APN-061:
NovAtel CORRECT™ with PPP using TerraStar Corrections

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Contents

April 6, 2016

What is NovAtel CORRECT™?

All applications have requirements and technical challenges that will drive your decisions about what GNSS products you need. What level of solution accuracy do you want? What are your operating constraints? Is your system connected to the internet or is it more isolated? Is the accuracy or solution availability more important to you?

NovAtel CORRECT offers a variety of options, to ensure your GNSS receiver will meet your every need.

Whether it's an RTK solution, for highest accuracy and availability, a PPP solution when you need to meet high accuracy requirements without all the extra setup, or a simple low accuracy, lower cost solution, NovAtel CORRECT offers it all.

Providing a single source of GNSS hardware, correction services and support, NovAtel CORRECT simplifies the process of acquiring the best possible position. NovAtel CORRECT RTK and PPP solutions are designed to work optimally together to deliver decimetre or better positioning. Most importantly, NovAtel CORRECT exemplifies NovAtel's OEM partnership model by offering system integrators and dealers flexible, scalable and competitive positioning technology with great opportunity for future innovation.

For more details on NovAtel CORRECT, visit our website:
http://www.novatel.com/products/novatel-correct-ppp

Figure 1: NovAtel CORRECT

What is PPP?

Precise Point Positioning (PPP) is a positioning method that uses precise, globally-applicable GNSS corrections to obtain a solution with decimetre-level accuracy. NovAtel CORRECT offers an innovative, real-time PPP solution designed for NovAtel OEM6® receivers with no additional base station infrastructure required.

Acquiring a real-time decimetre-level PPP solution depends on the reception of GNSS satellite clock, orbit and signal-bias corrections that are generated from a network of global reference stations. Once the corrections are calculated, they are delivered to the end user via satellite or over the Internet. These corrections are used by NovAtel CORRECT on a dual-frequency OEM6 receiver, resulting in decimetre-level or better positioning with no user-supplied or local base station required.

A typical PPP solution requires a period of time to resolve any local biases and converge to decimetre accuracy. The actual accuracy achieved and the convergence time required is dependent on the quality of the corrections and how they are applied in the receiver, as well as the local observing conditions.

Since PPP solutions are not dependent on a local reference receiver or network, users can achieve decimetre-level positioning in areas where it is not practical to use traditional RTK techniques. Delivery of the correction data over L-Band satellite means any user who can see the satellite has access to corrections, making PPP an ideal solution for precision applications in areas where communications infrastructure is either unreliable or not available.

If the PPP corrections and receiver algorithms are sufficiently advanced, then PPP ambiguity resolution is possible. Ambiguity resolution refers to the determination of the integer number of cycles in the ambiguous carrier-phase measurements. With the ambiguities resolved, the full accuracy of the carrier-phase measurement is unlocked. This, in turn, yields a corresponding improvement in solution accuracy. With a high-quality correction feed, even RTK-level accuracies are possible. PPP ambiguity resolution also improves the ability of a PPP solution to recover following signal interruptions: without ambiguity resolution, there can be discontinuities and re-convergence periods in solutions following signal interruptions; with ambiguity resolution, solutions can instantly recover to full accuracy.

PPP ambiguity resolution is possible on OEM6 receivers with a TerraStar-C subscription.

NovAtel CORRECT with PPP combines NovAtel's state-of-the-art receiver error models and positioning algorithms with TerraStar satellite (L-Band) delivered corrections, providing up to 4 cm of horizontal accuracy (RMS)[1] and instant re-convergence. NovAtel offers two TerraStar service levels with accuracies ranging from 4 cm to 40 cm for land, airborne and near-shore applications[2]. For more details, visit the NovAtel CORRECT with PPP webpage: http://www.novatel.com/products/novatel-correct-ppp

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[1] Calculated from 7 day static data collected in Calgary using GPS & GLONASS. Accuracy will vary with observing conditions.
[2] For marine applications, refer to "APN-062 NovAtel CORRECT with Veripos" available here: www.novatel.com/support/search/items/Application%20Note
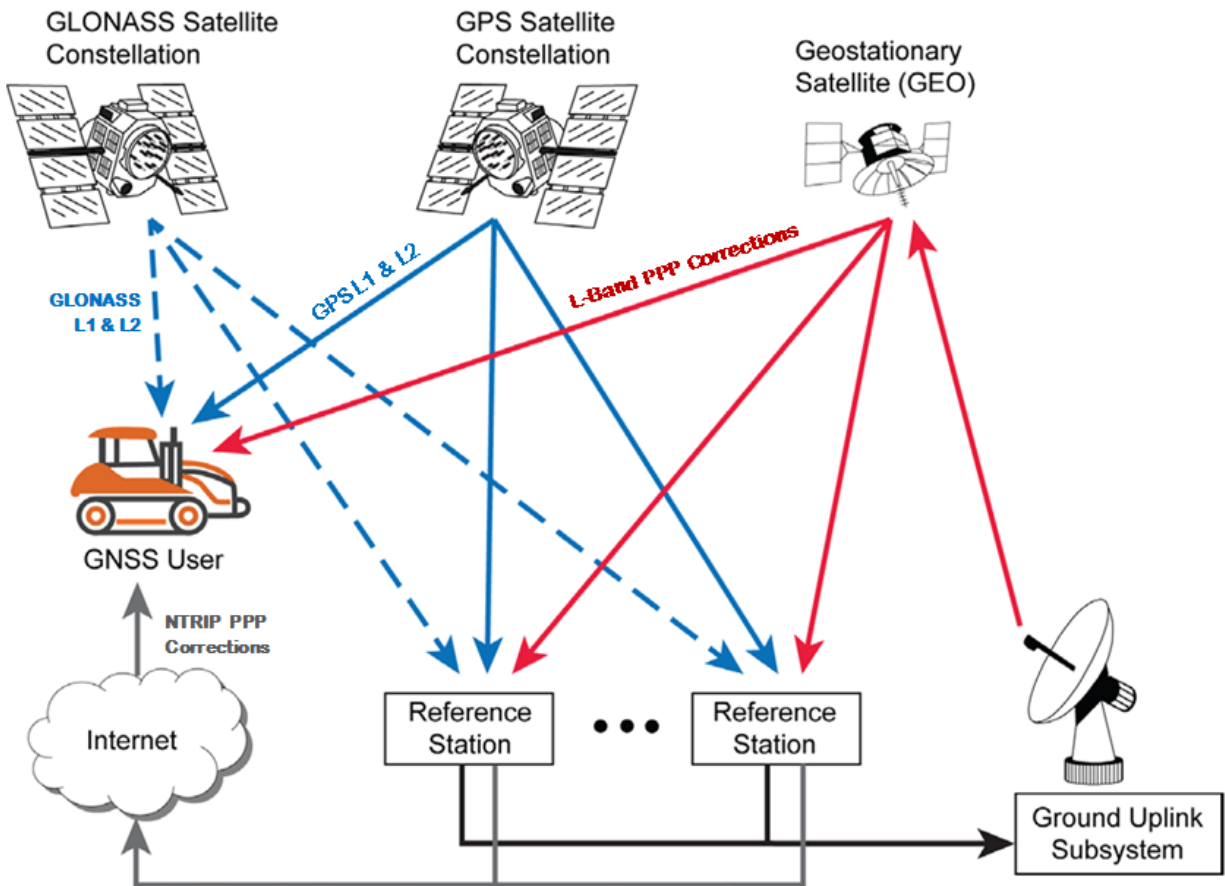
Figure 2: Typical PPP Infrastructure (L-Band & Internet Delivery)

What is TerraStar?

TerraStar is a global provider of precise satellite positioning services for land and near-shore applications. TerraStar owns, operates, maintains and controls its global network of over 80 GNSS reference stations and the associated infrastructure to ensure maximum operational reliability of its augmentation services for land precise positioning[3]. Corrections provided by the network are broadcast via seven geostationary satellites or "beams". For more information about TerraStar, visit www.terrastar.net.

TerraStar-L

TerraStar-L is a real-time correction service that includes GPS and GLONASS satellite clock and orbit corrections derived from the TerraStar network of reference stations that can be used in applications requiring decimetre-level to sub-meter accuracy.

NovAtel CORRECT with PPP is available using the TerraStar-L service on OEM6 receivers loaded with firmware version 6.700 (OEM060700RN0000) or later.

In order to use the TerraStar-L service, a subscription must be purchased for each receiver. To purchase a TerraStar subscription, contact your NovAtel dealer or sales office.

TerraStar-C

TerraStar-C is an advanced GNSS correction service that provides additional information, including higher rate clock and orbit corrections, and makes PPP ambiguity resolution possible. The benefits of using TerraStar-C corrections include sub-decimetre accuracy, faster initial convergence, and faster re-convergence after GNSS outages. Overall, using TerraStar-C corrections will provide more robustness and will enable better performance in all environments than the previously offered TerraStar-D service.

NovAtel CORRECT with PPP is available using the TerraStar-C service on OEM6 receivers loaded with firmware version 6.600 or later. Although receivers loaded with versions 6.400 or 6.510 can still accept a TerraStar-C subscription with no impact to the operating performance of the receiver, a firmware update to version 6.600 (or later) will be required to gain all of the benefits associated with TerraStar-C. Until the firmware is updated, the additional messages in the TerraStar-C subscription will be ignored by the receiver.

In order to use the TerraStar-C service, a subscription must be purchased for each receiver. Depending on the specific needs of the application and end user, different types of subscriptions can be purchased with flexibility in length and region. To purchase a TerraStar subscription, contact your NovAtel dealer or sales office[4].

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[3] www.terrastar.net/about-terrastar.html
[4] www.novatel.com/where-to-buy/sales-offices/

Coverage

There are seven different L-Band satellites that broadcast TerraStar corrections for specific regions and the distribution of the L-Band satellites allows for dual coverage in virtually any location. To provide additional coverage and redundancy, especially in large regions or countries, information for regional subscriptions is broadcast on the three beams best suited for that region.
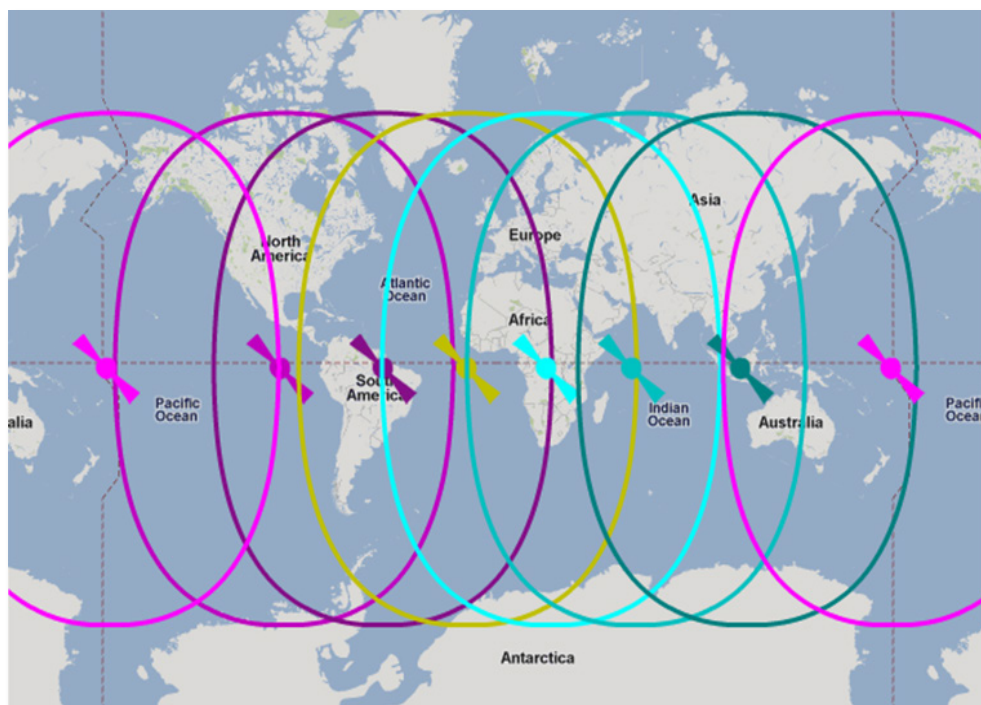
Figure 3: Global TerraStar Coverage

Coverage areas for specific beams can be viewed on TerraStar's website:
www.terrastar.net/coverage.html

For example, Figure 4 shows the region covered by one specific beam, "25E".
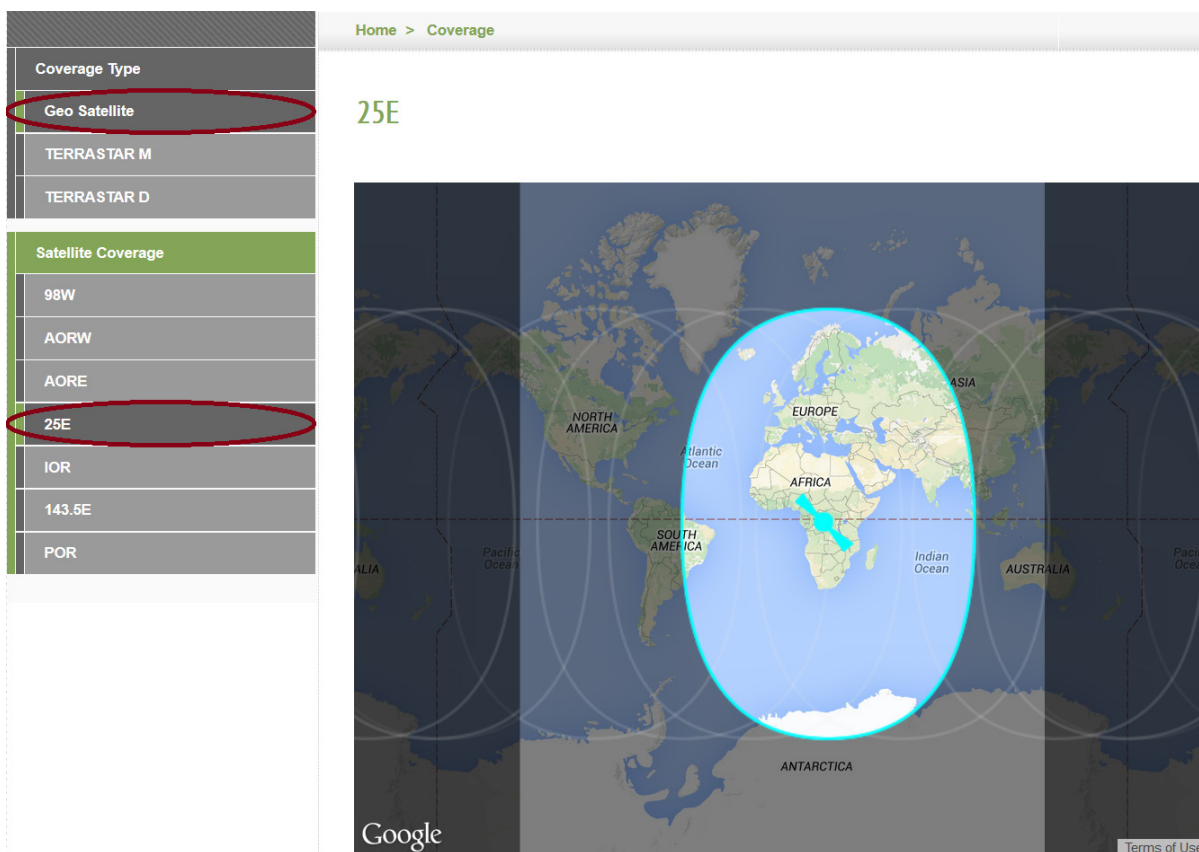
Figure 4: Example Coverage by Geo Satellite / TerraStar Beam[5]

Note that some subscription types (e.g., for airborne applications) are considered global and are broadcast on all 7 beams.

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[5] www.terrastar.net/coverage.html

Using TerraStar

In addition to a TerraStar subscription (see **Subscriptions**, page 14), there are specific hardware and software requirements that must be met in order to use TerraStar corrections and obtain a PPP solution.

Hardware Requirements

To use TerraStar corrections and obtain the best performance, the following hardware is required:

1. NovAtel OEM6 receiver capable of L-Band tracking, as well as dual-frequency GPS and GLONASS, including:
   - Receiver cards: OEM628™, OEM638™
   - Enclosures: FlexPak6™, ProPak6™, SMART6-L™
   - SPAN® on OEM6 (OEM628, OEM638, FlexPak6 and ProPak6)
2. Dual-frequency antenna compatible with GPS, GLONASS and L-Band signals. For example:
   - GPS-702-GGL

Note that the OEM615™ hardware does not support L-Band tracking and therefore does not support TerraStar over L-Band. This is also true for the SMART6™.

Firmware Requirements

NovAtel CORRECT with PPP requires firmware version 6.600 (OEM060600RN0000) or later[6] for TerraStar-C, and version 6.700 (OEM060700RN0000) or later for TerraStar-L. Also, specific model options are required to track and use the TerraStar service.

TerraStar-L

For TerraStar-L with firmware version 6.700, as a minimum, the receiver model must include the options for dual frequency GPS and GLONASS tracking.
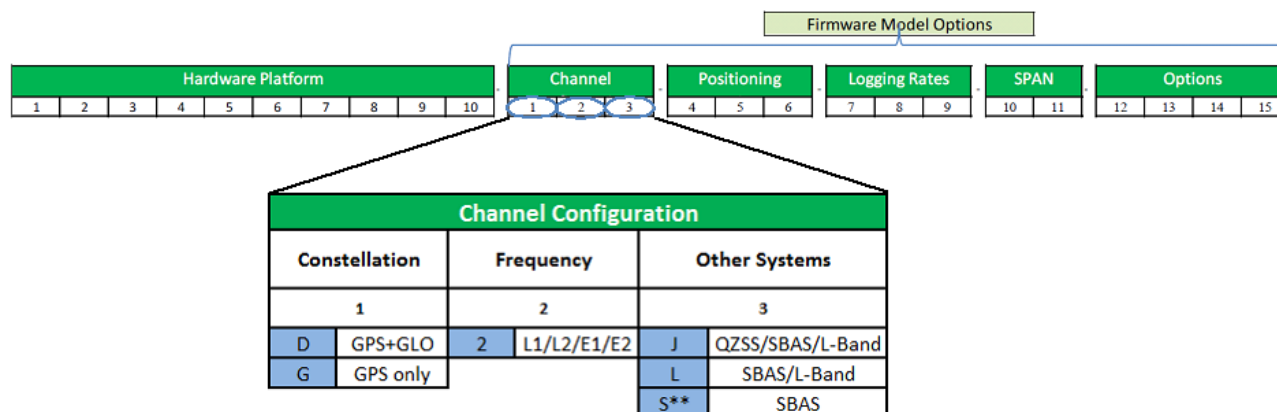
Figure 5: OEM6 Firmware Model Options Required for TerraStar-L

** The "L" or "J" option is not required. However, see **Enable L-Band Tracking** on page 15 for more details about the additional steps required to enable L-Band tracking with an SBAS-only model.

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[6] www.novatel.com/support/firmware-downloads

TerraStar-C

To track and use TerraStar-C, the PPP option must be enabled. Based on the OEM6 model structure, option 5 must be "P" and firmware option 3 should be "L" or "J". For example:

- OEM628-D2**L**-0**P**G-TT0
- OEM638-D2**J**-R**P**R-TTN
- SM6L-D2**L**-0**P**G-0T0
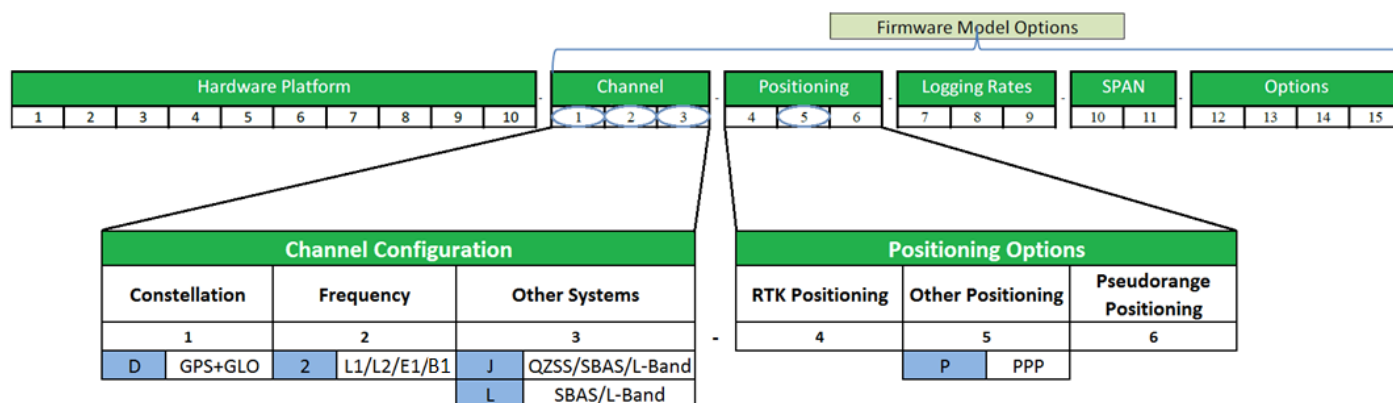
Figure 6: OEM6 Model Structure & Firmware Model Options Required for TerraStar-C

The "L" or "J" option enables L-Band tracking, and the "P" option allows the receiver to use TerraStar-C PPP corrections. However, the user must configure the receiver to track the TerraStar L-Band signal (see **Enable L-Band Tracking**) and a TerraStar subscription must be purchased and activated before the receiver will start using the corrections and providing a PPP solution.

Additional Model Information

To use either the TerraStar-L or TerraStar-C service, the channel configuration options for dual-frequency (L1 & L2) tracking must be included in the model, as well as GPS+GLONASS tracking for best performance. To allow for this, the first two firmware options must be a minimum of "D" and "2" as shown in the examples and **Figure 6** above.

While NovAtel recommends using both GPS and GLONASS with TerraStar for optimal results, it is possible to use TerraStar with dual-frequency GPS-only receivers. A GPS-only receiver model will have a "G" in the constellation model option instead of a "D". For example: **G**2L-0PG-TT0

Stated performance specifications for NovAtel CORRECT with PPP are based on GPS+GLONASS operation, which is required for the best performance and convergence time. The plots on the next page show typical results using GPS-only and GPS+GLONASS with TerraStar-C.
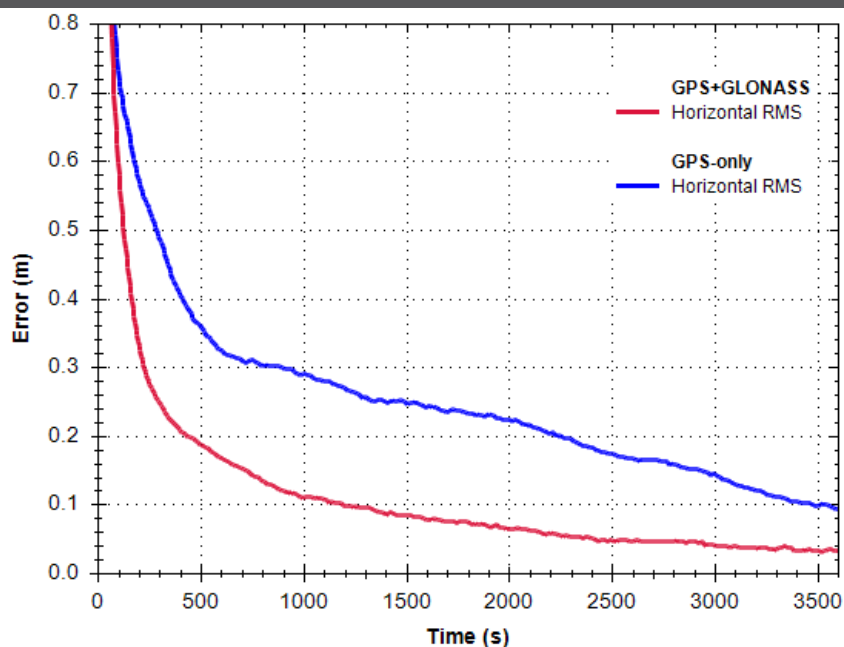
Figure 7: NovAtel CORRECT with PPP using TerraStar-C – Horizontal Position Accuracy during Convergence[7]
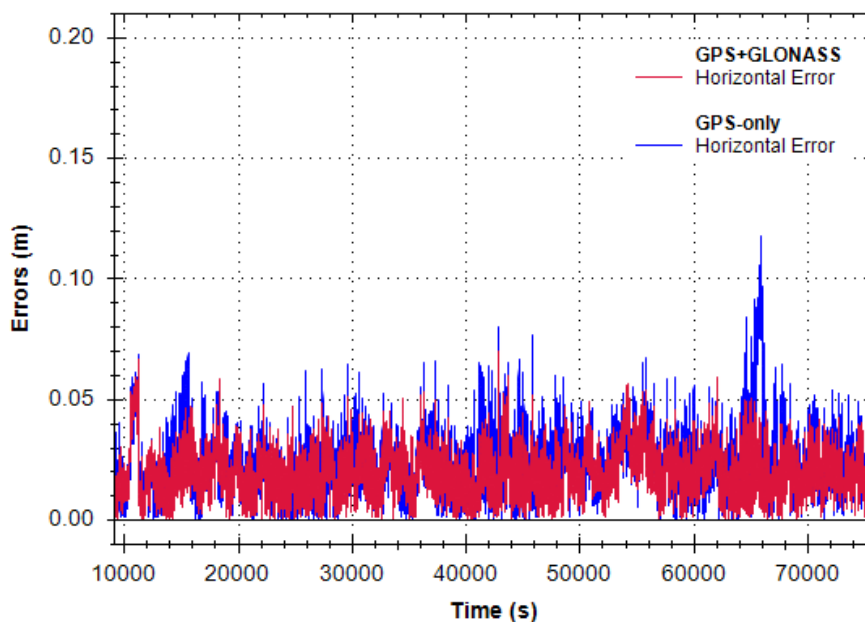
Figure 8: NovAtel CORRECT with PPP using TerraStar-C – Horizontal Position Accuracy with GPS-only and GPS+GLONASS[8]

As illustrated in the plots above, both convergence and accuracy are improved when using a GPS+GLONASS configuration compared to using GPS alone.

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[7] Data collected in Canada over three days with solution reset every hour.
[8] Data collected in Canada with no solution resets.

There are many other OEM6 firmware model options available, such as those that enable NovAtel's ALIGN®, RTK, API, SPAN, etc., but the options mentioned above are the minimum requirements to track and use TerraStar corrections. In the future it is possible that corrections for additional constellations will be broadcast by TerraStar and in that case a different "constellation" option will be required in the model, as well as a compatible antenna, in order to take advantage of those corrections.

To verify the model currently loaded and being used on a receiver, use the command "LOG VERSION" to output the version information. For example:

> **<VERSION COM1 0 81.0 FINESTEERING 1835 137855.119 00000020 3681 13306**
> **<   1**
> **<   GPSCARD "D2LRPGTT0" "BFN11210275" "OEM628-2.01" "OEM060600RN0000"**
> **"OEM060200RB0000" "2015/Jan/28" "15:27:29"**

In this example, the model options indicate the following:

- Channel configuration options allow tracking of:
  - **D**: GPS+GLONASS
  - **2**: L1/L2/E1/B1 signals
  - **L**: SBAS/L-Band
- Positioning options available:
  - R: RTK Fixed, RTK Float, RTK Tx (transmit), DGPS Tx/Rx (transmit/receive)
  - **P**: PPP (compatible with both TerraStar-C and TerraStar-L subscriptions)
  - G: GLIDE™

Subscriptions

To purchase a TerraStar subscription, contact your NovAtel dealer or sales office[9]. NovAtel Customer Support can provide free 5-day trial TerraStar subscriptions for test and demonstration purposes[10].

The receiver's NovAtel Product Serial Number (PSN) or TerraStar Product Activation Code (PAC) is needed to obtain a subscription. Before contacting your NovAtel sales office, obtain the PSN and/or PAC for the receiver you wish to activate using the commands "LOG VERSION" or "LOG TERRASTARINFO" respectively. In the example VERSION log on the previous page, the PSN is "BFN11210275". An example PAC is highlighted in the TERRASTARINFO log below.

> **<TERRASTARINFO COM1 0 72.5 FINESTEERING 1835 138108.148 00000020 e776 13306**
> **<   "QR244:2228:3410" TERM 00000301 0 0 0 GEOGATED 0.00000 0.00000 0**

Once a subscription is purchased, TerraStar begins broadcasting the details at a specific time. In order for the receiver to download the subscription information, it must be configured to track the TerraStar L-Band signal shortly before the activation time. However, the subscription information will be rebroadcast periodically since TerraStar continuously re-broadcasts all known and valid subscriptions in sequence.

In cases where the initial broadcast is missed, if the receiver remains powered on and tracking it will simply download the subscription the next time it is broadcast. Alternatively, NovAtel Customer Support is able to perform an immediate "resend" of the subscription in cases of urgency or for troubleshooting purposes.

If a subscription renewal is purchased before the current subscription ends, the new information will be broadcast by TerraStar during the last seven days of the current subscription. As long as the receiver tracks the TerraStar signal during that time, there will be no disruption in service when the new subscription begins.

The steps required to configure the receiver to track and use TerraStar are described in the next sections.

To verify the TerraStar subscription and status, use the command "LOG TERRASTARSTATUS" to output the TERRASTARSTATUS log. For example:

> **<TERRASTARSTATUS COM1 0 72.5 FINESTEERING 1835 140874.036 00000020 fdc1 13306**
> **<   ENABLE LOCKED 0 DISABLED ONSHORE**

In this typical example for a term subscription, the access status is "ENABLE" indicating the subscription is valid, the TerraStar decoder is "LOCKED" onto the data stream and the geogating status is showing that the receiver is "ONSHORE".

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[9] www.novatel.com/where-to-buy/sales-offices/
[10] Contact support@novatel.com for more details. Maximum of 3 test subscriptions will be provided per receiver.

Configuring a Receiver

Enable L-Band Tracking

Before a receiver can download the required subscription information and start using TerraStar corrections, it first must be configured to track the L-Band signal from a TerraStar geostationary satellite. To enable L-Band tracking, the "ASSIGNLBANDBEAM" command is used. The factory default setting for "ASSIGNLBANDBEAM" is "IDLE", which means that the receiver will not track an L-Band signal unless configured to do so.

To enable L-Band tracking, the "AUTO" setting is recommended in most cases. Specifically:

ASSIGNLBANDBEAM AUTO

The auto setting allows the GNSS receiver to automatically track the signal from the highest elevation TerraStar satellite for the best performance. The receiver firmware includes a default list of TerraStar satellites (see **LBANDBEAMTABLE** (List of L-Band Beams) on page 22) and the receiver will search through the list as part of signal acquisition and tracking. To determine which TerraStar signal is the best to use in a particular location, the receiver must have a position solution available.

A manual setting is also available with the "ASSIGNLBANDBEAM" command, which allows a user to specify a specific TerraStar satellite to track. For example:

ASSIGNLBANDBEAM 98W or **ASSIGNLBANDBEAM MANUAL 98W**

In the case where the receiver model includes an "S" instead of an L or J (see page 10), for example D2**S**-00G-0T0, the channel configuration must be changed to allow L-Band tracking. Specifically, the "SELECTCHANCONFIG" command must be used to select a new configuration. For example:

SELECTCHANCONFIG 3

Issuing the "SELECTCHANCONFIG" command will initiate an immediate reset of the receiver. Any settings previously entered and not saved with a "SAVECONFIG" command will be erased when the receiver reboots. Once the channel configuration has been set the new configuration will always be used unless a factory reset is performed ("FRESET"). A "SAVECONFIG" command is not required to save the channel configuration. The "CHANCONFIGLIST" log can be used to verify the configuration in use and to see a list of available configurations.

Verify L-Band Tracking

To verify the L-Band tracking status, the "LBANDTRACKSTAT" log can be used. For example:

<LBANDTRACKSTAT COM1 0 80.5 FINESTEERING 1835 140789.000 00000020 29fd 13306
<   1
<   "98W" 1539902500 1200 974c 00c2 0 345.395 42.398 3.5073 71580.844 1363392 1168
1085 173150784 136010 0.0038

This log reports the L-Band tracking status of the TerraStar signal. Some helpful fields are highlighted above and described below:

- **98W**: This is the name of the TerraStar beam or transmitting satellite being tracked. Additional details for the tracked beam can be output and viewed with the **LBANDBEAMTABLE** (List of L-Band Beams) log.
- **00c2**: This is the "Tracking Status Word". A tracking status of "00c2" indicates that the receiver is tracking and locked onto the TerraStar signal.
- **42.398**: This is the C/No or "Carrier to Noise Density Ratio" (in dB-Hz). The C/No is typically about 40-45 dB-Hz in ideal conditions. A low C/No can result in missed corrections and correspondingly degraded performance.
- **71580.44**: This is the "Lock Time" (in seconds). This field can be monitored to ensure that the L-Band signal is being tracked continuously without any loss of lock.

While the TerraStar signal can be tracked even without a subscription, the receiver will not decode and use the TerraStar service data until a valid subscription has been activated. For more reference, see **Subscriptions** (page 14).

Obtaining a PPP Position Solution

When the receiver is configured to track the TerraStar signal and has downloaded a valid subscription, it will then begin decoding the correction data coming from the TerraStar service. Shortly after the receiver begins decoding the corrections it will automatically start using the corrections to compute a PPP position solution. To verify the availability of a PPP position solution, the following position logs can be output using the "LOG" command:

- PPPPOS
- BESTPOS
- GPGGA

Here is an example command that will request the PPPPOS log in binary format on the Com1 port with a rate of 2 Hz:

LOG COM1 PPPPOSB ONTIME 0.5

The PPPPOS log will always output the PPP solution when available, whereas the BESTPOS and GPGGA logs will output the "best available" solution. When using BESTPOS or GPGGA logs, another solution can be output in some cases, typically an autonomous or SBAS ("SINGLE" or "WAAS") position type, until the accuracy of the PPP solution becomes the best available. The receiver uses the estimated standard deviations, based on the "SETBESTPOSCRITERIA" command setting[11], to determine the "best" solution available. By default, the receiver will use the three dimensional standard deviation.

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[11] See www.novatel.com/assets/Documents/Manuals/om-20000129.pdf for the SETBESTPOSCRITERIA definition.

At first, the PPP solution will be flagged as "converging" in the position logs. After the convergence period, the position type will change to indicate a converged solution with the following position types:

Table 1: Position Types by Log

PPP Solution Status	BESTPOS/PPPPOS	GPGGA (Quality Indicator)
TerraStar-L Converging	PPP_BASIC_CONVERGING	1
TerraStar-L Converged	PPP_BASIC	2
TerraStar-C Converging	PPP_CONVERGING	2
TerraStar-C Converged	PPP	5

For TerraStar-C, the PPP solution will transition from "PPP_CONVERGING" to "PPP" based on the "**PPPCONVERGEDCRITERIA** (Configure the Decision for TerraStar-C PPP Convergence)" command setting. By default, the solution will be flagged as converged when the estimated horizontal (2D) standard deviation of the solution is 0.32 meters.

For example, when the TerraStar-C solution is converging and is the best available:

<PPPPOS COM1 0 67.0 FINESTEERING 1835 138450.000 00000020 ec34 13306
<   SOL_COMPUTED PPP_CONVERGING 51.11679113545 -114.03886168434 1064.7791
-16.9000 WGS84 0.4998 0.4735 0.8064 "TSTR" 30.000 0.000 16 16 16 16 00 00 00 33

<BESTPOS COM1 0 67.0 FINESTEERING 1835 138450.000 00000020 b1f6 13306
<   SOL_COMPUTED PPP_CONVERGING 51.11679113545 -114.03886168434 1064.7791
-16.9000 WGS84 0.4998 0.4735 0.8064 "TSTR" 30.000 0.000 16 16 16 16 00 00 00 33

$GPGGA,142714.00,5107.0075,N,11402.3317,W,2,16,0.7,1064.78,M,-16.90,M,30,TSTR*64

And when the TerraStar-C solution has converged:

<PPPPOS COM1 0 56.5 FINESTEERING 1835 140380.000 00000020 ec34 13306
<   SOL_COMPUTED PPP 51.11679212035 -114.03886789158 1064.4984 -16.9000 WGS84
0.0542 0.0412 0.0994 "TSTR" 30.000 0.000 19 19 19 19 00 01 00 33

<BESTPOS COM1 0 56.5 FINESTEERING 1835 140380.000 00000020 b1f6 13306
<   SOL_COMPUTED PPP 51.11679212035 -114.03886789158 1064.4984 -16.9000 WGS84
0.0542 0.0412 0.0994 "TSTR" 30.000 0.000 19 19 19 19 00 01 00 33

$GPGGA,145924.00,5107.0075,N,11402.3321,W,5,19,0.7,1064.50,M,-16.90,M,30,TSTR*69

The "station ID" field in all three position logs can also be used to verify the type of corrections being used in the solution. For TerraStar-C, the station ID will be "TSTR" as shown in the above examples. For TerraStar-L, the ID will be "TSTL", as shown below.

Converging TerraStar-L:

<PPPPOS COM1 0 61.5 FINESTEERING 1886 507260.000 00000020 ec34 13716
<   SOL_COMPUTED PPP_BASIC_CONVERGING 51.11679029982 -114.03886572525 1064.5587
-16.9000 WGS84 0.5304 0.7067 0.7427 "TSTL" 15.000 0.000 18 18 18 18 00 00 00 33

<BESTPOS COM1 0 61.5 FINESTEERING 1886 507260.000 00000020 b1f6 13716
<   SOL_COMPUTED PPP_BASIC_CONVERGING 51.11679029982 -114.03886572525 1064.5587
-16.9000 WGS84 0.5304 0.7067 0.7427 "TSTL" 15.000 0.000 18 18 18 18 00 00 00 33

$GPGGA,205403.00,5107.0074,N,11402.3319,W,1,18,0.6,1064.56,M,-16.90,M,15,TSTL*77

Converged TerraStar-L:

<PPPPOS COM1 0 64.5 FINESTEERING 1886 507940.000 00000020 ec34 13716
<   SOL_COMPUTED PPP_BASIC 51.11679471221 -114.03886370105 1065.2274 -16.9000
WGS84 0.3549 0.3547 0.5028 "TSTL" 15.000 0.000 17 17 17 17 00 00 00 33

<BESTPOS COM1 0 64.5 FINESTEERING 1886 507940.000 00000020 b1f6 13716
<   SOL_COMPUTED PPP_BASIC 51.11679471221 -114.03886370105 1065.2274 -16.9000
WGS84 0.3549 0.3547 0.5028 "TSTL" 15.000 0.000 17 17 17 17 00 00 00 33

$GPGGA,210523.00,5107.0077,N,11402.3318,W,2,17,0.7,1065.23,M,-16.90,M,15,TSTL*7C

Commands

All of the commands and logs mentioned in this document are described in full detail in the OEM6 Firmware Reference Manual (www.novatel.com/assets/Documents/Manuals/om-20000129.pdf).

ASSIGNLBANDBEAM (Configure L-Band Tracking)

The "ASSIGNLBANDBEAM" command is used to configure L-Band tracking, which is disabled by default. In most cases, the "AUTO" setting can be used to enable tracking of TerraStar and to download subscription information as necessary (see **Enable L-Band Tracking**, page 15). In some cases it can be desirable to use a specific beam in which cases the "MANUAL" setting can be used. The **LBANDBEAMTABLE** (List of L-Band Beams) log (page 22) contains a list of TerraStar beams known to the receiver and can be helpful when using the manual option.

Examples:

> ASSIGNLBANDBEAM AUTO

> ASSIGNLBANDBEAM MANUAL AORW

The default setting for ASSIGNLBANDBEAM is:

> ASSIGNLBANDBEAM IDLE

PPPCONVERGEDCRITERIA (Configure the Decision for TerraStar-C PPP Convergence)

The receiver uses the standard deviation of the solution to determine when the PPP position has converged. The "PPPCONVERGEDCRITERIA" command allows the user to control this decision when using TerraStar-C. The default setting for this command is:

> PPPCONVERGEDCRITERIA HORIZONTAL_STDDEV 0.32

Under this default setting, the receiver will label the TerraStar-C PPP solution as "converged" when the horizontal standard deviation (2D) is 0.32 m or less.

Another example is as follows:

> PPPCONVERGEDCRITERIA TOTAL_STDDEV 0.25

The second example will use the total position standard deviation (3D) to determine when the solution has converged.

Relaxing the convergence threshold shortens the time before a PPP solution is reported as converged. However, it does not alter the absolute behavior of the solution. During the initial PPP solution period, the positions can have decimetre error variation. It is recommended to only relax the convergence threshold if the application can tolerate higher solution variability.

April 6, 2016

PPPDYNAMICS (Set the PPP Dynamics Mode)

This command configures the dynamics assumed by the PPP filter. The default setting is "DYNAMIC":

PPPDYNAMICS DYNAMIC

To take advantage of automatic detection of antenna dynamics, specify the "AUTO" setting:

PPPDYNAMICS AUTO

"AUTO" will allow the receiver to detect the antenna dynamics and adapt filter operation accordingly. This can be especially beneficial during convergence if the antenna will remain stationary during that time. However, very slow "creeping" motion, where the antenna consistently moves 2 cm/s or less, can be interpreted by the receiver as stationary. In such cases, the mode should remain as the default or explicitly be set to DYNAMIC.

PPPSEED (Control Seeding of the PPP Filter)

The "PPPSEED" command controls the seeding of the PPP filter. Accurate position seeding can accelerate PPP convergence. The command "PPPSEED SET" is used to explicitly specify a seed position. The seed position must be in a datum consistent with the PPP corrections that will be used. For NovAtel CORRECT with PPP, this is ITRF2008.

Caution must be exercised when using "PPPSEED SET". While a "good" or accurate seed position can accelerate convergence, a "bad" or inaccurate seed hurts performance. In some cases, a bad seed can prevent a solution from ever converging to a correct position. In other cases, a bad seed might be rejected immediately or the filter might operate with it for a period of time only to reject it later. In the last case, the filter position is partially reset with a corresponding discontinuity in the PPP position.

The available options with the PPPSEED command are as follows:

- CLEAR – resets the stored seed, and prevents any auto seeding from occurring
- SET – immediately apply the specified coordinates as a seed position
- STORE – store the current PPP position in NVM for use as a future seed
- RESTORE – retrieve and apply a seed that was saved in NVM via the STORE or AUTO options
- AUTO – automatically store and restore PPP seed positions

PPPSEED command uses this format:

PPPSEED option [<latitude> <longitude> <height> <northing_std_dev> <easting_std_dev> <height_std_dev>]

Examples:

PPPSEED SET 51.11635322441 -114.03819311672 1064.5458 0.05 0.05 0.05

PPPSEED STORE

PPPSOURCE (Specify the PPP Correction Source)

The PPPSOURCE command allows the user to specify the type or source of corrections the PPP filter will use. It can also be used to disable the PPP filter. The default setting is "AUTO", which allows the receiver to automatically select and use the best corrections.

Examples:

PPPSOURCE NONE

PPPSOURCE TERRASTAR_L

If desired, for testing purposes, a receiver with a TerraStar-C subscription can be configured to only accept TerraStar-L corrections using the "TERRASTAR_L" option.

PPPTIMEOUT (Set the Maximum Age of the PPP Corrections)

The maximum age of corrections that will be used by the PPP filter is determined by the PPPTIMEOUT command. If the correction stream is interrupted, the receiver will continue using the last received corrections but the age of those corrections will begin to grow. If the corrections become older than the specified PPPTIMEOUT duration, the receiver will no longer use those corrections. The default setting is 360 seconds (6 minutes), the minimum is 5 seconds and the maximum duration is 900 seconds. For example:

PPPTIMEOUT 360

PPPTIMEOUT 900

PPPTIMEOUT 200

Logs

Any of the logs described below can be output using the LOG command. Appending an "A" or a "B" to the log name when sending the LOG command will output the message in full ASCII (examples below are 'abbreviated' ASCII) or binary respectively. For example, the command "LOG PPPPOSB" will log the PPPPOS log in binary format.

For complete details about the LOG command, including how to specify the data rate/interval and trigger, see the LOG command definition in the OEM6 Firmware Reference Manual (www.novatel.com/assets/Documents/Manuals/om-20000129.pdf).

LBANDBEAMTABLE (List of L-Band Beams)

This log provides a list of TerraStar L-Band beams known to the receiver. The receiver firmware contains a default list that will be output until the receiver downloads new beam information from TerraStar. Using the command "LOG LBANDBEAMTABLE", this is an example output:

```
<LBANDBEAMTABLE COM2 0 71.5 UNKNOWN 0 1.397 00000020 f3b2 13306
<    7
<        "AORE" "A" 1539982500 1200 -15.50 1
<        "AORW" "B" 1539892500 1200 -54.00 1
<        "IOR" "C" 1539902500 1200 64.50 1
<        "POR" "D" 1539942500 1200 178.00 1
<        "25E" "E" 1539882500 1200 25.00 1
<        "143.5E" "F" 1539992500 1200 143.50 1
<        "98W" "G" 1539902500 1200 -98.00 1
```

The first two fields in each entry, for example ""POR" "D"", correspond to the beam/transmitting satellite name and the region ID. The next three fields correspond to the broadcasting frequency (Hz), the baud rate and the longitude (degrees) of the L-Band satellite. The last field is the beam access, where "1" indicates that access has been granted by the subscription for that particular beam. A receiver without a subscription will have access to all beams to permit the download of a subscription.

LBANDTRACKSTAT (Report the L-Band Tracking and Viterbi Decoding Status)

The LBANDTRACKSTAT log provides information that can be used to verify L-Band tracking. Specifically, the name of the L-Band satellite or beam and its frequency, baud rate and service ID are included in this log. Also, the carrier to noise density ratio or "C/No" (in dB-Hz) and lock time (in seconds) are indicators of tracking performance.

For example:

```
<LBANDTRACKSTAT COM1 0 78.0 FINESTEERING 1835 138913.000 00000020 29fd 13306
<    1
<        "98W" 1539902500 1200 974c 00c2 0 -271.092 44.380 4.8400 10121.678 192704 91 91
24473408 11363 0.0002
```

In this example, the receiver is tracking the "98W" beam with a frequency of 1539902500 Hz and a baud rate of 1200. Also, the C/No is 44.380 dB-Hz and the continuous lock time is 192704 seconds, indicating solid tracking performance. The C/No is typically about 40-45 dB-Hz in ideal conditions.

PPPPOS (PPP Filter Position)

The PPPPOS log contains the position solution computed specifically by the PPP filter. The possible position types in this log are as follows:

Table 2: PPPPOS Position Types

Position Type	Binary Value	Description
NONE	0	No solution
PPP_BASIC_CONVERGING	77	Converging TerraStar-L Solution
PPP_BASIC	78	Converged TerraStar-L Solution
PPP_CONVERGING	68	Converging PPP Solution
PPP	69	Converged PPP Solution

TerraStar-C examples:

**<PPPPOS COM2 0 67.0 FINESTEERING 1835 138450.000 00000020 ec34 13306
<   SOL_COMPUTED PPP_CONVERGING 51.11679113545 -114.03886168434 1064.7791
-16.9000 WGS84 0.4998 0.4735 0.8064 "TSTR" 30.000 0.000 16 16 16 16 00 00 00 33**

**<PPPPOS COM2 0 56.5 FINESTEERING 1835 140380.000 00000020 ec34 13306
<   SOL_COMPUTED PPP 51.11679212035 -114.03886789158 1064.4984 -16.9000 WGS84
0.0542 0.0412 0.0994 "TSTR" 30.000 0.000 19 19 19 19 00 01 00 33**

TerraStar-L examples:

**<PPPPOS COM1 0 61.5 FINESTEERING 1886 507260.000 00000020 ec34 13716
<   SOL_COMPUTED PPP_BASIC_CONVERGING 51.11679029982 -114.03886572525 1064.5587
-16.9000 WGS84 0.5304 0.7067 0.7427 "TSTL" 15.000 0.000 18 18 18 18 00 00 00 33**

**<PPPPOS COM1 0 64.5 FINESTEERING 1886 507940.000 00000020 ec34 13716
<   SOL_COMPUTED PPP_BASIC 51.11679471221 -114.03886370105 1065.2274 -16.9000
WGS84 0.3549 0.3547 0.5028 "TSTL" 15.000 0.000 17 17 17 17 00 00 00 33**

See also **Obtaining a PPP Position Solution**.

PPPSATS (Satellites Used in the PPPPOS Solution)

This log provides a list of the used and unused satellites for the corresponding PPPPOS solution. The signals of the used satellites are also described, along with the reasons for exclusions.

For example:

```
<PPPSATS COM2 0 47.0 FINESTEERING 1835 140613.000 00000020 ce3f 13306
<     23
<          GPS 29 GOOD 00000003
<          GPS 13 GOOD 00000003
<          GPS 32 GOOD 00000003
<          GPS 4 GOOD 00000003
<          GPS 16 GOOD 00000003
<          GPS 23 GOOD 00000003
<          GPS 10 GOOD 00000003
<          GPS 31 GOOD 00000003
<          GPS 7 GOOD 00000003
<          GPS 2 GOOD 00000003
<          GPS 20 GOOD 00000003
<          SBAS 138 NOTUSED 00000000
<          SBAS 133 NOTUSED 00000000
<          SBAS 135 NOTUSED 00000000
<          GLONASS 14-7 GOOD 00000003
<          GLONASS 23+3 GOOD 00000003
<          GLONASS 5+1 GOOD 00000003
<          GLONASS 15 GOOD 00000003
<          GLONASS 22-3 GOOD 00000003
<          GLONASS 13-2 GOOD 00000003
<          GLONASS 6-4 GOOD 00000003
<          GLONASS 3+5 GOOD 00000003
<          GLONASS 4+6 GOOD 00000003
```

TERRASTARINFO (TerraStar Subscription Information)

Details about the current TerraStar subscription are contained in the "TERRASTARINFO" log. Also, the receiver-specific Product Activation Code (PAC) is available from this log.

For "Term" subscriptions, the expiry or contract end date is indicated by a year and day of year (DOY). See below for an example.

Example:

```
<TERRASTARINFO COM2 0 72.5 FINESTEERING 1835 138108.148 00000020 e776 13306
<     "QR244:2228:3410" TERM 00000301 355 2015 0 GEOGATED 0.00000 0.00000 0
```

In this example the PAC is "QR244:2228:3414" and it has a term subscription. After the header, the fifth and sixth fields can be used to determine the expiry date for the subscription. Those fields specifically represent the "Service End Day of Year" (DOY) and the "Service End Year" respectively.

With firmware version 6.700 (OEM060700RN0000) or later, the Service End DOY matches the end date, in UTC time, indicated when the subscription was purchased. In the example below the Service End is day 79 of 2016, which means the subscription will expire on March 19th, 2016.

<TERRASTARINFO COM1 0 71.5 FINESTEERING 1888 162835.801 00000020 a7ce 13716

< "QT365:5653:9885" TERM 00000700 79 2016 0 GEOGATED 0.00000 0.00000 0

With firmware versions older than 6.700, for example 6.620, the Service End DOY is the day <u>following</u> the TerraStar contract end DOY. Assuming older firmware, in the example above the Service End is reported as day 79 of 2016, correlating to March 19th, which means that the subscription will expire on March 18th, 2016.

The third field (after the header) in the TERRASTARINFO log provides subscription details and the bits can be decoded to determine which services are enabled by the subscription. **Table 3** below outlines the bits used for TerraStar-C and TerraStar-L.

Table 3: TERRASTARINFO Subscription Details Mask

Bits	Mask	Description
0-8	0x000001FF	Reserved
9	0x00000200	TerraStar-C
10	0x00000400	TerraStar-L
11-31	0xFFFFF800	Reserved

A receiver can have only one active subscription at a time but a subscription can enable multiple services or bits. In the example above, the receiver has a TerraStar-C subscription though TerraStar-L is also allowed. Other bits in the subscriptions details field may be populated but they are currently reserved.

TERRASTARSTATUS (TerraStar Decoder and Subscription Status)

Additional TerraStar decoder and subscription status information is provided in the TERRASTARSTATUS log. This log can be used to verify that the receiver is locked onto the TerraStar signal and is decoding data.

For example:

> **<TERRASTARSTATUS COM2 0 72.5 FINESTEERING 1835 140874.036 00000020 fdc1 13306**
> **<   ENABLE LOCKED 0 DISABLED ONSHORE**

If the receiver currently has a valid subscription, the first field will be "ENABLE" and in most cases the last field or "geogating status" will be "ONSHORE".

Convergence Recommendations

The TerraStar solution will have an associated convergence time during which the accuracy will stabilize and converge towards the quoted accuracy for NovAtel CORRECT with PPP[12].

Although it is not currently possible to completely remove the convergence period of the PPP solution, there are techniques to help improve or shorten the time required to reach the specified accuracy. Some of these include:

- Ensure the antenna is located in an area that has a clear view of the sky with no obstructions, especially during initial startup and convergence.
- If the vehicle and antenna can and will be stationary during convergence, use the "AUTO" setting for **PPPDYNAMICS** (Set the PPP Dynamics Mode) (page 20) to take advantage of automatic dynamics detection and filtering.
- Use the **PPPSEED** (Control Seeding of the PPP Filter) (page 20) command to specify the location of the antenna if it is located in a known position, but at the same time avoid using a "bad" seed if the accuracy of the known location is poor as this can increase the convergence time.

For most applications it is best to allow the PPP solution to be flagged as "converged" before proceeding with operation. This is due to the variation that can be present in the solution as it converges. Waiting for a converged position status will help ensure the solution has stabilized and is operating within the expected accuracy. With TerraStar-C, if the application can tolerate higher solution variability the **PPPCONVERGEDCRITERIA** (Configure the Decision for TerraStar-C PPP Convergence) command (page 19) can potentially be used to relax the convergence tolerance or threshold.

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[12] www.novatel.com/products/novatel-correct/novatel-correct-ppp/

Where to go for Support

To help answer questions and/or diagnose any technical issues that may occur, the NovAtel Support website is a first resource: www.novatel.com/support/

Remaining questions or issues, including requests for test subscriptions or activation resends, can be directed to NovAtel Support by visiting www.novatel.com/support/contact/. To enable the online form and submit a ticket, first select a "Product Line" and then an associated "Product" from the list.

However, before contacting Support, it is helpful to collect data from the receiver to help investigate and diagnose any performance-related issues. In those cases, if possible, collect the following list of logs (the LOG command with the recommended trigger and data rate is included):

```
LOG VERSIONA ONCE
LOG RXSTATUSA ONCHANGED
LOG RAWEPHEMB ONCHANGED
LOG ALMANACB ONCHANGED
LOG IONUTCB ONCHANGED
LOG GLORAWEPHEMB ONCHANGED
LOG GLORAWALMB ONCHANGED
LOG GLOCLOCKB ONCHANGED
LOG RANGEB ONTIME 1
LOG BESTPOSB ONTIME 1
LOG PPPPOSB ONTIME 1
LOG PPPSATSB ONTIME 1
LOG LBANDTRACKSTATB ONTIME 1
LOG TERRASTARINFOA ONCHANGED
LOG TERRASTARSTATUSA ONCHANGED
LOG LBANDBEAMTABLEA ONCHANGED
LOG RXCONFIGA ONCE
```

The data described above can be collected using a terminal program that supports binary data logging, or NovAtel's CONNECT utility can be downloaded and installed from the NovAtel website: www.novatel.com/support/info/documents/809.

April 6, 2016