APN-087

# Advanced TerraStar Services: TerraStar-X and TerraStar-C PRO

Contents

TerraStar-X Overview

TerraStar-X™ GNSS correction technology leverages Hexagon's continuously operating global and regional reference networks for correction generation, data compression and delivery for precise, safe, reliable solutions at centimeter level accuracy with less than one minute of convergence.

TerraStar-X correction data generation takes place at Hexagon Positioning Intelligence's processing centers where service reliability, redundancy and guaranteed service uptime[1] ensure that corrections are available for users 24/7/365. TerraStar-X's convergence to centimeter level accuracy in less than a minute is available in select regions in North America, saving users time and money while delivering the precision and speed of traditional RTK networks without the need for base stations.

There are six different L-Band satellites that broadcast TerraStar corrections for specific regions. Distribution of the L-Band satellites allows for dual coverage in virtually any location. Coverage areas for specific beams can be viewed at NovAtel's website: www.novatel.com/products/terrastar-gnss-corrections/terrastar-coverage-map/.

TerraStar-X is delivered over the 98W beam in North America. Users with TerraStar-X subscription are provided with regional corrections in the rapid convergence region, "Corn Belt" (Figure 1), as well as global corrections for the TerraStar-C PRO service over the 98W beam.
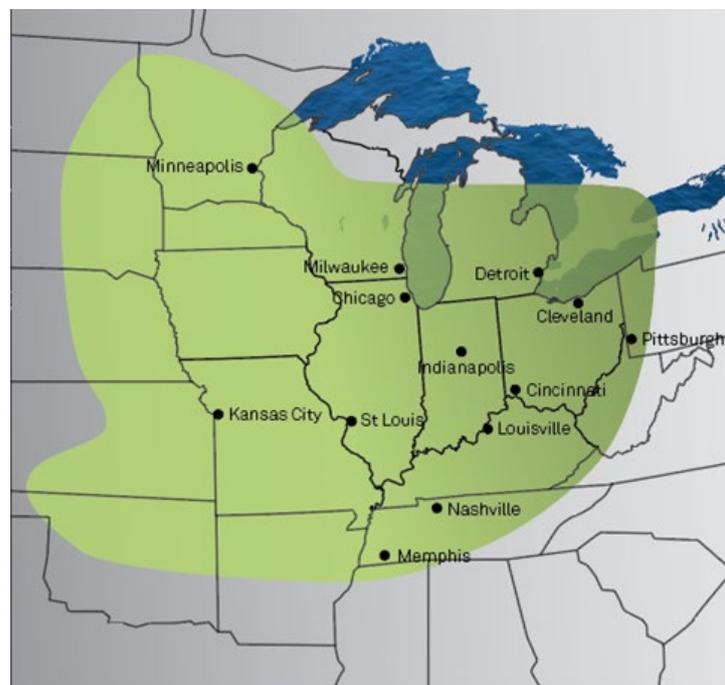
Figure 1 - TerraStar-X Rapid Convergence Region (Iowa, Illinois, Indiana, Kansas, Nebraska, Michigan, South Dakota, Missouri, Ohio, Kentucky, Wisconsin and Minnesota)

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[1] Please see our Application Note-085 that talks about how users can subscribe to the RSS Feed to receive real-time updates on TerraStar service outages.

With TerraStar-X, convergence time can be reduced significantly within the Corn Belt region, which is a region of densified reference stations in an enhanced infrastructure. In the Corn Belt, users can expect a significantly shorter time to reach a fully converged PPP solution: less than one minute with TerraStar-X compared to about 18 minutes with TerraStar-C Pro. When started outside the rapid convergence area, a receiver with active TerraStar-X subscription operates seamlessly with the global TerraStar-C Pro service to maintain centimeter-level accuracy.

TerraStar-X is delivered through the 98W beam which provides regional and global corrections. These corrections are received simultaneously over separate frequencies by the receiver. The regional beam of TerraStar-X provides corrections for rapid convergence in the Corn Belt region; regional corrections are only available with a TerraStar-X subscription.

From a user perspective, 98W beam is tracked on two different frequencies or L-Band channels when the receiver is operating with an active TerraStar-X subscription. Two entries will appear in LBANDTRACKSTATS, with "SP98W1" being for the new regional corrections:

```
#LBANDTRACKSTATA,COM1,0,71.0,FINESTEERING,2045,331169.000,02004008,29e3,32768;
5,
"SP98W1",1545885000,1200,974c,00c2,0,-132.095,42.138,3.9499,2395.248,45504,0,0,5824512,0,0.0000,
"98W",1545865000,1200,974c,00c2,0,-138.875,41.949,4.0328,2421.916,46080,0,0,5898240,0,0.0000,
"AORW",1545845000,1200,974c,00c2,0,-190.871,45.021,4.5517,2417.987,45952,0,0,5881856,0,0.0000,
"",0,0,0000,0003,0,0.000,0.000,0.0000,0.000,0,0,0,0,0,0.0000,
"",0,0,0000,0003,0,0.000,0.000,0.0000,0.000,0,0,0,0,0,0.0000
```

NovAtel receivers will use the corrections as permitted by their active TerraStar subscription, for instance:

- TerraStar-X subscription: Permits access to regional corrections therefore a receiver makes use of 98W beam's regional ionospheric corrections. The same receiver will also have access to global corrections with an active TerraStar-X subscription and this provides TerraStar-C PRO level performance outside the Corn Belt region.
- TerraStar-C PRO subscription: Permits access to use only the global corrections over 98W beam both inside and outside the Corn Belt region and cannot do rapid convergence in the Corn Belt region.

Using TerraStar-X and TerraStar-C PRO

Hardware Requirements

TerraStar-X and TerraStar-C PRO are only available with OEM7 hardware.

Firmware Requirements

Firmware version 7.06.03 or later is required for TerraStar-X. For TerraStar-C PRO, firmware version 7.05.00 or later is required.

Model Requirements

To use TerraStar-X, the "R" designator is required in the char[4] position under the Positioning options (Table 1) of the firmware model. Example models that support TerraStar-X are DDN-**R**NN-TBN, FDN-**R**NN-TBN.

Positioning Options	
	CORRECT Positioning
	char[4]
N	None
L	Low End Positioning
P	**L** + High Accuracy PPP
R	**P** + RTK --> RTK / Fast Convergence PPP
B	**R** + RTKAssist

Table 1 – Letter designators for positioning option character [4]

A receiver with an "R" model as in FDN-**R**NN-TBN can support positioning modes ranging from TerraStar-L to TerraStar-X and also allows for TerraStar-C PRO, RTK, RTK-Assist and RTK-Assist PRO functionalities. For example, an "R" model with TerraStar-X subscription will give TerraStar-X performance (rapid convergence) in the Corn Belt and TerraStar-C PRO performance as fall back outside the Corn Belt.

Enable L-Band Tracking

Before a receiver can start using corrections through a TerraStar service, it first must be configured to track the L-Band signal from a TerraStar geostationary satellite.   To enable L-Band tracking, "ASSIGNLBANDBEAM" command is used. The factory default setting for "ASSIGNLBANDBEAM" is "IDLE" meaning that the receiver will not track an L-Band signal by default.

To enable L-Band tracking, the "AUTO" setting is recommended in most cases; below command should be issued to the receiver:

ASSIGNLBANDBEAM AUTO

The auto setting allows the GNSS receiver to automatically track the signal from the highest elevation TerraStar satellite for best performance. The receiver firmware includes a default list of TerraStar satellites beam IDs (see **LBANDBEAMTABLE**) 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 first.

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

```
#LBANDTRACKSTATA,COM1,0,71.0,FINESTEERING,2045,331169.000,02004008,29e3,32768;
5,
"SP98W1",1545885000,1200,974c,00c2,0,-132.095,42.138,3.9499,2395.248,45504,0,0,5824512,0,
0.0000,
```

"98W",1545865000,1200,974c,00c2,0,-138.875,41.949,4.0328,2421.916,46080,0,0,5898240,0, 0.0000,
"AORW",1545845000,1200,974c,00c2,0,-190.871,45.021,4.5517,2417.987,45952,0,0,5881856,0, 0.0000,
"",0,0,0000,0003,0,0.000,0.000,0.0000,0.000,0,0,0,0,0,0.0000,
"",0,0,0000,0003,0,0.000,0.000,0.0000,0.000,0,0,0,0,0,0.0000

This log reports the L-Band tracking status of the TerraStar signal (alias, "L-band beam"). Some important fields are highlighted above for three beams that the receiver is tracking and are described below for beam "98W":

- **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 <u>LBANDBEAMTABLE log</u>.
- **00c2**: This is the "Tracking Status Word". A tracking status of "00c2" indicates that the receiver is tracking the TerraStar signal.
- **41.949**: 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 tracking conditions. A low C/No can result in missed corrections and correspondingly degraded performance.
- **2421.916**: 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 actual tracking of the L-band beam does not require a subscription, the receiver will not decode and use the TerraStar service data until a valid subscription is activated. This initial activation takes place when a receiver tracks an L-band beam for the first time following the purchase of a TerraStar subscription.

Subscriptions

A valid subscription is required for the TerraStar-X service and the user must configure the receiver to track the TerraStar L-Band signal (see "Enable L-Band Tracking**"** section) before the receiver starts using the corrections for a position solution.

To purchase a TerraStar subscription, users should contact their NovAtel dealer or sales office[2]. NovAtel's eCommerce system also allows purchasing TerraStar-X and TerraStar-C PRO subscriptions for OEM7 receivers.

Test subscriptions can be made available for test and demonstration purposes. Please contact NovAtel Customer Support[3] for more information.

For purchase or trial subscription purposes, NovAtel receiver's Product Serial Number (PSN) or TerraStar Product Activation Code (PAC) is needed. 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 below, the PSN is "BMHR17300202B". An example PAC is also shown in red in the TERRASTARINFO log further below:

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[2] <u>www.novatel.com/where-to-buy/sales-offices/</u>
[3] Contact <u>support@novatel.com</u> for more details. Maximum of 3 test subscriptions allowed per receiver.

```
[COM1]<VERSION COM1 0 76.0 FINESTEERING 2057 494698.848 02004000 3681 15526
<     9
<      GPSCARD "FFNXNNTBN" "BMHR18210047D" "OEM7700-1.01" "OA7CR0601RN0000"
"OM7BR0100RB0000" "2019/Apr/10" "06:09:54"
<      OEM7FPGA "" "" "" "OMV070001RN0000" "" "" ""
<      APPLICATION "" "" "" "ES7AR0601RN0000" "" "2019/Apr/10" "06:10:12"
<      DEFAULT_CONFIG "" "" "" "ES7CR0601RN0000" "" "2019/Apr/10" "06:10:31"
<      PACKAGE "" "" "" "ES7PR0601RN0000" "" "2019/Apr/10" "06:10:23"
<      DB_WWWISO "WWWISO" "0" "" "WMC020204RN0003" "" "2018/Dec/06" "12:51:56"
<      ENCLOSURE "SMART7-W" "NMSR18270010E" "0.0.0.0" "" "" "" ""
<      WIFI "RS9113" "" "" "1.7.0" "" "2019/Apr/10" "06:10:37"
<      REGULATORY "US" "" "" "" "" "" ""


[COM1]<TERRASTARINFO COM1 0 75.5 FINESTEERING 2057 494825.948 02004000 91ea 15526
<     "QY198:9565:5428" TERM 00007f00 170 2019 0 NEARSHORE 0.00000 0.00000 0
```

Once a subscription is purchased, TerraStar L-band delivery satellites begin broadcasting what is referred to as "the subscription activation signal" at the specified start date and time. The receiver must be configured to track TerraStar L-Band signal prior to the subscription start time in order to receive the subscription information. Note that the subscription information is rebroadcast periodically during the 30 days following the subscription start date. Thus, a receiver can still receive the subscription activation from one of those periodic (every 4-6 hours) broadcasts, if configured to track the L-Band signal during the initial 30 days.

Customers can also contact NovAtel Customer Support or use NovAtel's eCommerce system to "resend" the subscription activation in cases where the initial activation was missed within the 30-day period, for troubleshooting purposes or when the resend time window is not convenient. Alternatively, customers can resend the TerraStar activation signal through the customer self-service at NovAtel's web portal.

When an active but expiring subscription is renewed, the updated subscription information gets broadcast during the last seven days of the still active, expiring subscription. As long as the receiver tracks the TerraStar signal during that time, there will be no disruption in service when the new (renewal) subscription begins. The activation information for the renewal subscription continues to be broadcast for the subsequent 30 days.

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 (paid) subscription, the access status "ENABLE" indicates that the subscription is valid, the TerraStar decoder is "LOCKED" onto the data stream and the geogating status of the subscription is showing that the receiver is "ONSHORE".

Positioning with TerraStar

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[4], to determine the "best" solution available. By default, the receiver uses the three-dimensional standard deviation.

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 position types as shown in Table 2 where different TerraStar correction types are referenced:

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

Table 2 – PPP Position Status by Log and GPS Quality

For example TerraStar-C PPP solution transitions from "PPP_CONVERGING" to "PPP" based on the "PPPCONVERGEDCRITERIA" command setting. By default, the solution is flagged as converged when the estimated horizontal (2D) standard deviation of the solution is under 0.32 meters:

[COM1]<PPPPOS COM1 0 71.0 FINESTEERING 2057 414472.000 02040020 ec34 14968
< SOL_COMPUTED **PPP_CONVERGING** 51.15044107608 -114.03068004318 1097.1153 -17.0000
WGS84 0.8505 1.3157 2.0220 "**TSTR**" 12.000 0.000 31 31 31 27 00 00 3f 37

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[4] See www.novatel.com/assets/Documents/Manuals/om-20000129.pdf or
http://docs.novatel.com/OEM7/Content/Home.htm for the SETBESTPOSCRITERIA definition.

[COM1]<PPPPOS COM1 0 76.0 FINESTEERING 2057 414928.000 02000020 ec34 14968
<   SOL_COMPUTED **PPP** 51.15043714755 -114.03067696242 1097.6564 -17.0000 WGS84 0.0799 0.2168
0.1836 "**TSTR**" 18.000 0.000 33 33 33 29 00 00 3f 37

With TerraStar-X, PPP solution is reported similar to above PPPPOS logs however one difference is in the
base station ID field which reports "TSX" for TerraStar-X:

[COM1]<PPPPOS COM1 0 71.5 FINESTEERING 2057 415640.000 02000000 ec34 15437
<   SOL_COMPUTED **PPP** 51.15043856926 -114.03068169619 1097.4570 -17.0000 WGS84 0.0250 0.0237
0.0536 "**TSX**" 14.000 0.000 17 17 17 16 00 00 00 33

[TERRASTARINFO](#) log reports the subscription type and in the case of TerraStar-X subscription, it indicates
as below:

[COM1]<TERRASTARINFO COM1 0 76.0 UNKNOWN 0 0.224 02000020 91ea 15437
<   "QU243:3775:7727" TERM **00007f00** 167 2019 0 GEOGATED 0.00000 0.00000 0

Valid TerraStar-X subscription enables rapid convergence PPP within the rapid convergence area. With
TerraStar-X subscription, user has access to TerraStar-C PRO service for the entire duration of the
subscription. TerraStar-C Pro will be used by default when operating outside the rapid convergence area.
The firmware makes use of both correction services to provide the best PPP solution at any time.

Additional Information for TerraStar-X and TerraStar-C PRO

Multi-Constellation Multi-Frequency (MCMF) upgrade

Upon reception of a TerraStar-X or TerraStar-C PRO subscription, receiver will enable multi-constellation
and multi frequency tracking so long as the [TERRASTARAUTOCHANCONFIG](#) command is set to ENABLE
mode, which by firmware default is enabled. This new channel tracking configuration can be different from
the receiver's paid model default channel configuration or the one that was changed and saved on the
receiver. In current implementation, MCMF channel configuration only applies to single antenna models.

MCMF upgrade gets applied on the next reboot after the subscription is received, in other words, the
receiver will require a power cycle or reset (RESET command) in order to apply the new channel
configuration following the activation of a subscription. As long as there is a TerraStar-X or TerraStar-C PRO
subscription active on the receiver, as reflected in the [TERRASTARINFO](#) log, channel configuration (see
[CHANCONFIGLIST](#) log) will be modified on the next reboot. It is important that all configuration is saved on
the receiver with the SAVECONFIG command prior to a reset or power cycle.

To give an example, an OEM729 card with a model starting as "DDN" changes its existing channel
configuration after a reset or power cycle to the default of "FDN" following the activation of a TerraStar-X
or TerraStar-C PRO subscription.

There is hardware limitation for certain OEM7 cards (OEM7600, OEM7720, OEM718D) where the updated
channel configuration for MCMF is a "reduced" channel configuration i.e. it is different than what e.g.
OEM729 or OEM719 cards would get. By "reduced" it is meant that MCMF unlock applies an inferior
model's default channel configuration. For example, an OEM7720 loaded with a model starting with "GFN"
changes its tracking configuration to the default channel configuration of a model that starts with "MFN"

as opposed to an OEM729 that gets the default channel configuration of a model that starts with "FFN" for the same case.

MCMF default upgrade is important since TerraStar-X grants TerraStar-C PRO level performance during any corrections outage in the Corn Belt or when rover moves out from the Corn Belt region.

With TerraStar-X service inside the Corn Belt region users can achieve converged solution with horizontal accuracy under 2cm (RMS) and vertical accuracy under 5cm (RMS). Pass-to-pass accuracy is applicable for 15min periods and has horizontal accuracy of less than 2cm when tracking with an OEM7 receiver in multi-constellation, multi-frequency mode.

Operating at the Fast Convergence Region

A receiver with a TerraStar-X subscription has access to both the regional (rapid convergence) and global corrections for use in the positioning solution. The receiver will utilize the corrections that provide the fastest convergence and the best accuracy possible and will seamlessly manage the transition between the global and regional correction sources.

For the primary use case where a receiver with TerraStar-X subscription starts for full convergence inside the Rapid Convergence Region (Corn Belt, Figure 1), there will be no change to accuracy if the receiver exits the boundary of this region after convergence. In the event that a converged PPP solution is lost outside the zone, for example due to intermittent or complete loss of GNSS or L-band tracking, the receiver will have to re-converge. Re-convergence for a brief outage outside the rapid convergence region may still take under a minute.

If a receiver's PPP convergence starts outside the rapid convergence region for the initial position fix, the expected horizontal accuracy is under 10cm for an initial convergence period that is under 5 min (RMS).

If a receiver converges in the rapid convergence region and moves out of it, system will continue operating with TerraStar-C PRO performance until the receiver is reset or power cycled. Any total reconvergence outside the rapid convergence region will be of TerraStar-C PRO convergence performance (full convergence under about 18 minutes unless other settings are activated, such as PPPSEED) despite the receiver having a TerraStar-X subscription.

Both inside and outside the Corn Belt region, TerraStar-C PRO is a fall back service level for TerraStar-X.

All of the commands and logs mentioned in this document are described in full detail in the OEM7 documentation (http://docs.novatel.com/OEM7/Content/Home.htm). Some of the commands and logs specific for L-band tracking, TerraStar status and PPP positioning are listed below:

Commands

For general information about issuing commands to a NovAtel receiver, please visit our online documentation for Commands.

ASSIGNLBANDBEAM

PPPCONVERGEDCRITERIA

PPPDYNAMICS

PPPRESET

PPPSEED

PPPSOURCE

PPPTIMEOUT

TERRASTARAUTOCHANCONFIG

Logs

Any of the logs described below can be output using the LOG command. For general information about requesting logs from a NovAtel receiver, please visit our online documentation for Logs.

LBANDBEAMTABLE

LBANDTRACKSTAT

PPPPOS

PPPSATS

TERRASTARINFO

TERRASTARSTATUS

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 RXCONFIGA ONCE
LOG LBANDTRACKSTATB ONTIME 1
LOG TERRASTARINFOA ONCHANGED
LOG TERRASTARSTATUSA ONCHANGED
```

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.

Documentation

All logs and commands described below can be found in documentation for OEM7:

Documentation Portal: http://docs.novatel.com/OEM7/Content/Home.htm