 2011 realization of North American Datum of 1983 at epoch 2010.0.

Do you need a geoid model to receive orthometric height?

Yes, the default output of Montana RTN is latitude, longitude, and ellipsoid height. You need a NGS geoid model installed in your data collector to receive orthometric height. We recommend using the latest geoid model which is GEOID18 at present.

What is the use of it?

- Provides a common correction on national datum for the entire state with improved accuracy, and city and county maps will have less conversion errors
- Machine guidance for grading or superelevation
- Construction and transportation for critical engineering infrastructure
- Land surveying for boundary survey, engineering, construction and others
- Precision agriculture for various agricultural needs

- Drone and robotics for mapping, technology development & others
- Energy & utility for geospatial needs
- Environmental, ground water, geologic & mining needs.

What hardware and software are needed to use the MTSRN?

You need high-precision GPS/GNSS receiver and antenna, either in the form of a standard "rover", or other receiver and antenna combinations. The receiver needs to be capable of using external corrections, and can track at least GPS satellites, or multiple constellations (e.g., combinations of GPS, GLN, GAL, BDS, etc.). To receive corrections from the MTSRN you will need internet connectivity, typically via a cellular connection. You will need field software that supports your GPS/GNSS hardware, it will also need to support NTRIP connections (see the NTRIP section below).

You have to set up a cell connection with a cellular carrier directly (the MTSRN does not do this) i.e., use a modem or phone with a data plan. Some rovers have a modem built into the rover head, others have a modem in the field data controller, and other users work via an app on a phone. Some users prefer a portable WiFi "hotspot", and connect their controller to it via WiFi, while others use their phone as a hotspot. In any scenario, you need to have a data plan with a cell carrier. Nearly all field software or apps for surveying/mapping are set up for NTRIP protocols. If it does not, there are free apps that can receive corrections and pass them to a receiver, but you will still need a cellular data plan. See the NTRIP section below.

Can you recommend hardware and software?

Nearly all rovers made in the past 20 years can use services like the MTSRN. There are some common protocols and formats offered by all RTN globally, and there is nothing inherent in what an RTN offers that would be advantageous or disadvantageous for any brand or model. There are a few RTN (out of many hundreds) that only provide proprietary formats. The MTSRN offers common non-proprietary services. However, depending on the age of a rover, and what constellations of satellites and signals the rover supports, you would choose different flavors of corrections. For example: we broadcast multiple correction flavors (standard formats) for each station, and subnet (e.g., RTCM3.1, RTCM3.2_MSM, CMR+, CMRX) because there are some users with older gear that cannot use newer formats. See the multi-constellation section below for those broadcast correction types and mount point naming convention. Contact us if you are

unsure, though your equipment dealer should tell you the format your gear supports, as well as the equipment data sheet.

The same applies to field software. We can discuss rovers and software generically. The feedback we receive from users and testing is that nearly all newer gear can achieve similar results. Shop around.

How do I apply for a subscription? (How do I create an Account?)

Registration is a two-step process:

1st step: visit www.mtsrn.org site and use the register tab on the left, fill out the information and submit your application.

2nd step: Pay through the state payment portal below,

https://opp.mt.gov/doa/opp/MSLMontanaStateReferenceNetwork/cart

In the payment portal there is an option where you can mention your username. For more information, visit https://msl.mt.gov/mtsrn.

What do you mean by VRS and single base?

VRS is a type of network RTK (NRTK) that uses data from multiple stations surrounding where you are working, and creates corrections modeled for your location to send corrections, as if you have a base right next to you with a near-zero baseline length. There are several types of NTRK, like MAC/MAX (master auxiliary approach), and FKP.

Keep in mind that the “virtual” in VRS is a bit of misnomer. It refers the corrections derived from the surrounding stations, but there is also direct relationship to a physical reference. Typically, the nearest station in the VRS solution is the source of reference coordinates. This can be found in different field software under the name PRS (physical reference station) or PBS (physical base station). You can export (in your field software) vectors from the PBS/PRS for inclusion in post processing, same as with vectors from single bases.

Single base is where differential-style corrections are from one individual station. One drawback of single base is that results degrade over distance, typically at distances of 10km or more. Real-time networks globally found that NRTK allowed for much greater station spacing; it would be impractical to be able to afford to build a network with 10km spacing. With NRTK they can be

spaced at 30km-70km (depending on local conditions). That was the impetus for developing network corrections and RTN.

Is single base better than VRS?

It can be, but only under very specific conditions. Single base degrades over distance. If you have a site base (that you can see from the rover, or under a km), or a station within a few km, that may yield better results than VRS on good iono days but may vary from day to day. One rule of thumb is to not use single base if you are more than 10km from a station or base. For single base to work best, the base must be set up in as good, or better, sky conditions than the rover, with low multipath conditions, and it has to support the same constellations as the rover—and it does not get stolen.

It is possible (yet not recommended) to get fixed results from single base at very long baseline lengths, 20km, 30km, and more. The problem is that you will not get consistent results at long baseline lengths as the conditions could vary from day to day, even hour to hour.

Contrary to some marketing-driven rumors from the early days of RTN, VRS does include a physical base station (PBS or PRS); a PBS code is in all VRS corrections. The model of the corrections is virtual, but there is still a tie to a fixed station. Nearly every rover that can export vectors can export the rover-PBS vector.

What is subnet? How many subnets exist in MTSRN?

Long separation between stations prohibits creating network solution. Subnets are formed to create network solution using a cluster of closely spaced base stations. There are currently five (5) subnets in the network.

These are named geographically such as,

- Northeast Montana Subnet (NEMT)
- Northcentral Montana Subnet (NCMT)
- Northwest Montana Subnet (NWMT)
- Southwest Montana Subnet (SWMT)
- Southcentral Montana Subnet (SCMT)

What is mountpoint?

Corrections relative to any network or relative to any single station in MTSRN are provided separately. Each correction source is called a mountpoint.

MTSRN Output Formats?

What are the correction output data formats?

MTSRN provides,

- CMR format. CMR stands for Compressed Measurement Record (CMR), and it is Trimble proprietary format. And,
- RTCM format. RTCM stands for Radio Technical Commission of Maritime Services (RTCM). RTCM is internationally accepted & non-vendor specific.

What are the CMR formats in MTSRN?

- CMR+ (provides solution based on GPS+GLN)
- CMRX (Provides solution based on GPS+GLN+GAL+BDS+QZS)

What are the mountpoint solution formats in CMR for a single station?

For example, we have following single station solution formats for station FTPP.

- FTPP (This is a CMR+ format which is older version of CMR and contains GPS+GLN based solutions)
- FTPPCMRx (This is a CMRX format which is newer version of CMR and contains multi-constellation or GPS+GLN+GAL+BDS+QZS based solutions)

What are the mountpoint solution formats in CMR for a network?

For example, we have following network mountpoints or solution formats for subnet NEMT.

- NEMTVRSCMR (This is a CMR+ format which is older version of CMR and contains GPS+GLN based solutions)
- NEMTVRSCMRx (This is a CMRX format which is updated version of CMR and contains multi-constellation or GPS+GLN+GAL+BDS+QZS based solutions)

What are the RTCM formats in MTSRN?

- RTCM 3.1
- RTCM 3.2 & above, or Multi-System Messages (MSM)

What are the mountpoint solution formats in RTCM for a single station?

For example, we have following single station solution formats for station FTPP.

- FTPP_3 (This is a RTCM3.1 format which is older version of RTCM and contains GPS+GLN based solutions)
- FTPP_MSM (This is a RTCM3.4 format which is updated version of RTCM and contains multi-constellation or GPS+GLN+GAL+BDS+QZS based solutions)

What are the mountpoint solution formats in RTCM for a network?

For example, we have following network mountpoints or solution formats subnet NEMT.

- NEMTVRSRTCM3 (This is a RTCM3.1 format which is older version of RTCM and contains GPS+GLN based solutions)
- NEMTVRS_MSM (This is a RTCM3.4 format which is updated version of RTCM and contains multi-constellation or GPS+GLN+GAL+BDS+QZS based solutions)

What are the multi-station mountpoint formats where software selects the nearest single station mountpoint for your rover?

Mountpoints with prefix MTSS_ are multi-station mountpoints. It provides single station solution, and software chooses the nearest single station to the rover.

- MTSS_CMR_PLUS (contains GPS+GLN based solutions)
- MTSS_CMRX (contains multi-constellation or GPS+GLN+GAL+BDS+QZS based solutions)
- MTSS_RTCM (contains GPS+GLN based solutions)
- MTSS_RTCM_MSM (contains multi-constellation or GPS+GLN+GAL+BDS+QZS based solutions)

Formats at a glance:

		Single Station (example for FTPP)	Network Format (example for NEMT)	Multi-Station	Constellation
CMR	CMR+	FTPP	NEMTVRSCMR	MTSS_CMR_PLUS	GPS+GLN
	CMRX	FTPPCMRx	NEMTVRSCMRx	MTSS_CMRX	GPS+GLN+GAL+BDS+QZS
RTCM	RTCM3.1	FTPP_3	NEMTVRSRTCM3	MTSS_RTCM	GPS+GLN
	RTCM3.4	FTPP_MSM	NEMTVRS_MSM	MTSS_RTCM_MSM	GPS+GLN+GAL+BDS+QZS

What kind of results should I expect using the MTSRN?

Just like with a base-rover RTK setup or static, there are many factors and sources of error that can affect precision and accuracy: sky view, capabilities of the rover, age and quality of the

rover and what constellations it supports, multipath, user errors, space weather conditions, and (to a much lesser degree) weather conditions.

In general, you should be able to get reliable and repeatable results under 3cm 3D with newer survey-grade gear. Note that there are many 'resource grade' receivers that are only designed to get sub-meter, sub-foot, or decimeter results; these are often used, and work well for asset or resource mapping.

How far outside of the network can I use it?

While the VRS corrections will work outside of the network, the rule of thumb for base rover RTK should be followed: no more than 10km beyond the outermost stations.

How much does the MTSRN cost?

For partners that invest in MTSRN infrastructure or host sites, there is no additional cost. For non-partners, there is an annual contribution, or "subscription" from the date of the subscription. This is $1,500 per year for each login.

Can I pay by the day, week, or month, and can I use a credit card?

The MTSRN is only set up for yearly accounts. This is a relatively small operation, without the resources to manage complex accounting.

How do MTSRN partnerships work?

The infrastructure of the MTSRN was funded and built primarily through partnerships: site hosts, contributions and loans of base receivers and antennas, power, communications, mount hardware, and software upgrades. To maintain, update, and improve the MTSRN, new hardware and software is added on a continuous basis. Partners are given logins in exchange for the contribution or loan of hardware/software.

The needs of the MTSRN change as we work through various upgrade phases, and especially as the technology changes and constellations modernize. For example, we may need antennas for a while, and new receivers at another time. Depending on the type/amount of hardware or software, a partner would receive 'x' number of logins for 'x' number of years. Contact us by email, mtsrn@mt.gov or phone, (406) 444-0240 if you'd like to hear current partnership opportunities.

We're a school or scientific institution, how can we gain access?

Most public schools are eligible for academic accounts, as do most scientific entities. Contact us and we can look up if you are eligible under those partnerships for accounts.

We no longer need the MTSRN, how can I suspend or cancel?

If you wish to suspend or cancel, please fill out, sign, and email us an 'Intent to Cancel Form'.

If the MTSRN is run by the government, why isn't it free?

Montana State Reference Network (MTSRN) is managed by Montana State Library (MSL) in accordance with 22-1-230, Montana Code Annotated. The MTSRN is a public/private cooperative. Subscription income is applied directly to operational costs, and together with partnerships, for infrastructure construction, upgrades, and maintenance. Every dime gets invested in the network.

Do You Send out Regular Bulletins Via Email?

If you sign up for any MTSRN GOVDELIVERY services, the email you provided is added to the email list for when we send out update bulletins. Your contact info is shared with no one. We usually only send to 2-3 bulletins per year, or if we are planning any major maintenance (though we typically do those after hours and users do not even notice).

If you receive a bulletin email and would like to stop receiving them, use the unsubscribe link in the bulletin. If you'd like to add a colleague to the email list, use the subscribe link in the bulletin.

I can't connect, have my logins been turned off?

No, unless it is an expired test account period. If you attempt a login with an incorrect password 10 times, it may lock. In that case, contact us immediately and we can do a reset. If you cannot log in, it is likely for the reasons discussed below.

I can't connect, is there something going on with the network today?

Very rare. Network outages are rare but can happen for various reasons. For such contingencies, we operate redundant servers that are identical without any differences in performance.

Are you doing maintenance on the system right now?

System maintenance and updates are done after hours, and typically on weekends (e.g., monthly security patches). For whatever reason that a server might be down (individual server uptime is over 98%) it is extremely unlikely that both would be down at the same time.

My logins are OK, and the network looks OK, why can't I connect?

This is almost always related to cellular service. It can be frustrating as you may see bars on your phone, voice works OK, and it may have worked OK on a different day, but that does not necessarily mean that data is steaming well enough where you are at that time. One easy check is to open a browser on your field data collector and navigate to a website (choose one that changes a lot as you may see a cached page otherwise). Another tool is a cell status app, like Network Cell Info Lite, that shows the signal strength in detail (for instance, a value of -100 dBm – 110 dBm often means spotty data streaming, and -110(+) dBm can mean no data streaming). Even though you show bars and have voice, the data streaming may be spotty or not flowing. iPhone users can also view a native analysis tool by cutting/pasting or typing *3001#12345#* into the phone dialer; this will show much the same info as the app mentioned above.

I forgot my username and/or password, can you give them to me again?

Please keep a copy of your credentials email handy and give one to your crews. And it's always a good practice to test your gear before going to the field. We can help if you are stuck in the field and forgot your password, but it might take some time.

What can I do in a poor cell environment?

You are at the mercy of the cellular coverage, and it might be poor in that area all the time, and somewhat usable on other days or different times of the day. The cell coverage maps from the main carriers are not always accurate but can give you a general idea. The carriers have been rapidly upgrading their systems and coverage. There are apps that show cell tower locations and what carriers are on each tower. If you have a built-in modem, see if you have the option of connecting an external cell antenna. It is hard to keep up on which carrier works best in which region of the state; that continues to evolve over time.

From feedback from users: some carry phones/modem for two or more carriers if they work in multiple areas across the state. Some users who use their phone as a hotspot or have a portable WiFi hotspot will put those on a telescoping rod to get some elevation; it is surprising how an extra 10' can improve cell reception in some places. Some WiFi hotspots come with an

external antenna jack (SMA coax connector). There are large dipole cell antennas, and directional (yagi-style, that you can point at the nearest cell tower). Adding a booster to the mix may not help: if you have RF 'garbage' coming in, the booster may just amplify the 'garbage'. In marginal cell areas, a booster can help, but it can be hit-or-miss. The in-line boosters work better than proximity-style boosters. An effective booster can cost hundreds of dollars and needs its own power source.

For spotty cell areas: switch to single base (but there are trade-offs). The reason this might work is that single base does not require consistent bi-directional communications with our caster like VRS does; a single base solution is a request that starts the flow, and if there are gaps in the flow, your rover will simply wait until it has enough data. The one big caveat is that if you are in an area with poor cell, there is likely not a reference station nearby, and the long-baseline, single base solution may be poor quality and inconsistent.

A key recommendation from users who encounter poor/no cell areas: collect static and or PPK and post process or use one of the commercial precise point positioning (PPP) services that broadcast from L-Band satellites (lower precision, especially in the vertical, but good in a pinch). The MTSRN has a post processing service for static observations (not PPK), for account holders; see more below.

My positions are off by several feet, what's up?

Another common support call is when the user sees values off by about 4 feet horizontal. This is a datum transformation issue. GPS/GNSS is referenced to WGS/IGS/ITRF, and the values you typically want to work in are NAD-based (i.e., the current national reference framework). These are two different ellipsoids, separated by about 2m at the center of the earth, which means different separations around the globe. Your field software does a transformation on the fly (i.e., the Molodensky transformation). The issue is in your settings. The MTSRN is constrained to NAD83-2011, and in some brands of field software you have to choose "No transformation" or you will be double transforming, which is about 4 feet in horizontal. For example, in some Topcon field software you choose "No Transformation", and in some Trimble software you choose "NAD83" and not "NAD83-2011". Consult with your equipment vendor on this. If your orthometric elevation values are off between 60-80 feet, that indicates that a geoid model is not being applied in your field software. Again, consult with your equipment vendor.

My positions, compared to published control values are off by several tenths, what's up?

The Earth is dynamic. Differences may be due to the age of the published values, and/or the methods used to establish them. Published values may have been established with legacy methods, or legacy reference frameworks that do not have the same network accuracy as more recent ones. Plus, the marks may have been set 50 or 60 years ago, and there may be many reasons why they might be suspect. We suggest doing checks shots on recently published NGS marks that have NAD83-2011 values. You may wish to use a "localization" or "calibration" (it is called different things in different vendors field software) routine if you need to constrain your project to old, published values.

What datum, or reference frame does the MTSRN work in?

The MTSRN constrains all reference stations to the National Spatial Reference Framework (NSRS) of the National Geodetic Survey (NGS). Currently, this is NAD83-2011 Epoch 2010.00. Vertically, MTSRN stations are also NSRS, expressed in ellipsoid heights. Orthometric heights, like NAVD 88 are derived in your field or office software by applying a geoid separation model, For instance, GEOID 2018 from the NGS. We recommend using whatever the latest geoid model is from the NGS. You can obtain the geoid files from the NGS or your GNSS rover vendor.

Does the MTSRN provide me with State Plane Coordinates?

No, the MTSRN works purely in geodetic references. Any plane projections or SPCS 2022 are done in your field or office software. Again, talk to your vendor about how to set that up in your field software.

Does the MTSRN provide grid or ground?

No. Again, this is all handled in your field or office software.

Does the MTSRN provide low-distortion projections (LDPs)?

Again, those are projections that would be handled in your field or office software.

Do I need to do any localization/calibration, or constrain to any passive mark to get a desired output for my project?

Although reference stations are adjusted to NSRS following the NGS guidelines, it is pertinent to note that the rover's position including orthometric height can't be more accurate than the

reference stations because the ppm error associated with RTN, error in hybrid geoid model along with other observation errors. There might be situation that you might use local monument(s) to bring your desired grid or ground output. Please follow the NGS guidelines to accomplish this localization (Henning, 2014 page 32-37, Constraining to Passive Monuments).

What do you mean by VRS and single base?

VRS is a type of network RTK (NRTK) that uses data from multiple stations surrounding where you are working, and creates corrections modeled for your location to send corrections, as if you have a base right next to you with a near-zero baseline length.

Keep in mind that the “virtual” in VRS is a bit of misnomer. It refers the corrections derived from the surrounding stations, but there is also direct relationship to a physical reference. Typically, the nearest station in the VRS solution is the source of reference coordinates. This can be found in different field software under the name PRS (physical reference station) or PBS (physical base station). You can export (in your field software) vectors from the PBS/PRS for inclusion in post processing, same as with vectors from single bases.

Single base is where differential-style corrections are from one individual station. One drawback of single base is that results degrade over distance, typically at distances of 10 km or more. Real-time networks globally found that NRTK allowed for much greater station spacing; it would be impractical to be able to afford to build a network with 10km spacing. With NRTK they can be spaced at 30km-70km (depending on local conditions). That was the impetus for developing network corrections and RTN.

Can I receive MTSRN corrections with my rover radio?

Not directly. With the limited range of radios, it would be impractical to set up enough base radios to cover large areas. Some users though, use a modem to receive corrections from the MTSRN and rebroadcast them via base radio, or various types RTK bridges. This approach is employed, for instance, for some construction sites.

Can you help me set up my rover?

In short, no. While we will try to help, we are not versed in every hardware/software combination, and that is more rightly the responsibility of the vendor that sold you the rover, through whatever support arrangement you have with them. When you receive login credentials from us via email when you first start working with the MTSRN, it includes the key things you will

need to put in the settings of your field data collector software, like caster address, and port. In general, you look for any screen in your software that has key words like ‘NTRIP’ or ‘caster’.

We may have a general idea of what different manufacturers call different settings in their software, and will try to help if we can, but the best bet for settings help is to ask the vendor first. If the vendor gives you the new gear with the settings preset, we recommend you go over those (in detail) with them. Becoming familiar with the settings, and how to change them if needed, can help avoid getting stuck in the field trying to figure things out. Like if someone has changed your settings, or if you need to change them for other reasons.

Where do I find the current positions of the stations (e.g., for post processing)?

You can go to the sensor map and click on any station, then choose the info tab. That will list the live NAD83-2011 Epoch 2010.00 position and ellipsoid height of the antenna reference point (ARP) of the station.

What do the different color dots on the web map indicate?

On the sensor map, green indicates that the station is connected and in solution. Yellow indicates that we may have a connection, but that there may be an issue with data completeness, spotty comms, or data quality and that it does not presently meet standards for inclusion in the solution. Red means we have lost connection altogether for the time being.

Why is that station down?

Stations might be down for various reasons, mostly comms, or weather in the winter. For instance, a station (with power source of solar panels) can be down for weeks at a time in winter (deep snow over the solar panels). Most often with sites, an outage can be attributed be spotty comms that usually gets better in a matter of hours or a day. We usually pass this with the point-of-contact person for the station. Fortunately, even if individual stations are down, the network solution (VRS) is usually still fine—another reason why RTN were developed.

Is the MTSRN multi-constellation?

Yes, currently there are 54 stations that receive signals from US Global Positioning System (GPS), Russian Glonass (GLN), European Galileo (GAL), Chinese BeiDou (BDS), and Japanese Quasi-Zenith Satellite System (QZSS), 16 stations receive GPS+GLN+GAL and 5 stations receive GPS+GLN only.

What does ‘MSM’ mean?

This means ‘multi-system message’, a term used for RTCM corrections that support multiple constellations. We use MSM as a suffix for any of our mountpoints that provide RTCM3.2-MSM corrections, a format that nearly all newer rovers can use. This is the format we recommend users of newer gear use so they can take advantage of as many satellites and signals as possible.

The login page for the MTSRN asks for an ‘Organization’, what is my ‘Organization’?

The organization is the group, or type of account you have. When you receive your MTSRN credentials via email it will state your organization.

How do I get Rinex files for post-processing?

You can use MTSRN website (www.mtsrn.org) to get static files for post processing.

If you are looking for static files within the past 60 days, you can use the ‘Reference Data Shop’. Log in to the website (with your credentials or as a guest) and look for that option in the upper left. You create a request, choose one or more stations, a time period, type of static file you want, and sample rate. Orders must be specified in GPS time, which is (for ordering purposes) the same as Greenwich Mean Time (GMT). That is 6 or 7 hours different from local MT time depending on the time of year.

Note your order numbers. It may take a while to process the order (usually 5 min to an hour depending on how much you order), but you can log in later and see your order status. Never pick the email option (this is disabled due to potential file size issues)—choose the download option. When the order is ready you will see a download link; it will download as a single .zip file.

What is Virtual Rinex?

Another option in the “Reference Data Shop’ is Virtual Rinex. Using the same network (VRS) processing in our system, a static file is modeled from 6-9 stations around a location you specify in the order page. Other than picking a ‘virtual’ location it is the same steps as a regular static data order (see above). Once processed, it will show a download link of a .zip of the single Rinex file. It will post process just like any other Rinex.

Virtual Rinex was developed to be able to reduce the length of static sessions, though with as many satellites as there are now, it is not used as much as in the past. There has been a resurgence of use more recently, with UAS (drone) operators finding it can be a good option in some situations for PPK post-processing.

Please note: the storage of the specific data needed to create virtual Rinex is very resource intensive, therefore **we only keep the source files for two days**. If you plan to order Virtual Rinex, please do so within two days of your field work.

What is NTRIP?

You will likely see this term in the settings of your field data collector software. NTRIP is 'Network Transport of RTCM over Internet Protocol'. It is an international standard for accessing real-time network (RTN) data. It was created decades ago by the BKG (German geodetic and mapping agency), when RTN were first developed, and adopted by the international Radio Technical Commission for Maritime Services (RTCM) 104 committee. The core code has been adopted by GPS/GNSS manufacturers. NTRIP consists of 'casters', like those the MTSRN and all RTN host, that allow multiple users to access multiple 'sources', or 'mountpoints'. One analogy for NTRIP is that it is like an app that connects to a web service listing many steaming music or video channels: but with GNSS corrections instead.

The other component of NTRIP is the 'client'; the software in your field controller is the client. Required settings are a caster (typically an I.P. address of a caster), a port, a username and password, and you choose a mountpoint. See our mountpoint naming convention guide. Often, the field software builds list of mountpoints each time you access the caster, in some software you need to manually refresh the list. Depending on the software, if you choose single-base or network (e.g., VRS) you will see different lists. In some, you see all the many hundreds of mountpoints.

Why are there so many different mountpoints on the list?

We need to offer different flavors (standard formats) of corrections to serve a wide range of rovers, new and old. For instance, CMR+ (GPS+GLN) for some older rovers, RTCM3.1 (GPS+GLN) for other older rovers, CMRx and RTCM3.2-MSM (GPS+GLN+GAL+BDS+QZS) for newer, multi-constellation rovers. You would not see any significant difference between results

from any of the formats, except that some support more satellites. See our mountpoint naming convention guide.

So, for 75 stations, and 5 VRS subnets, with 4 formats supported each, that adds up to a very long mountpoint list. One frustration is that the original core NTRIP code does not do alphabetical order. However, many of the field software manufacturers give you an option to list them in alphabetical order once the list is refreshed. Otherwise, keep scrolling and you'll find it eventually. Note that if you refresh when a particular station is down, it will exclude it, and you might need to refresh later when it is back up.

I can't connect, am I being jammed?

The short answer is no. Things like jamming, interference, and spoofing are rare. Examples are mostly related to altimeter radar at the end of large runways; it only happens when that is turned on for a plane to land, it is brief, and it simply blanks out any GPS/GNSS reception. Working under high power transmission lines is usually OK, but there have been some rare occasions where it messes up the cell and GPS/GNSS signals.
Deliberate jamming is rare, and usually occurs only in combat zones. Even in those instances it is very localized, focused, and mostly brief.

Other RF interference is rare, and there are no persistent areas of interference in our state that we know of by now. Interference, when it is present, would mostly result in a denial of service, and not a false position. A map of persistent interference/jamming zones is: gpsjam.org.
Incidents of suspected GPS issues should be and are reported to the U.S. Coast Guard Navigation Center: NAVCEN and investigated by multiple federal agencies. Spoofing is when a party deliberately overrides signals to create false positions. It is rare, difficult to do, and would result in values being many miles off, and not just a few tenths.

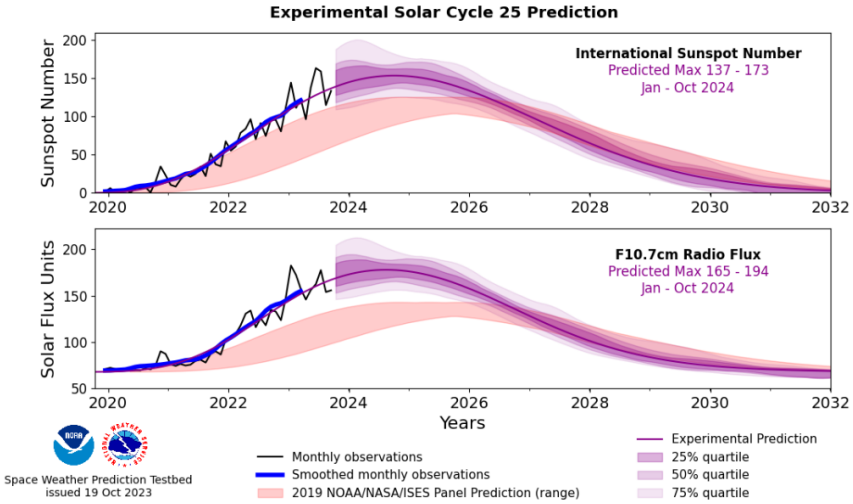
There are signal jammers like the cheap "trucker jammers" that some people have used to jam their on-board GPS to block being tracked. This is very rare, highly illegal, and only a few cases have been confirmed (nationwide). Plus, the vehicle with the jammer is moving and you might not even notice the few epochs of outage as it passes by.

We have spectrum analyzers on many of our reference stations (and have never seen any persistent interference). Plus, we have some portable devices, so we can investigate areas of suspected interference if need be.

Can solar storms mess up my results?

Yes. Though relatively rare, please note the solar cycle info below.

Solar Cycle 25. We are approaching the peak years of the latest solar cycle (the 25th since the phenomenon was tracked) which coincidentally will peak in 2025. There could be brief periods of high activity that can impact (mostly older) GNSS field gear. For example, the solar storm of May 10, 2024. Below is NOAA's current prediction:



NOAA's Space Weather Prediction Center released a revised prediction for solar activity during Solar Cycle 25. The new Experimental Solar Cycle Prediction issued on Oct. 25 concludes that solar activity will increase more quickly and peak at a higher level than previously predicted The updated prediction calls for Solar Cycle 25 to peak between January and October of 2024, with a maximum sunspot number between 137 and 173. (NOAA)

How could this affect field operations? The types of symptoms you could see as a result of increase space weather activity can include:

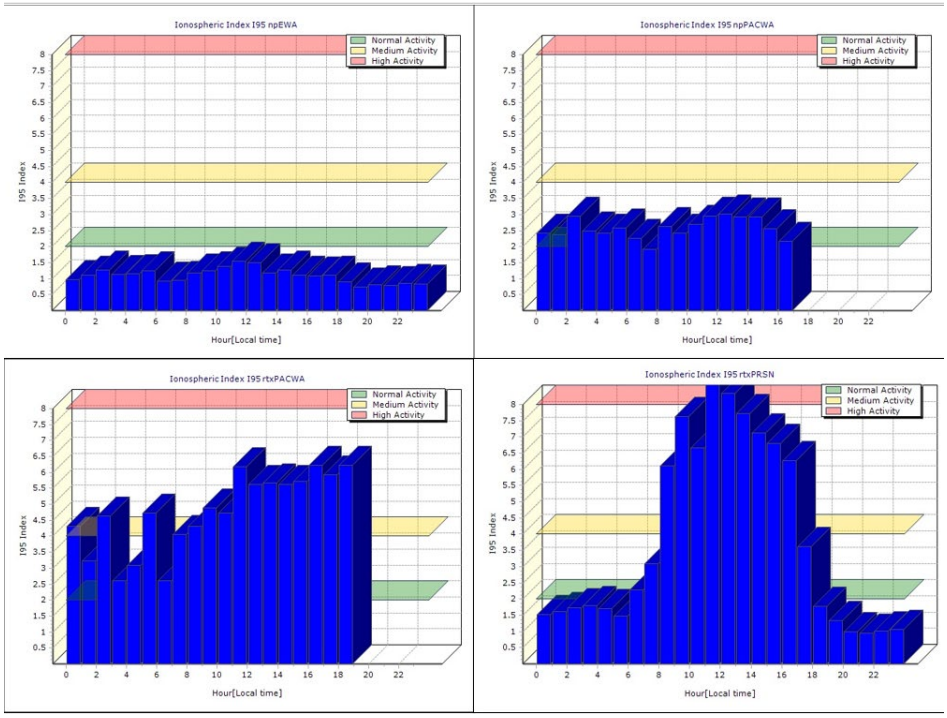
- *Significantly longer time to obtain fixed carrier phase ambiguities.*
- *Fixed navigation solutions with increased predicted precision estimates.*
- *Float or differential navigation solutions rather than fixed*
- *Biased fixed navigation solutions due to bad ambiguity fixing.*

Combinations of the above can lead to reduced productivity.

How can I tell if the symptoms are due to space weather issues? Your issues may be due to other factors, but you can see what the current space weather status is to help troubleshoot**.** Like many RTN, our network tracks the effects of ionospheric activity with data from our own sensors. To see the status (for the current day or past days), log into either of our websites and choose the 'I95 Ionosphere option in the upper left'. The I95 is a common index (Wanninger) that has been adapted for the I95 index on our network. The value is calculated for each subnet; it is one value. The higher it is, the more likely a rover will be impacted by ionospheric disturbances.

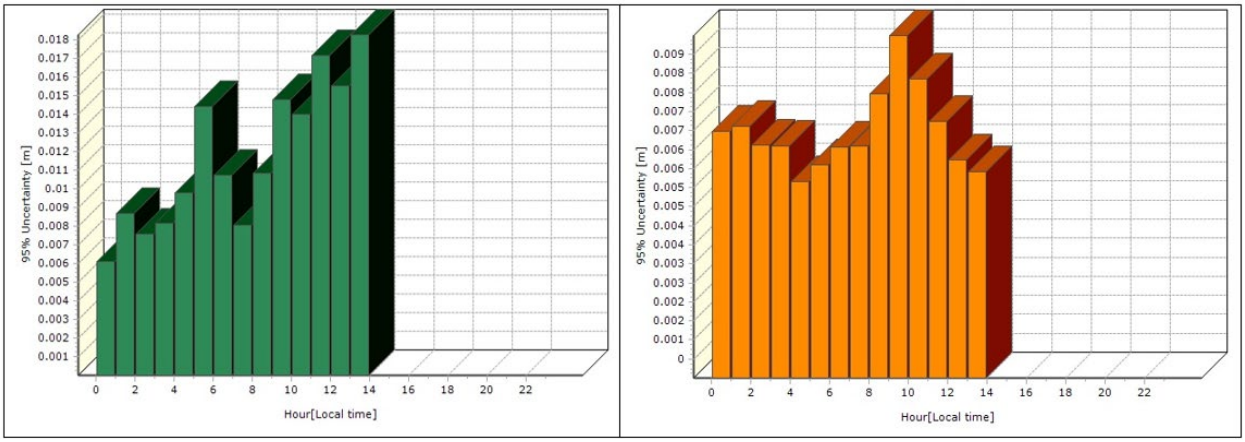
The rule of thumb for interpreting the I95 (as adapted for our network) is:

- *Below 2 (below green): Very low activity, no impact*
- *Between 2 and 4 (between green and yellow): Normal activity, very little impact*
- *Between 4 and 8 (between yellow and red): Increased activity. Impact can be noticeable (e.g., longer initialization times for the rover)*
- *Above 8 (above red): High activity. Impact very likely noticeable (e.g., potentially no rover fixes at all)*



Examples of I95 plots from different subnets on different days. Clockwise from upper left: Below 2 (very low activity), Between 2-4 (normal activity), Between 4-8 (increased activity (noticeable effects), Some periods above 8 (possibly no fixes).

IRIM/GRIM graphs. There is another set of plots that can help estimate what the positional errors might be due to space weather conditions. Values show the "predicted remaining error" and indicate estimated impact you could expect in a rover measurement. This is the error that remains that cannot be completely modelled out. IRIM/GRIM can be calculated for the whole network or for individual stations. The network value is an average of the individual stations in a subnet. The method works in a way that e.g., network software takes the whole subnet, takes out one station and sees how the Iono model fits to the actual observations on that station. The part that does not fit is represented by IRIM. GRIM shows the remaining error in respect to the coordinate. In the example below, during a heightened space weather period, you may have 18mm of IRIM error (left), and 9mm of GRIM error (right) remaining. Of course, the conditions for where you are may vary, but these plots can be a good indicator of expected results. Typically, you will do better than the plots indicate, as they are looking at a whole subnet.



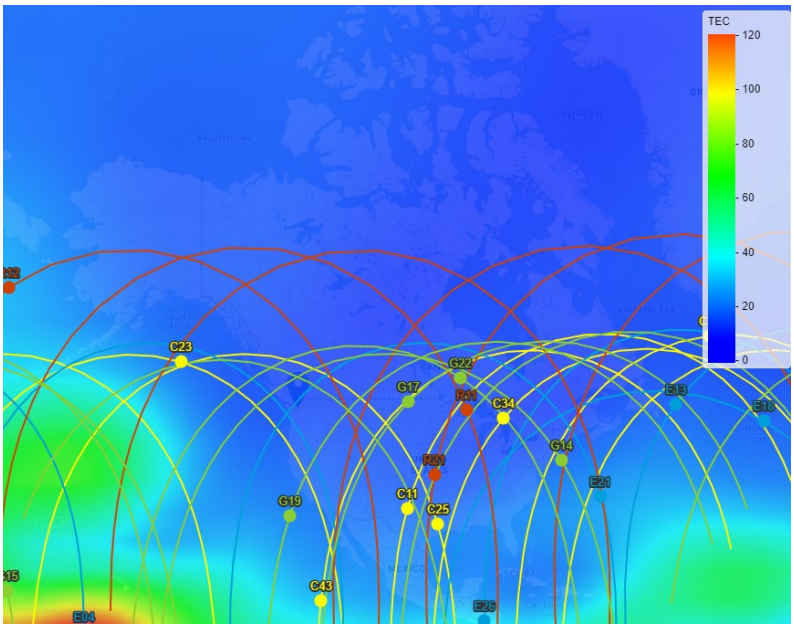
Example IRIM plot (left) and GRIM plot (right).

Note that if you can fix (even under high conditions), you are probably Ok, but keep an eye on your residuals. Only when it goes into the red for several hours would you see enough degradation to consider using non-GNSS methods. If you have a handheld recreational GPS unit, and it is having trouble getting a position, that can confirm that the current conditions will not be good for your rover.

How can you predict what the conditions will be for a given day? That is a challenge that even the scientific community struggles with. However, you can look at trends in current conditions. The I95 only shows what the present conditions are, but as it updates hourly, you can see the way it is trending. You may see many kinds of space weather alerts from various

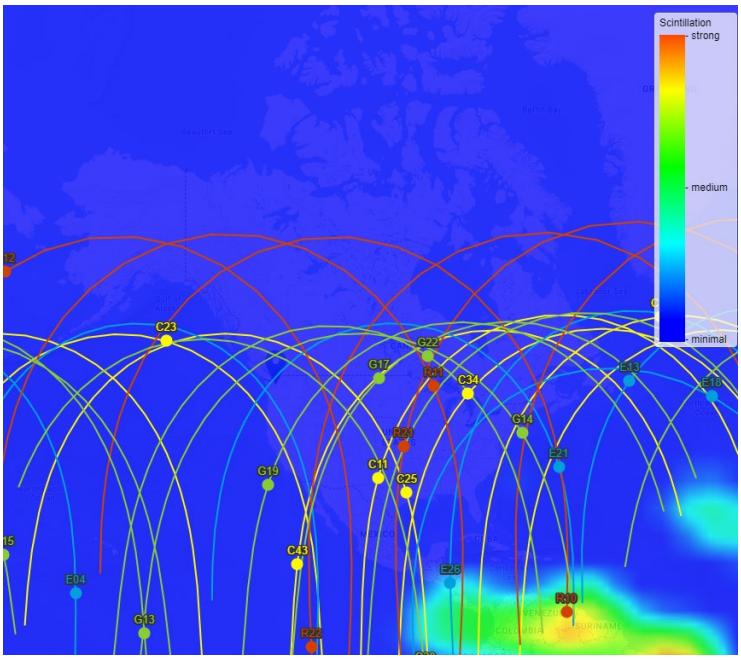
scientific agencies/institutions. Those alerts may be reporting levels of activity that would likely not impact your operations but are provided for scientific applications.

The GNSS Planning Tool linked at the bottom left of our websites (then choose “World View”) gives you look at the conditions centered around your location (you have to go to ‘My Settings’ in the tool to set your location). Not only can you see the availability of various satellites, but also the total electron content (TEC), which gives you an idea of how rough it might be out there. You can’t go forward in time, but you can see the general trend of the iono that would be headed to your region as the world turns and the time-of-day changes. The tool also has an option to “playback” a whole period to see how the conditions progressed.



An example TEC map, centered on Western Washington, also showing a snapshot of satellites.

Note that you can also see the ‘Scintillation’ map. During heightened space weather conditions, scintillation can occur more often: acute but often brief events that can cause brief spikes in disruptions. NOAA and others are working on better prediction tools, but for now, you can look at ongoing current daily trends to see what you might expect. There can be increased scintillation at dusk and dawn, and the general Iono peak is usually around midday.



An example scintillation map, centered on Western Washington, also showing a snapshot of satellites. Note that during this snapshot in time, the observed scintillation is far way in Central America.

How can we make it through this cycle with minimal disruption? The good news is that with multi-constellations/signals your field operations may not be as adversely affected as when there was a single constellation. Plus, some manufacturers have released, or are working on software upgrades for newer rovers that can substantially mitigate (all but the most severe) conditions. Users made it through the previous cycle with only spotty disruptions, chances are this one will be the same.

A caveat about single base operations: if you do single base on one day with calm ionospheric conditions, you may get different results than on a day of high ionospheric activity. Network corrections, like VRS are often the better choice, but neither will have much luck if in the red. There are hazards to mixing solutions: If you start a project with one method, you may get different results when switching baseline lengths or on different iono status days.

In short, we could be in for several years where the potential for detrimental space weather effects could be heightened on occasion. However, with today's modern equipment, you may only experience issues when the values are "in the red".

Is single base better than VRS?

It can be, but only under very specific conditions. Single base degrades over distance. If you have a site base (that you can see from the rover, or under a km), or a station within a few km, that may yield better results than VRS on good iono days but may vary from day to day. One rule of thumb is to not use single base if you are more than 10km from a station or base. For single base to work best, the base must be set up in as good, or better, sky conditions than the rover, with low multipath conditions, and it has to support the same constellations as the rover—and it does not get stolen.

It is possible (yet not recommended) to get fixed results from single base at very long baseline lengths, 20km, 30km, and more. The problem is that you will not get consistent results at long baseline lengths as the conditions could vary from day to day, even hour to hour.

Contrary to some marketing-driven rumors from the early days of RTN, VRS does include a physical base station (PBS or PRS); a PBS code is in all VRS corrections. The model of the corrections is virtual, but there is still a tie to a fixed station. Nearly every rover that can export vectors can export the rover-PBS vector.

When I connect to VRS, sometimes I see less satellites, why is this?

It depends on the age of your rover. There are new sats and signals that were only implemented in the past few years. An older rover may not be able to utilize all of the sats and signals it "sees". In legacy VRS/MAC/FKP solutions, it would cull out some satellites that were not fixing, to create the corrections. Your rover would likely not use bypassed sats for the same reason. And your rover needs to use satellites that are in common with 6-9 surrounding stations.

How will the deprecation of the U.S. Survey Foot affect the MTSRN?

No. Any projection to plane coordinates, and feet units is performed in your field and/or office software. There will be no changes to the MTSRN related to measurement units. The MTSRN operates with geographical references, constrained to the National Spatial Reference System of the National Geodetic Survey (i.e., NAD83-2011 Epoch 2010.00) and applies geographic values (i.e., Lat/Long) and an ellipsoid height in meters.

Users should consult their respective local jurisdictions and applicable state agencies for any requirements to work in international feet and consult vendors for any questions about how to

apply this (if applicable) in their field and/or office software. Read more about the deprecation of the US Survey Foot here.

What are the MTSRN plans for the upcoming national datum shift?

The National Geodetic Survey (NGS) is planning on a new reference framework, NATRF22 (but will likely be in 2025 or 2026). This is a significant shift, much like the change from NAD27 to NAD83. Our network and primary caster will be in NATRF22, and we will try to provide an alternate caster in NAD83-2011 for a transition period.

What field procedures should I use to gain confidence in my results?

This is a subject that would take volumes to cover and is much discussed among surveyors and mappers. Using the MTSRN or any other RTN is not different from RTK fundamentals for base-rover, the baseline length considerations we discussed earlier aside. All the MTSRN operations team are surveyors or professinals, and we are keenly aware that they must do whatever steps and analysis may be needed to have confidence in their data—confidence enough to stand behind their data. How each surveyor approaches this process is their call based on their own knowledge and experience. Therefore, we do not weigh in on what the “best” approach would be. Instead, we can relate some of the best practices our users have developed, and what we hear from peer RTN.

As with any use of GPS/GNSS, it is a rather mind-blowing proposition that using satellites 20,000km out can deliver what is needed to get centimeter results, as there are multiple sources of error that can affect quality and repeatability. When taking a field ‘shot’, an amazing convergence of physics gets applied, and in short, a best practice is to see if it can do that magic repeatedly under the same conditions and in slightly different conditions. To do this, multiple observation methods are best practices, doing things like reinitializing, and checking in on test marks, etc. There are tools in the many different field software packages that can help you do this in the field.

Some manufacturers accommodate multiple shots on the same point for a statistical analysis. Some users will reobserve at a different time of day, to affect a different satellite geometry (though there is less of a need for that with so many satellites up there now). There are even options in some field software to have it choose different geometries from the many satellites for you. Some may also offer an option for long observations, say minutes, and it does a kind of

convergence, reducing outliers. Your vendor would be the best resource for what approaches might work best with your specific gear.

Where can I find control points to check into?

A common method to test your field gear is to check results against published values on passive control marks. While there are caveats to doing this (more on this later), it is a practice that can be quite valuable.

There are many National Geodetic Survey horizontal and vertical control marks, and you can find datasheets for them through their interactive map and text lookup: geodesy.noaa.gov/datasheets/

Keep in mind that when you are comparing an observed position to a published position, you must make sure you are comparing apples-to-apples. When using passive control, you need to consider the source, method of establishment, reference framework (datum), and especially the date. For example, there are control marks that may have multiple published values, and none of them are "wrong". A mark might have an NGS value, a local county value, etc. They are all valid for the specific folks who published that value. However, you need to consider what datum and year the values were established. Due to plate tectonics, the value may have changed as much as 0.5' over 20 years. And there have been successive reference framework (datum) updates.

The MTSRN constrains all stations to the National Geodetic Survey active control; the NGS CORS. When you use the MTSRN, you get a position in the NAD83-2011 Epoch 2010.00 reference framework, the same as if you did an NGS OPUS solution. Is the control record expressed in the same reference framework? Likely it has but look at the date of the record an consider how much plate movement has happened in the intervening years.

Establishing your own check point can be very useful. Some firms and public entities set a point, for instance, in their parking lot. It comes in handy for seeing if all your gear is working before you head to the field. And to see if all the settings are OK and you are getting the values in the reference framework you are expecting. There are several common ways folks establish coordinates on their own check points. You could do several days of long static and submit to NGS OPUS. Or do several hours of static and use the MTSRN online post processing tool for

several hours. But also keep in mind that (depending on where you are in the state), the plate velocities can change values even after just a year.

Another idea for a checkpoint could be to establish one in public right of way, and Bluebooking it with the NGS. Once it is in the NGS database, they may publish new values when there are iterations of the national spatial reference framework. This could be handy as a check when there is a new published datum (e.g. when the pending NATRF2022 supersedes NAD83-2011). Even if not Bluebooked, you can determine your own values for the new datum on your check point.

What are the different networks on the printable map?

You should have received a PDF map of the MTSRN with your login credentials email. And you can get updated the latest version from the 'printable map' link in the lower left of the webpage. It is schematic, and not-to-scale.

You will see designators like 'NEMT' for Northeast Montana subnet, SWMT for Southwest Montana, etc. There are respective VRS solutions for each subnet. The subnet is the prefix for VRS solutions in the mountpoint lists. And the suffix is the corrections format i.e., MSM is RTCM3.2-MSM; multiple constellations. See the Mountpoint Name Guide. It is very important that your crews know how to change mountpoints, especially if working in a different part of the state.

Are there some recommended presets for using the MTSRN?

In some survey software they call presets "survey styles". Having the presets means they can switch back and forth easily, one for VRS, and one for single base. A naming convention can be: "MTSRN_VRS", and "MTSRN_SB".

How far outside of the network can I use it?

While the VRS corrections will work outside of the network, the rule of thumb for base rover RTK should be followed: no more than 10km beyond the outermost stations.

Does the MTSRN have an automated post-processing service?

To provide our users with an option to post-process (e.g., when they work out of cell range, or wish to check control values) we have an automated service that constrains to our stations, and the NGS CORS (that are within tolerance). Registered users (e.g., partners and subscribers)

can log in, choose ‘Online Post Processing in the upper left of the page, submit static files from 6 minutes to 6 hours (please convert them to Rinex first) and our system does the baseline processing. It will return a PDF and/or an XML report of the results as NAD83-2011 geographic coordinates (not state plane; you will need to convert that yourself.

Can I use the MTSRN for my drone operations?

Certainly, but there can be a lot of nuances to this answer, as there are many different approaches that drone (UAS) operators take to meet their desired relative/absolute precision and accuracy goals. You can use the MTSRN services, real-time and static, as part of such varied approaches—when appropriate.

For many drone operations, setting up a base on the site can be the best choice. Be that for real-time (RTK), or post-processing (baseline and PPK). This is because a very short baseline length can yield the best results. However, if your site is only a short distance from a MTSRN station (e.g., under 10km on a good iono day), this could work well for RTK and/or static post-processing. Some users use VRS for their real-time data, and/or for establishing ground control points (GCP). Some users will use Virtual Rinex, requested for a virtual location on the site. Generally, working without GCP is not a preferred choice, unless you are only interested in relative precision, and even for that, including at least some GCP can be a best practice.

One aspect of processing drone data is the inertial (IMU) data, that when processed together with the observations from the on-board GNSS, in a PPK workflow, has grown in popularity. It is not as if PPK is much different than RTK (it is simply delayed RTK so to speak) but the addition of the IMU, and precise orbit data, that can make a difference. Your drone vendor can recommend software to do this PPK/IMU step. This is essentially the same as many mobile mapping workflows.

General Geodesy, Surveying, and Technology Questions?

If a question is directly related to access to your account, and/or the status of, the MTSRN, we are more than happy to answer emails and calls as rapidly as we can get to them. However, there have been many instances where folks get the impression that we offer more services and support than we are chartered to. Some misconceptions:

Is the MTSRN the state geodetic entity? No, even though we do operate valuable geodetic infrastructure, constrained to the NGS reference framework. If there are matters of geodetic control, then you should contact the entity that established the control, like the NGS, MDT, cities counties, etc. For anything NGS related, contact your NGS regional advisor.

Does the MTSRN publish surveying standards? No. Surveying standards (and recommendations) are published by federal, state, local, and private entities (e.g., ALTA), and professional associations/societies. The MTSRN offers infrastructure and corrections and does not otherwise publish any procedures or standards.

Does the MTSRN support user hardware and software? No. As explained in a prior section, there are too many combinations of make and model; your dealer or vendor is a better source for this type of support. Plus, we are prohibited from doing that: we cannot be doing the work that your service/support vendor should be doing.

Is the MTSRN is a great 24/7 resource for anything tech related? No. Our operations hours for support are 9:00am-3:00pm M-F. We try to be as helpful as we can, and try to make the service work for everyone.

Some of the terminology in the FAQ is unfamiliar, can you explain those?

We aimed the FAQs at the core user groups, like surveyors, mappers, construction, etc. But there are new user segments and if there are answers in the FAQ that you'd like further explanation on, contact us by email. Then we can set up a call or online meeting (or group training) to explain; we might be delayed but will get to those as soon as we can.

Contact

RTN Coordinator

Email: mtsrn@mt.gov

Phone: (406) 444 0240

Acknowledgement

Mr. Gavin Schrock, Washington State Reference Network (WSRN)