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Waypoint Software

**Inertial Explorer
Inertial Explorer Xpress
GrafNav / GrafNet
GrafNav Static**

User Manual

Waypoint Software 10.00 User Manual

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This manual reflects Inertial Explorer software version 10.00.

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Foreword

Inertial Explorer, Inertial Explorer Xpress, GrafNav, GrafNet and GrafNav Static are Windows®-based programs that support GNSS and GNSS+INS data post-processing. This manual will help you install and navigate your software.

Scope

This manual contains information on the installation and operation of Inertial Explorer, Inertial Explorer Xpress, GrafNav, GrafNet and GrafNav Static. It allows you to effectively navigate and post-process GNSS or GNSS and IMU (Inertial Measurement Unit) data in combination with updates from external sources, such as wheel sensor data, dual antenna data, gimbal units, and external position updates. It is beyond the scope of this manual to provide details on service or repair. See *Customer Service* below for customer support.

How to use this manual

This manual is based on the menus in the interface of the Waypoint software package. It is intended to be used in conjunction with the corresponding version of Waypoint's software.

Although previous experience with Windows is not necessary to use Waypoint software packages, familiarity with certain actions that are customary in Windows will assist in using the program. This manual has been written with the expectation that you already have a basic familiarity with Windows.

Conventions

This manual covers the full performance capabilities of the Waypoint software. The conventions include the following:

> ⓘ This is a note box that contains important information before you use a feature, or to give additional information afterward.

> ⓘ In this document, the term Inertial Explorer is used to represent both Inertial Explorer and Inertial Explorer Xpress. When information is specific to one of the software programs, the software program is identified (e.g. Inertial Explorer Xpress only).

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Chapter 1   Waypoint Software Overview

NovAtel's Waypoint Products Group offers GNSS post-processing software packages including GrafNav (a static/kinematic baseline processor), GrafNet (a static baseline processor/network adjustment package) and Inertial Explorer (a GNSS+IMU post processing software). All of these products have a Windows based Graphical User Interface (GUI) and use the same precise GNSS processing engine. This processing engine has undergone years of development effort and has been optimized to give the highest precision with the least amount of operator intervention.

1.1   Overview of the Waypoint Products

1.1.1   Inertial Explorer

Inertial Explorer shares a similar interface with GrafNav and provides both GNSS and INS processing capabilities. Inertial Explorer is powerful and feature rich, including support for both loosely and tightly coupled processing, multi-pass processing, a backsmoother, automatic processing profile detection and many other features. See *Inertial Explorer Overview* on page 43 for more information.

1.1.2   Inertial Explorer Xpress

Inertial Explorer Xpress provides the same core processing and utilities as Inertial Explorer along with simplified functions and workflows that have been tailored for UAV markets and small project areas. Data can be post-processed efficiently without compromising position, velocity or attitude accuracy. Inertial Explorer Xpress produces centimeter-level position and attitude solutions compatible with LiDAR, camera and other sensor data.

1.1.3   GrafNav

GrafNav is a kinematic and static GNSS post-processing package. Included with GrafNav is a Precise Point Positioning (PPP) module, support for multi-base applications, and support for moving base applications. See *GrafNav Overview* on page 43 for more information.

1.1.4   GrafNet

GrafNet is a batch static baseline processor and network adjustment package. It is often used to check or establish base station coordinates for later use within GrafNav or to survey static networks. GrafNet is included with the installation of GrafNav and Inertial Explorer, but is not included with the installation of Inertial Explorer Xpress. See *GrafNet Overview* on page 135 for more information.

1.1.5   GrafNav Static

A GrafNav Static license allows a user to process GNSS data within either GrafNav or GrafNet, however only static data will be processed. See *GrafNav Static Overview* on page 43 for more information.

1.1.6   Waypoint TerraStar Near Real-Time (NRT) Precise Products

NovAtel's Waypoint post-processing software is now available with access to TerraStar Near Real-Time (NRT) precise clock and orbit products. This is a subscription-based service that requires activation of an additional license.

With the NRT feature enabled, TerraStar precise products may be downloaded within Waypoint software with an approximate latency of only 15 minutes and are of comparable accuracy to common correction services (CODE, IGS, STA etc.) with significantly longer latency. This facilitates Precise Point Positioning (PPP) in

applications that demand a quick turnaround. When used with NovAtel data, NRT files will also allow for PPP with ambiguity resolution (AR) providing faster convergence times equivalent to TerraStar C-PRO.

The TerraStar NRT service offers the following advantages as compared to publicly available rapid precise products:

- Fast availability
- Support for all constellations
- High rate precise satellite clock data (good for kinematic processing)
- High reliability and redundancy

1.1.7   Moving Baseline Features

GrafNav includes a moving baseline module that processes GNSS data between two moving antennas. Heading can also be computed if the two antennas are mounted on the same vehicle. Moving baseline capability is not included in Inertial Explorer or Inertial Explorer Xpress.

Relative Processing

All of the same advanced GrafNav processing features including ARTK, a robust Kalman filter, and forward/reverse processing are also supported in moving base processing. The only restriction is that only one base station can be used when processing the relative vector.

For applications where both antennas are mounted on the same vehicle, the surveyed distance between the antennas can be entered to assist ambiguity resolution. Heading can also be computed for these applications.

Relative Vector Output

After processing, the included Export Wizard profiles are available to output the relative vector in local level or ECEF format.

Relative Velocity

In addition to relative position information, GrafNav uses Doppler measurements to compute instantaneous relative velocity between two moving antennas.

1.2   Software Utilities

The following utilities are installed automatically and can be accessed from *Start | Programs | Waypoint GrafNav GrafNet 10.00 | Utilities*.

1.2.1   Concatenate, Slice and Resample

This utility is most often used for combining multiple GPB files together and resampling GPB files to higher intervals. There are many other uses of this utility however and a full description can be found in *Concatenate, Slice and Resample Files* on page 171.

1.2.2   Copy User Files

User created content from previous versions of Waypoint software can be found in the *User* directory of the previous software version. To find this directory, open the previous version of software and navigate to *File | Preferences* then select the *Update* tab. The directory listed under the label *All user created or modified profiles, grids, datums, favorites, etc.* is your User directory.

The User directory of your previous version of software may contain files such as:

- User created export profiles (*.prf)
- User created processing profiles (*.DefOpt)
  Be sure to check your installation directory for user created processing profiles as well.
- User created datums (user.dtm)
- User created grids (user.grd)
- User created favorite points/coordinates (user.fvt)
- User created plot groups (user.pgr)
- User created download service links (user.xml)
- User created 3rd party IMU conversion profiles (user.cim, Inertial Explorer/Inertial Explorer Xpress only)
- User created IMU error models (user.imu, Inertial Explorer/Inertial Explorer Xpress only)
- User created vehicle profiles (user.vpf, Inertial Explorer/Inertial Explorer Xpress only)

To find your 10.00 User directory, navigate to the installation directory of your 10.00 software and read the *waypoint.settings* file. This is an ASCII file that you can read with any ASCII text editor. Your 10.00 User directory path will be saved in the node labeled *UserDir*. By default UserDir will be in your 10.00 installation directory.

To migrate your old user created content simply copy the files from the User directory of the previous version of software to the User directory of your new software.

All user files from 9.00 are fully compatible with 10.00 and you can copy them directly from 9.00 to 10.00. Waypoint cannot guarantee 10.00 User file compatibility for older software versions (e.g. the lever arm favourites – user.lvf – file is not supported in 8.90). If a user file is incompatible with 10.00, you will have to recreate the file using 10.00 utilities.

1.2.3   Download Service Data

This utility allows you to search for freely accessible base station data provided by government organizations. The utility will download, convert, and if necessary resample and concatenate the downloaded data so that it is ready to be used within your project.

The download utility can also be used to obtain precise satellite clock and ephemerides, and alternate broadcast ephemerides.

HxGN SmartNet

We offer the ability to obtain HxGN SmartNet stations directly through our download utility. This allows anyone with a HxGN SmartNet subscription easy access to improve their post-processing workflow. More information on how to enable the service can be found in *Services* on page 64.

1.2.4   GPB Viewer

This utility allows you to view converted GNSS data as well as perform certain functions, such as changing the static/kinematic processing flag. See *GPB Viewer Overview* on page 167 for more information.

1.2.5   GNSS Data Converter

This utility converts raw GNSS data files into Waypoint GPB format. The following table shows the supported receivers and formats. See *GNSS Data Converter Overview* on page 172 for more information.

You will also see the Local License Manager utility.

Table 1: Supported Data Formats

Make	Model
NovAtel	OEM4 and later
Javad	All Models
Leica	System 500 System 1200 GX1230
NavCom	SF-20x0 SF-30x0 Sapphire
RTCM	3.0
Septentrio	SBF
Ashtech	Real Time B-file
u-blox	Antaris F9 M-8
RINEX	2.x 3.x

1.3   Processing Modes and Solutions

1.3.1   Processing Modes

The following are the types of processing modes:

Static Mode

Static processing involves the determination of a single coordinate for an entire static session. There are two types of static solutions supported by GrafNav: float and fixed solutions.

Kinematic Mode

When processing kinematic data, it is of interest to optimize the entire trajectory. This is in contrast to static processing, which solves one coordinate for the entire session.

In order to quickly achieve cm-level accuracy in kinematic processing environments, ARTK is used to resolve integer carrier phase ambiguities.

1.3.2   Processing Solutions

ARTK solution

AdVance RTK is NovAtel's industry leading RTK engine which provides rapid centimeter level positioning. ARTK is used in Waypoint products to resolve integer carrier phase ambiguities.

With short baseline lengths (several kilometers), open sky conditions and dual frequency data, ARTK often requires only several seconds of data to fix ambiguities. Although ARTK needs at least 5 satellites to resolve,

in practice it is most robust when 7 or more satellites are available. ARTK may resolve at baseline lengths as long as 70 km, however it is most reliable at distances of 30 km and less provided dual frequency data.

Fixed static solution

The fixed static solution uses ARTK with static constraints to resolve integer carrier phase ambiguities. New ambiguities are automatically fixed whenever there is a change in satellite geometry (i.e. a new satellite rises or a satellite drops out). A history of ARTK solutions over the static session is kept and GrafNav/GrafNet allows you to choose which is accepted as the final solution based on estimated error, lowest RMS, highest reliability, or an average of all fixes.

Float solution

Float solutions, unlike fixed static and ARTK solutions, do not resolve carrier phase ambiguities as integer values. As such, they are associated with lower accuracy applications than fixed solutions. Provided good data, float solutions improve with time and can still achieve centimeter-level accuracy, depending on factors such as baseline length, number of satellites and geometry, raw measurement data quality, etc.

Chapter 2   Installation

Waypoint software supports software-based licensing only. Installation instructions are provided in the following sections.

2.1   What You Need To Start

2.1.1   Activation ID

A license is required to convert raw GNSS data, use the Download Service Utility and to process GNSS and INS data. The license will be delivered electronically by either NovAtel Order Management or Support staff.

(i) No license is required to convert NovAtel data to Waypoint format.

A second activation ID can be purchased which provides access to TerraStar Near Real-Time (NRT) precise satellite clock and orbit data. The activation and return process for an NRT license is the same as for a software license described in *Activate Your License* on the next page. For more information on the NRT feature, see *Waypoint TerraStar Near Real-Time (NRT) Precise Satellite Clocks and Orbits* on page 56.

2.1.2   Installation file

Information on how to download the installation files will be provided with your software license. If you are missing this information, contact NovAtel Support at support.novatel@hexagon.com with your activation ID.

See *Supported Operating Systems* below for the hardware requirements.

2.2   Supported Operating Systems

Windows 10 and 11.

2.3   How to install Waypoint software

Administrator privileges are required to successfully install all components of Waypoint software.

(i) It is recommended that a license be returned prior to any significant computer maintenance or changes (i.e. upgrading of the operating system, motherboard replacement, etc.).

1. If you have a previous version of Waypoint software installed, we do not recommend uninstalling it prior to installing a new version. This is because any user created content such as favourites, processing profiles, customized grids or conversions etc. can be copied over to the new version. This is only possible if the new version is installed prior to uninstalling the old version.

    Each major version of Waypoint software will install to a separate default installation directory and will thus not overwrite or remove content from a previous major version.

    All installation files are provided on a password protected website. Contact support.novatel@hexagon.com with your software activation ID for login instructions if required.

2. Launch the setup and follow the on-screen instructions.

3. If you are upgrading from a previous major version, such as 9.00, you will need to upgrade your license.

    For upgrade instructions, see *Activate Your License* below.

4. See *Copy User Files* on page 17 for instructions on how to copy user created content from previous major versions.

2.4   Activate Your License

This section applies to customers who wish to activate a new license or upgrade an existing license in order to use Waypoint software.

> ⓘ   If using Waypoint software on a virtual computer, please see the following application note: hexagondownloads.blob.core.windows.net/public/Novatel/assets/Documents/Papers/APN-081-Waypoint-Virtual-Computer/APN-081-Waypoint-Virtual-Computer.pdf.

2.4.1   License Activation Utility

The license activation methods in this section use the LLMForm.exe utility to activate and return a license. You can activate a license with or without internet using the utility or manually through the command line.

Opening the License Manager

1. Install the Waypoint software that you intend to use.

    Please contact support.novatel@hexagon.com with your activation ID if you need help locating the setup file.

2. Open the NovAtel Local License Manager.
    From the Windows® Search Bar, access the *Local License Manager*, or *LLMForm* as shown below. Alternatively, you can navigate to the Waypoint software installation folder (e.g. C:\Novatel\InertialExplorer10\bin) and open LLMForm.exe.
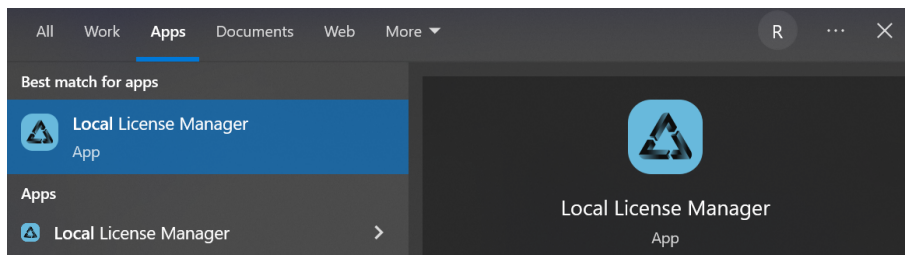
    You can also access the Local License Manager from the *License Information* button on the *Help |*

About… dialogue directly from Inertial Explorer or GrafNav.
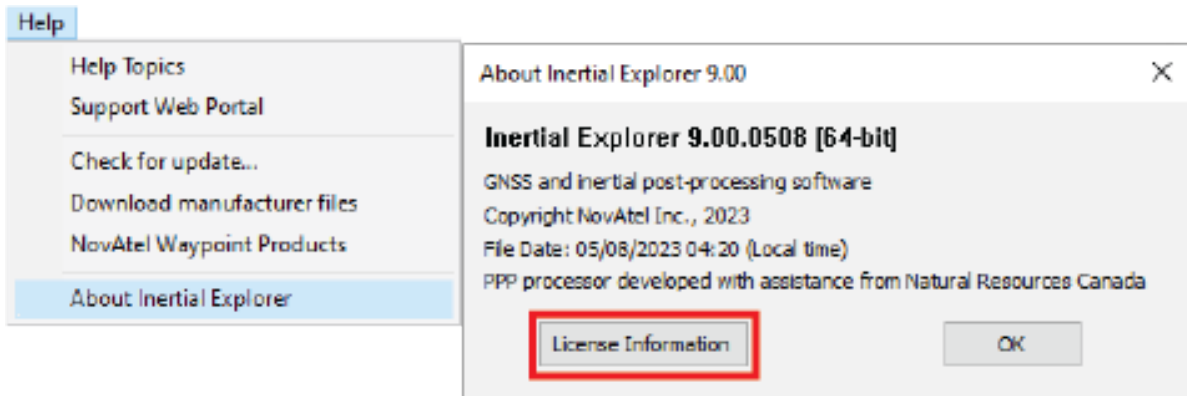
Activate and Return with Internet

If you are activating a new license, not upgrading an existing license, skip to step 2.

1. If you are upgrading an existing license (upgrading from a previous version), you will first need to return the original license by selecting your existing license under *Local Licenses* and clicking the *Return* button.
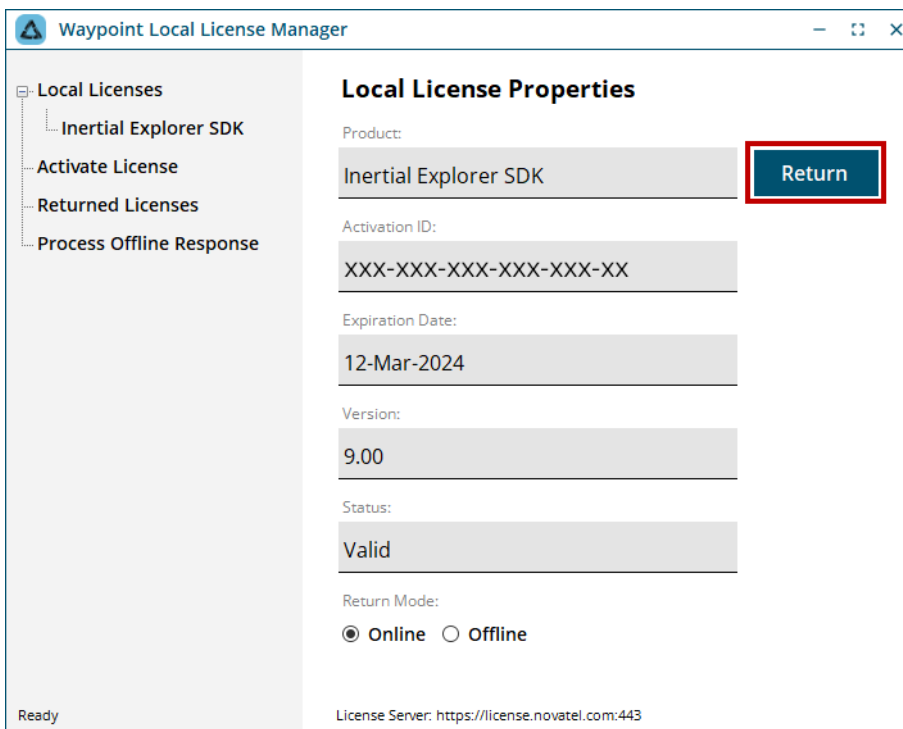
2. Activate the license by copying the activation ID that was provided to you by NovAtel and pasting it into the *Activation ID* box under the *Activate License* branch and clicking the *Activate* button.

> ℹ️ When activating a license, it is recommended to enter identifying information in the *Activator Info* field, such as your name, username, device name, etc. The *Activator Info* field is a simple text field intended to help users keep track of who currently has the license activated. This can be very helpful in cases where a single license is shared among multiple users or devices. See *Retrieve basic information about a license* on page 38 for instructions about how to retrieve that information when needed.
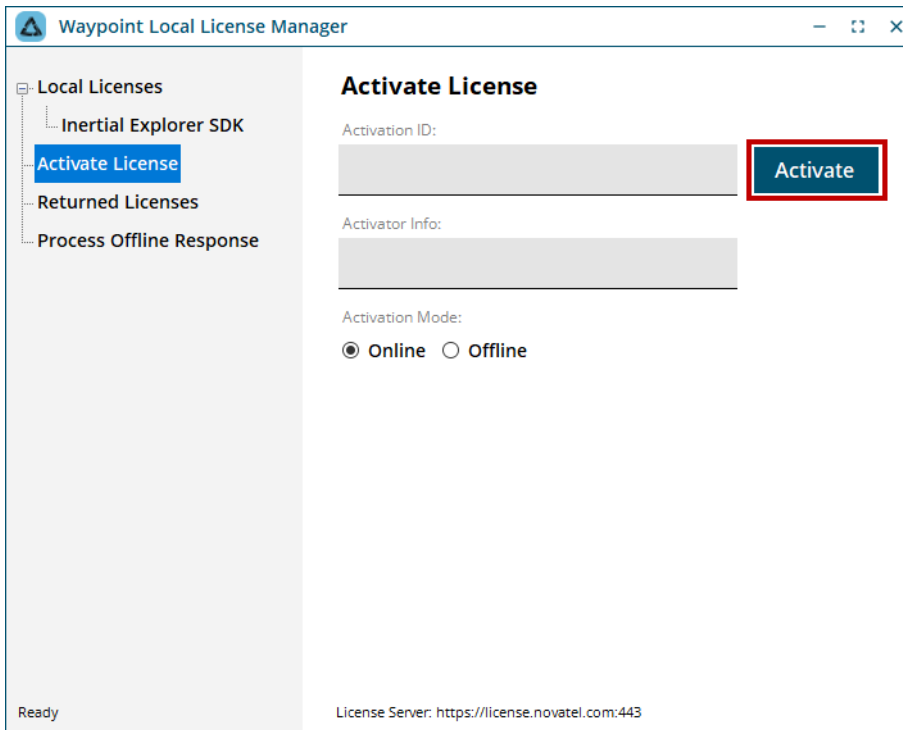
3. Confirm the license was successfully activated, by checking that your license appears under *Local Licenses*. You can view the license information by selecting it.
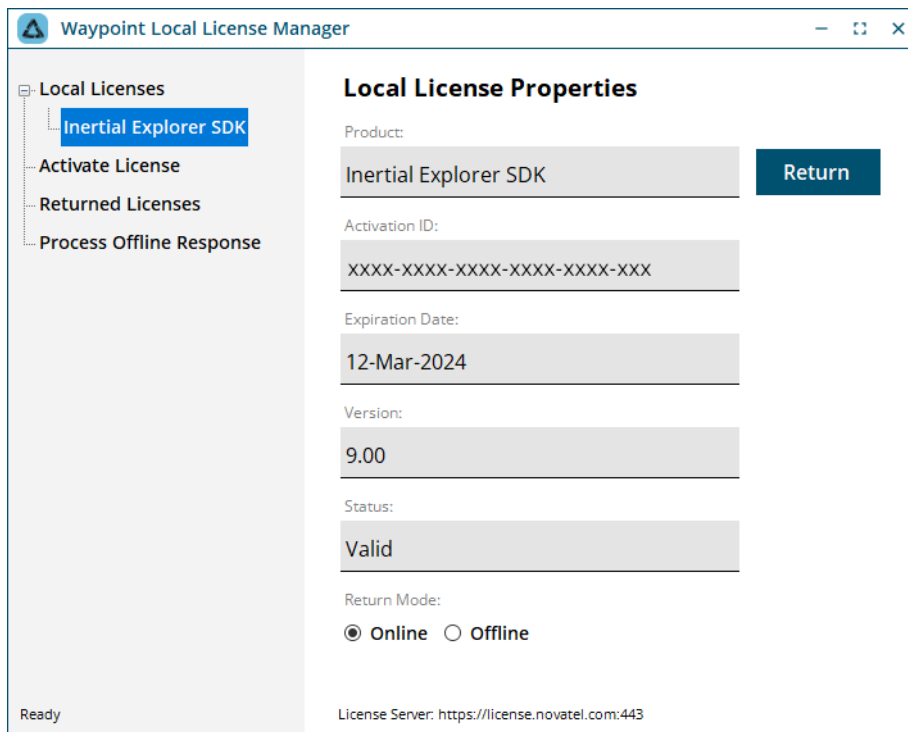
If the activation fails, contact Customer Support (support.novatel@hexagon.com) with your activation ID and a screen shot of the error.

Activate and Return without Internet

If you are activating a new license, not upgrading an existing license, skip to step 2.

1. Manually return the existing license.
   If you are upgrading an existing license, the original license must be manually returned before the upgrade code can be activated.

a. Generate a manual return request by selecting the "*Offline*" radio button, then clicking *Return*.
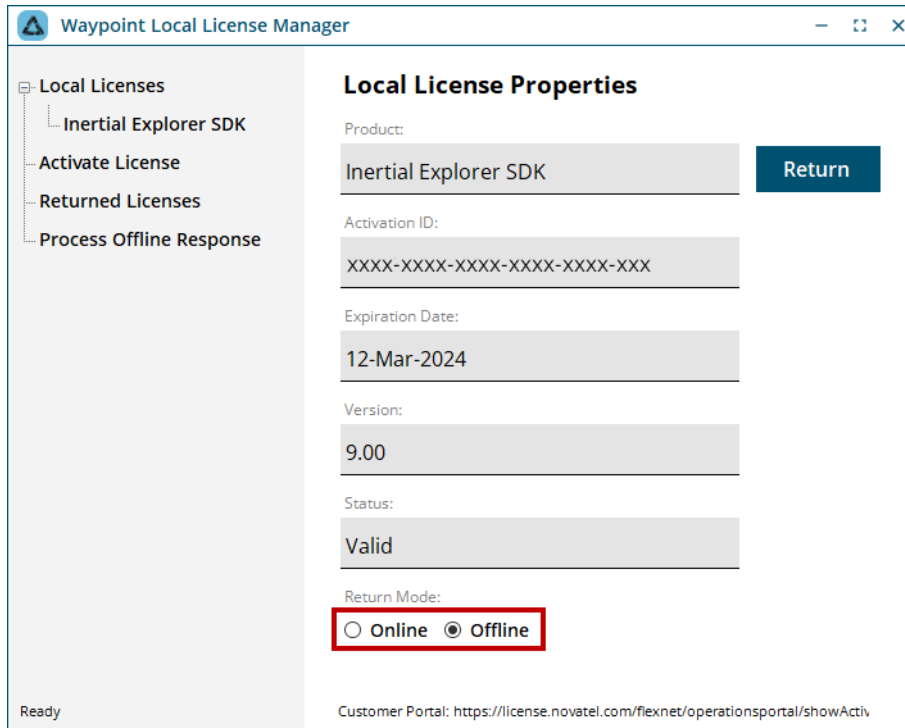
LLMForm will indicate where the return request file was written to.
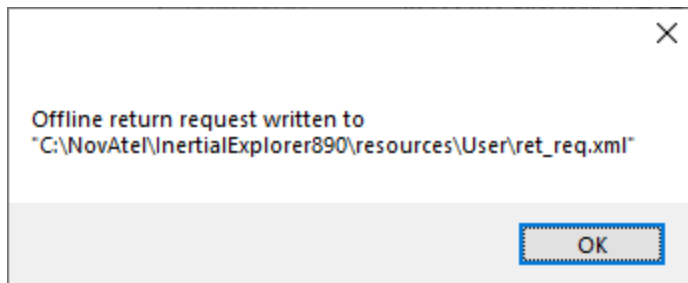
Copy the return request file to a computer with Internet access.

b. Process the Return Request through the FlexNet Customer Portal.

From a computer with Internet access, sign in to the FlexNet customer portal (https://license.novatel.com/flexnet/operationsportal/showActivationIdLogon.do) using your activation ID.
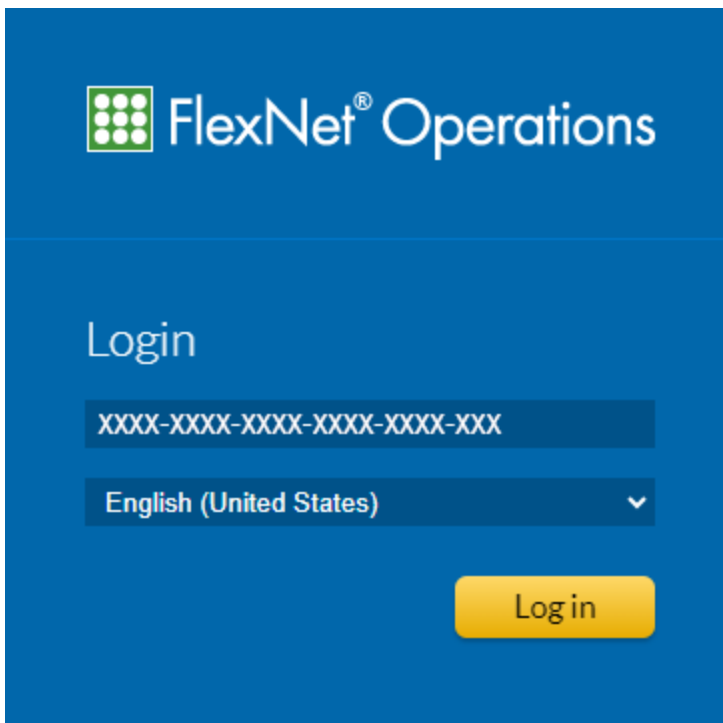
Once logged in, select *Manual Return* under the *License Support* tab.

Select *Choose File…* to browse to the previously generated return request XML file that was moved from the computer with the Waypoint software installed.

Manual Return

Generate the trusted storage return request as an XML file on the client machine. Load that file here.

Request XML File

Request XML File: *   Choose File   ret_req.xml

Submit   Cancel

Click *Submit* to generate the manual return response.

Manual Return Summary

Generate the trusted storage return request as an XML file on the client machine. Load that file here.

Generated license: XXXX-XXXX-XXXX-XXXX-XXXX-XXX

Product(s):   Inertial Explorer

Fulfillment ID(s):   FID_20034a8b_2628_4249_aa5f_7920e881
b411

Sold to: NovAtel Internal Licenses

<?xml version="1.0" encoding="UTF-8" ?>
<Response
xmlns="http://www.macrovision.com/fnp/20
04/11/activation"><ResponseHeader>
<VersionNumber>2</VersionNumber>
<ResponseType>RETURN</ResponseTyp

Save To File

Click *Save To File* to save the response file (responseXML.xml).

Copy the response file to the computer with Waypoint software installed.

c. Process the Response.

From the computer with Waypoint software installed, open the Local License Manager and go to the *Process Offline Response* tab.

Click *Browse* to find the response file generated above and then click *Process* to complete the manual return.
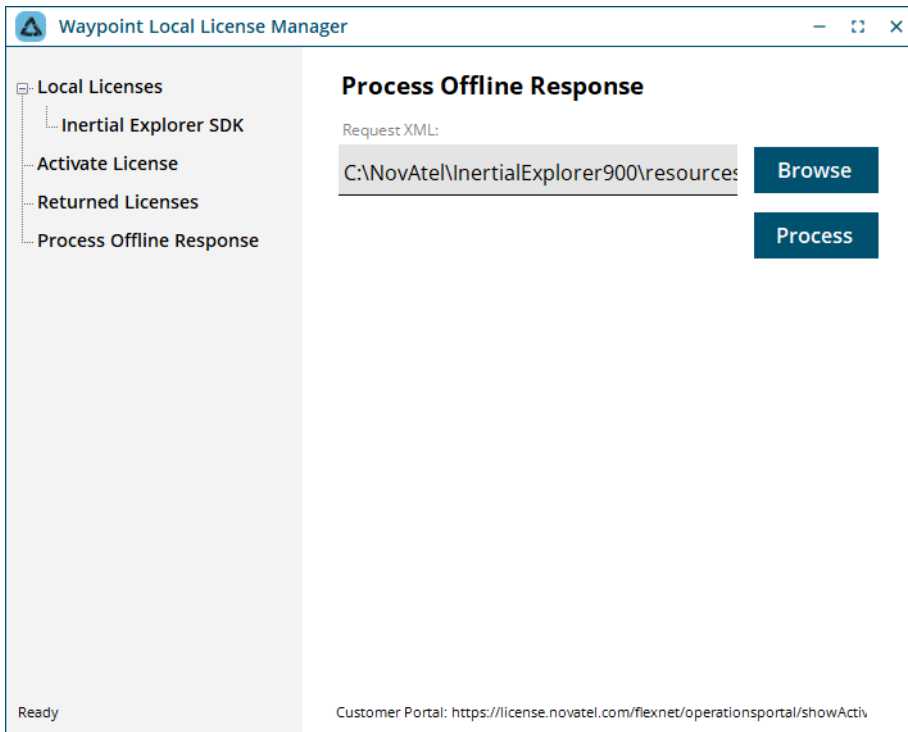
A popup message will appear to indicate success.
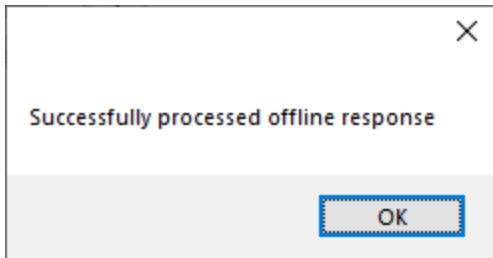
The license should now be returned. To verify, look under the *Local Licenses* branch to ensure that the license is no longer listed.
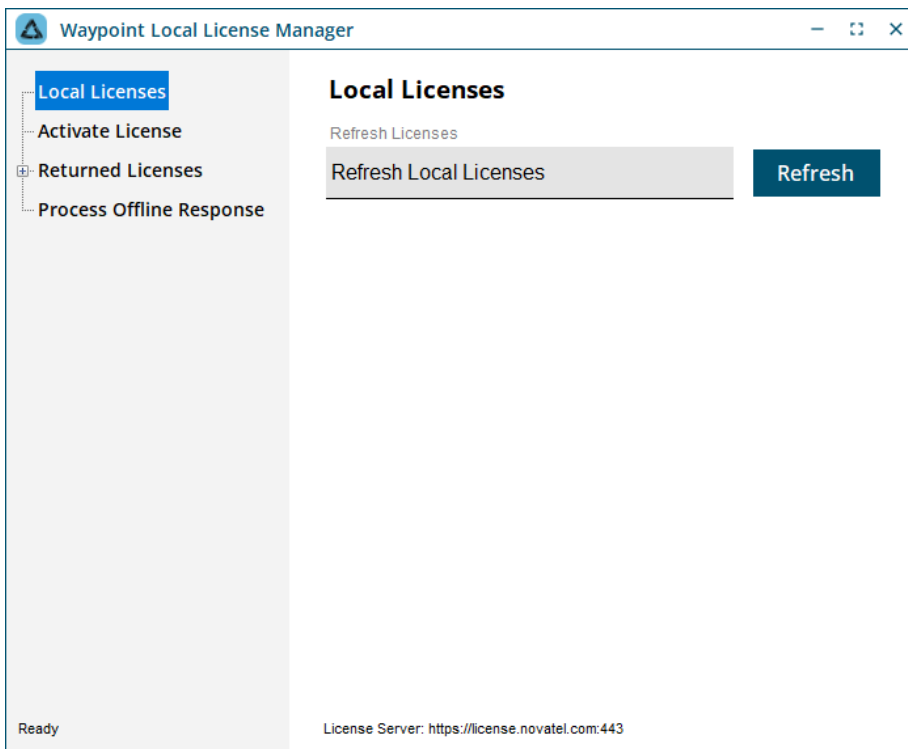
2. Manually activate a license.

a. Generate a Manual Activation Request by selecting the *Offline* radio button, then clicking *Activate*.
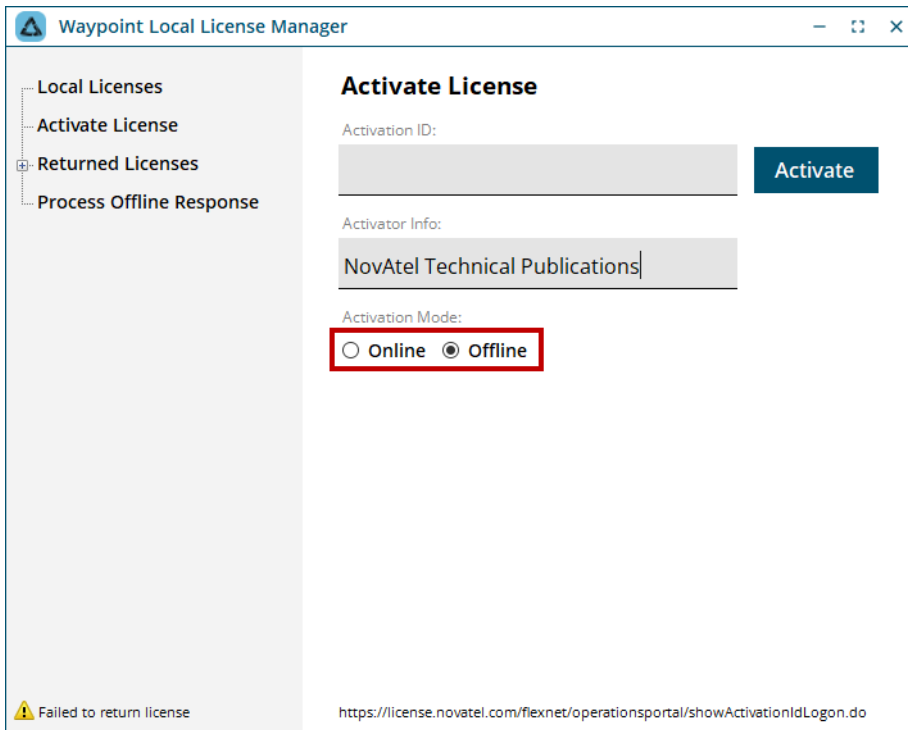
> ℹ️ When activating a license, it is recommended to enter identifying information in the *Activator Info* field, such as your name, username, device name, etc. See *Retrieve basic information about a license* on page 38 for instructions about how to retrieve that information when needed.

LLMForm will indicate where the activation request file was written to.
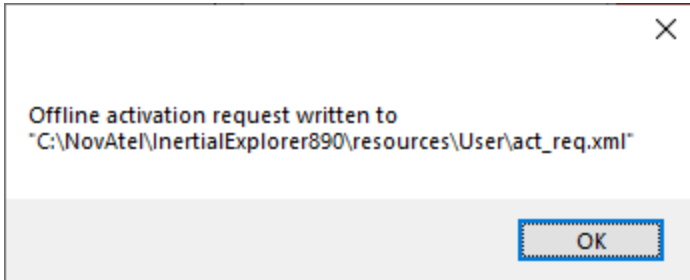
Copy the manual activation request file to a computer with Internet access.

b. Process the Activation Request through the FlexNet Customer Portal

From a computer with Internet access, sign in to the FlexNet customer portal (https://license.novatel.com/flexnet/operationsportal/showActivationIdLogon.do) using your activation ID.
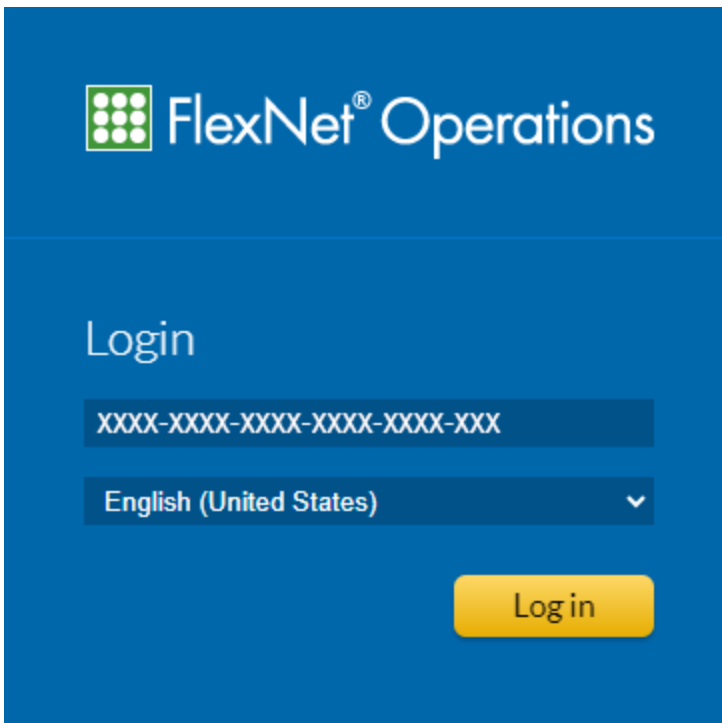
Once logged in, select *Offline Trusted Activation* under the *Activation & Entitlements* tab.
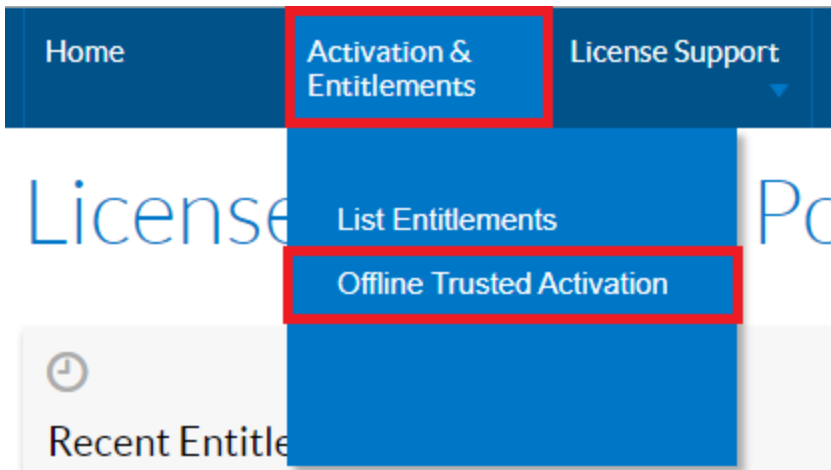
Select *Choose File…* to browse to the previously generated activation request XML file that was moved from the computer with the Waypoint software installed.

Click *Submit* to generate the response.

Offline Trusted Activation Summary

Generate the trusted storage activation request as an XML file on the client machine. Load that file here.

Offline Trusted Activation Details

Generated license: XXXX-XXXX-XXXX-XXXX-XXXX-XXX

Product(s): Inertial Explorer

Fulfillment ID(s): FID_057c4d72_e2b6_41bd_a71a_9a3c0bfa ef94

Sold to: NovAtel Internal Licenses

Generated file:
```
<?xml version="1.0" encoding="UTF-8" ?>
<Response
xmlns="http://www.macrovision.com/fnp/20
04/11/activation"><ResponseHeader>
<VersionNumber>2</VersionNumber>
<ResponseType>ACTIVATION</Response
```

[Complete] [Save]

Click *Save* to save the response file (responseXML.xml).

Copy the response file to the computer with Waypoint software installed.

c. Process the Activation Response

From the computer with Waypoint software installed, open the Local License Manager and go to the *Process Offline Response* tab. Click *Browse* to find the response file generated above and click *Process* to complete the manual activation.

Waypoint Local License Manager   — :: ×

- Local Licenses
  - Inertial Explorer SDK
- Activate License
- Returned Licenses
- Process Offline Response

Process Offline Response

Request XML:

C:\NovAtel\InertialExplorer900\resources   [Browse]

[Process]

Ready   Customer Portal: https://license.novatel.com/flexnet/operationsportal/showActiv
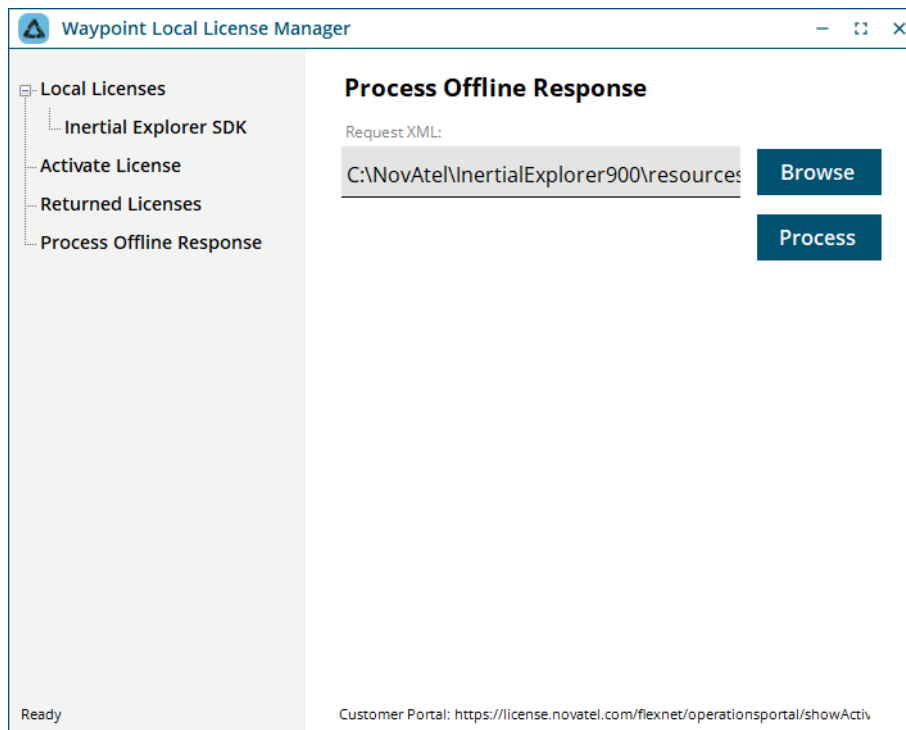
A popup message will appear to indicate success.
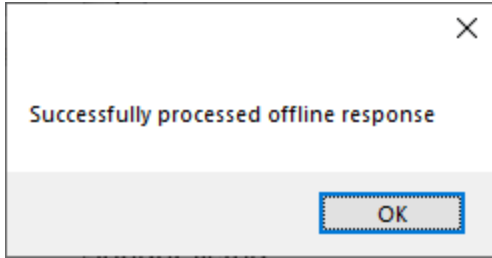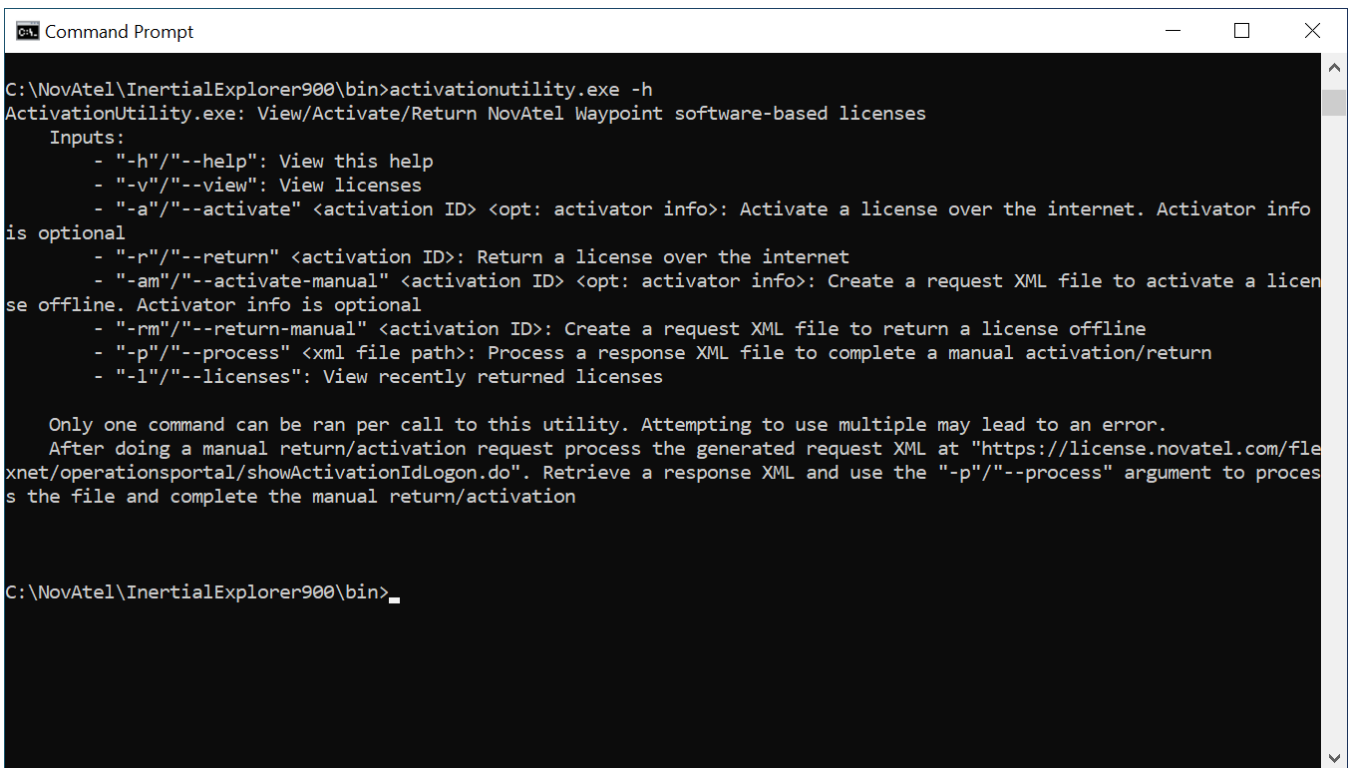
The license should now be activated. To verify, look under the Local Licenses branch to ensure that the license is now listed.
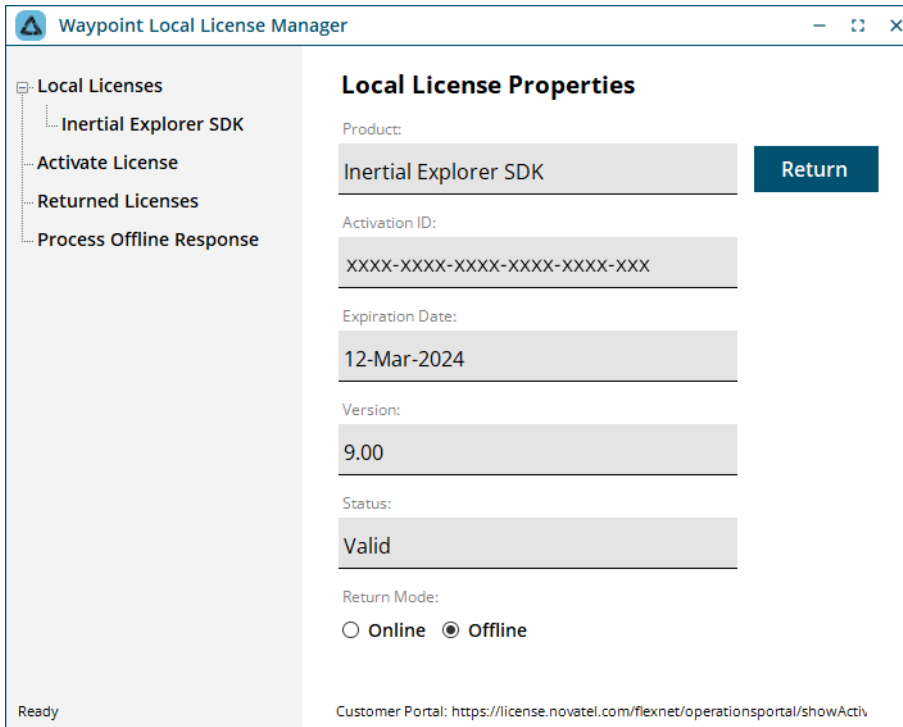
Command Line Activation

If you prefer to use the command line for license activation and return, the *ActivationUtility.exe* tool can be used from the software installation folder (e.g. C:\NovAtel\InertialExplorer10\bin). An example of command line activation is shown in the following image.

```
C:\NovAtel\InertialExplorer900\bin>activationutility.exe -h
ActivationUtility.exe: View/Activate/Return NovAtel Waypoint software-based licenses
    Inputs:
        - "-h"/"--help": View this help
        - "-v"/"--view": View licenses
        - "-a"/"--activate" <activation ID> <opt: activator info>: Activate a license over the internet. Activator info
is optional
        - "-r"/"--return" <activation ID>: Return a license over the internet
        - "-am"/"--activate-manual" <activation ID> <opt: activator info>: Create a request XML file to activate a licen
se offline. Activator info is optional
        - "-rm"/"--return-manual" <activation ID>: Create a request XML file to return a license offline
        - "-p"/"--process" <xml file path>: Process a response XML file to complete a manual activation/return
        - "-l"/"--licenses": View recently returned licenses

    Only one command can be ran per call to this utility. Attempting to use multiple may lead to an error.
    After doing a manual return/activation request process the generated request XML at "https://license.novatel.com/fle
xnet/operationsportal/showActivationIdLogon.do". Retrieve a response XML and use the "-p"/"--process" argument to proces
s the file and complete the manual return/activation


C:\NovAtel\InertialExplorer900\bin>
```

2.4.2   Auto Activate/Return

A Waypoint license may only be activated on one system at a time. It is recommended to return your license when it is not in use in order to:

- Ensure it is available for activation if it is a shared license

- Protect against loss of the license due to hard drive failure

In order to assist with license management of shared licenses, Waypoint software comes with an auto-activate/auto-return functionality available through the *File | Preferences* menu of Inertial Explorer, GrafNav and GrafNet.
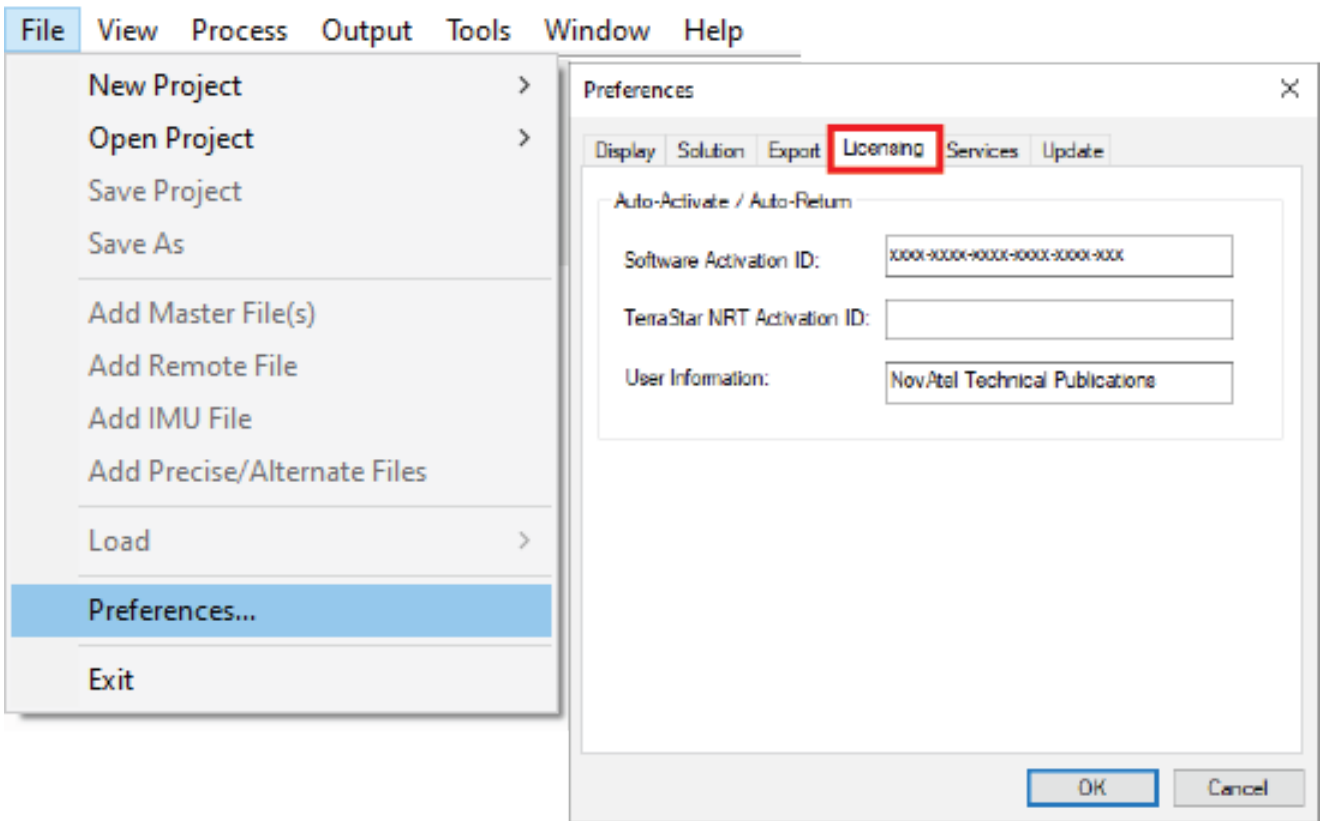
ⓘ   The Auto Activate/Return feature requires a working Internet connection.

This interface requires the *Software Activation ID* and *User Information* entries to be filled. The *TerraStar NRT Activation ID* entry is optional.

When you open and close the software you will be prompted to activate and return the license entered.
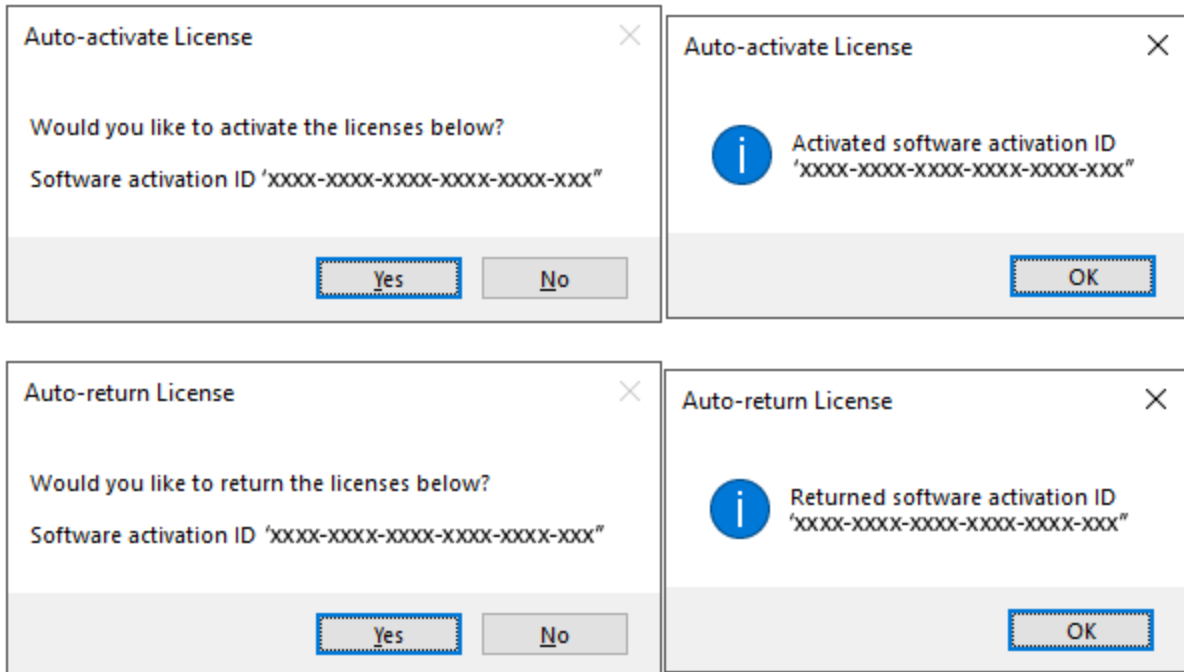
In the event the license is misplaced, you may log into the user portal with your activation ID and retrieve the last *Activator Info* string entered to help find who last activated the license. See *Accessing the Activator Info String* on page 40.
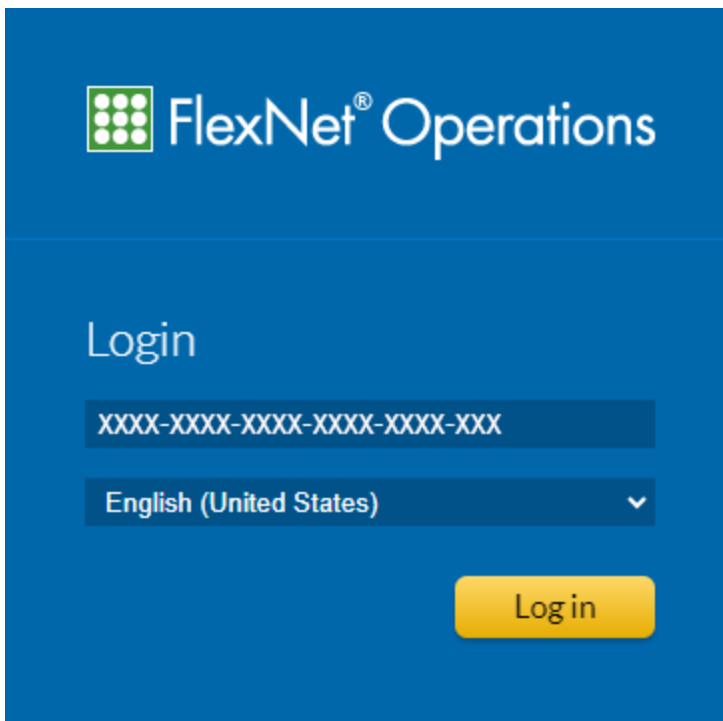
2.4.3   License Information

The Licensing portal may be used to retrieve basic information about a license, including:

- Whether the license is available for activation
- The *Activator Info* information which can help track down the user or machine that has the license activated
- Support end date for a permanent license
- The part number of a product
- Whether the license is available for activation
- The end date of a term license

Logging in to the user FlexNet portal

1. Enter the following link to access the user license portal,
   https://license.novatel.com/flexnet/operationsportal/showActivationIdLogon.do.

2. Log in with your activation ID:

Retrieve basic information about a license

1. After logging in, click on the *Activation ID* hyperlink on the main page.
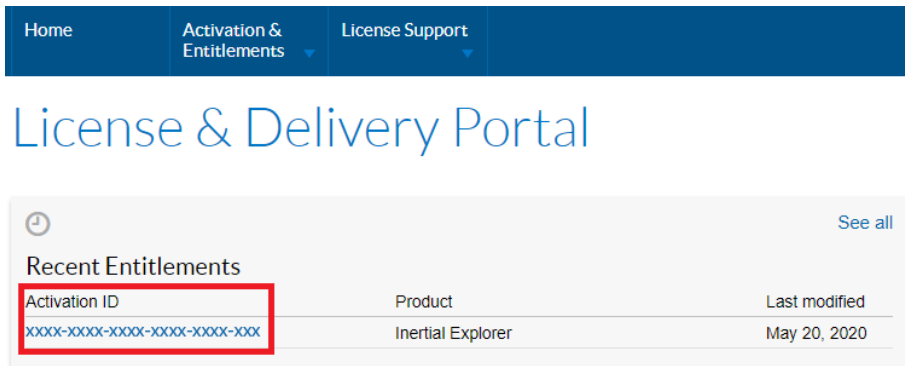
2. The *Entitlement Details* summary will report the following.

Accessing the Activator Info String

1. After logging into the portal, select *List Licenses* under *License Support*:
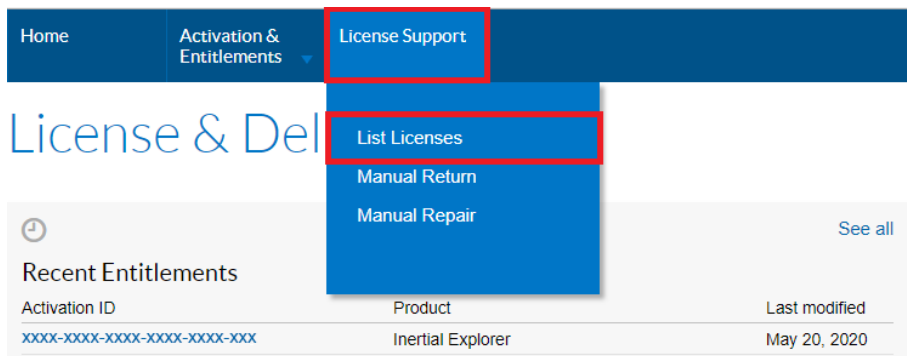
2. The *Activator Info* string, if one was entered, will be accessible here.
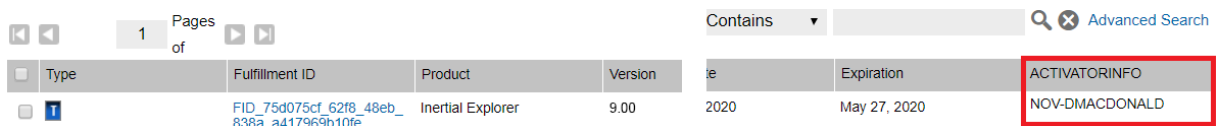
2.4.4 Retrieve Activator Information

In order to retrieve the activator info without contacting NovAtel support:

1. Login to the FlexNet customer portal with your activation ID here:
   https://license.novatel.com/flexnet/operationsportal/showActivationIdLogon.do.
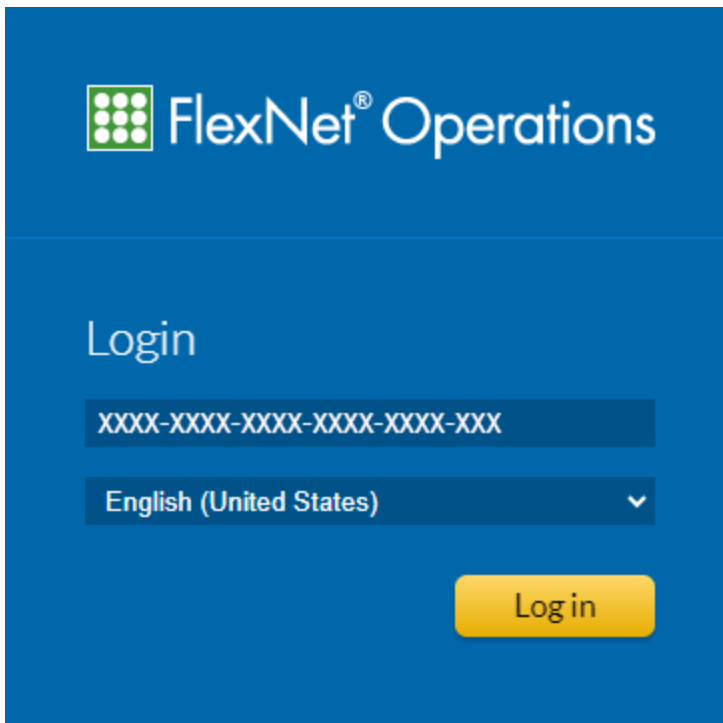
2. Select *List Licenses* under *License Support*.
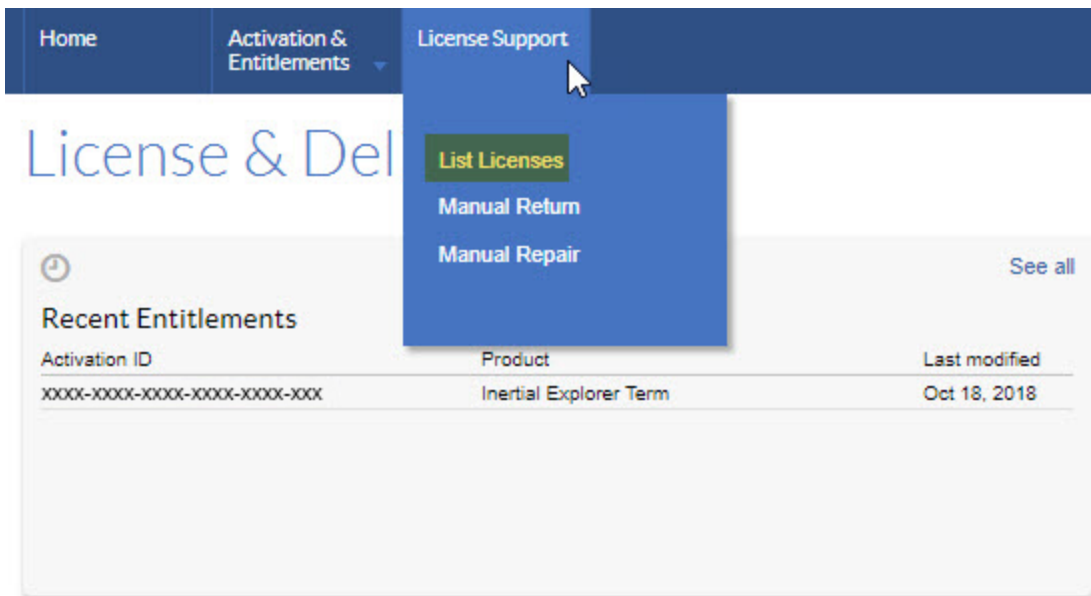
3. You will see the *Activator Info* user string under the *ACTIVATORINFO* heading on the right

Type	Fulfillment ID	Product	Version	License hosts	Count	Support type	Fulfill date	Expiration	ACTIVATORINFO
1	FID_96962127_5 19b_48d5_b32a_ 3516cbddd3d4	Inertial Explorer Term	9.00	..6CE38CC88D6 B45D10CD2BBB 1B9,8C37727D62 A2F8F26034570 E39E6A46A4256 DC36,1135DCAB 90D83619B7DA7 8DB93D30ED38E BAA02A	1	MASTER	Nov 12, 2018	Jun 14, 2019	DM's PC

Chapter 3   Inertial Explorer/Inertial Explorer Xpress/GrafNav

All Waypoint products described below share a similar interface. As such, all features and functionality described in this chapter will reference Inertial Explorer unless otherwise explicitly stated.

This chapter describes how to get started with Inertial Explorer and goes through each menu of its interface. Step-by-step instructions for first-time users are also included.

3.1   GrafNav Overview

GrafNav is a full-featured kinematic and static GNSS post-processing package that uses a proprietary GPS, GLONASS, BeiDou, Galileo and QZSS processing engine. It supports single and multi-baseline processing, moving baseline processing, Precise Point Positioning, and directly supports many different receiver formats. For any receiver formats not currently supported, RINEX files can be imported. See *Table 1: Supported Data Formats* on page 19 for more information.

3.2   GrafNav Static Overview

GrafNav Static provides the same processing features as GrafNav, but only for static baselines.

3.3   Inertial Explorer Overview

Inertial Explorer builds upon NovAtel's GNSS-only processor, GrafNav. Inertial Explorer shares a similar interface to GrafNav but also includes IMU processing capabilities. Both Loosely Coupled (LC) and Tightly Coupled (TC) are supported for both single and multi-base differential and Precise Point Positioning (PPP).

Inertial Explorer is well integrated with NovAtel SPAN products, however support is also available for processing third party IMU data. Inertial Explorer comes pre-configured with aerial, ground vehicle, marine, pedestrian and UAV processing profiles as well as a New Project Wizard that helps new customers get started quickly.

3.4   Inertial Explorer Xpress Overview

Inertial Explorer Xpress (IEX) is a feature and area-limited version of Inertial Explorer intended to meet the needs of the UAV market.

IEX will produce GNSS+INS solutions within a radius of 3 km from the project centroid. The centroid is an average of all non-stationary processed coordinates in the project. Any solutions outside of this area are encrypted and cannot be exported.

IEX retains the same core processing functionality and utilities as Inertial Explorer, however features that are not required for UAV applications have been removed for simplicity and to enforce the recommended workflow. IEX is differentiated from Inertial Explorer by the following:

- IEX accepts only a single base station
- IEX supports GNSS-only differential processing and Precise Point Positioning (PPP), as well as differential and PPP Tightly Coupled (TC) processing. Loosely coupled processing is not supported in IEX.
- Multi-pass processing is required when processing TC
- IEX does not include access to the *Solve Boresight Angles* utility

- IEX does not support input of Distance Measurement Instruments (DMR), Gimbal Mount data (MMR), or usage of a PVA update file

- No CUPTs or ZUPTs can be manually entered in IEX

- The *User Command* tab is not available within either the Advanced GNSS or Advanced INS options

- IEX will not compute marine heave

- IEX includes a simplified list of QC plots that are relevant to the capabilities of the product

3.5   Getting Started with Inertial Explorer

This section provides step-by step procedures on how to process data in Inertial Explorer.

3.5.1   Data Collection

Prior to data collection, NovAtel SPAN users are encouraged to review the SPAN Data Logging for Inertial Explorer application note accessible here: hexagondownloads.blob.core.windows.net/public/Novatel/assets/Documents/Bulletins/APN-076-SPANLoggingEI8-7/APN-076-SPANLoggingEI8-7.pdf. This reference will help ensure all required and recommended logs are requested.

In order to realize the full benefits of GNSS+INS post-processing, every survey must include an initialization and convergence period. During this period, initial conditions are computed (initial position, velocity, and attitude) and IMU biases converge and stabilize. If an IMU outage occurs before the end of this initialization and convergence period, you will not see expected performance from your system. Ideally, this initial data should be collected with a reasonably open view of the sky, and the same field procedures that are observed at the start of the survey should be mirrored at the end for the benefit of reverse processing. Regardless of the quality of the IMU, here are general data collection recommendations:

- Start your survey with 2 to 3 minutes of stationary data collection. This will serve as a warm-up period for the GNSS and IMU and can be used directly for static alignment for systems that are capable of this.

- Move straight and level along the forward-pointing axis of the vehicle for approximately 10 seconds. This data will be used in kinematic alignment should the static alignment fail, or if your system is not capable of static alignment. Assumptions are required in kinematic alignment in regards to the initial direction of movement, and it is also assumed that no significant roll or pitch is occurring.

- Collect 2 to 5 minutes of kinematic data with heading changes. Do not observe repeated, tight turns with high angular rates. It is recommended to observe similar dynamics during this period as you expect to experience during your normal survey. During this period, IMU biases converge and stabilize to provide you optimal performance for your system.

- Preform your survey.

- Repeat the initialization and convergence steps in reverse order.

> (i)   Data must be logged during the entire alignment procedure so that it can be used during post processing.

We also recommend review of the following application notes:

- Determining Rotations in SPAN & Inertial Explorer (hexagondownloads.blob.core.windows.net/public/Novatel/assets/Documents/Bulletins/APN065/APN065.pdf)

- SPAN Data Collection Recommendations
  (hexagondownloads.blob.core.windows.net/public/Novatel/assets/Documents/Bulletins/APN-080-SPAN-Data-Collection/APN-080-SPAN-Data-Collection.pdf)

- Inertial Processing with Backpack Systems (
  hexagondownloads.blob.core.windows.net/public/Novatel/assets/Documents/Bulletins/APN068/APN068.pdf)

3.5.2   Start Inertial Explorer

1. Verify installation and activation of a license. See *Installation* on page 21 for instructions if required.

2. Launch Inertial Explorer through a desktop icon (if created during installation) or from entering *Inertial Explorer* in the Start Menu.

3.5.3   Create a project using the New Project Wizard

This method of project creation is recommended for new users, as it is a guided step-by-step process that only requires you have raw GNSS/GNSS+INS data on your system ready to process. The New Project Wizard is accessed through *File | New Project | Project Wizard* or through the Project Wizard icon (🖺) on the toolbar.
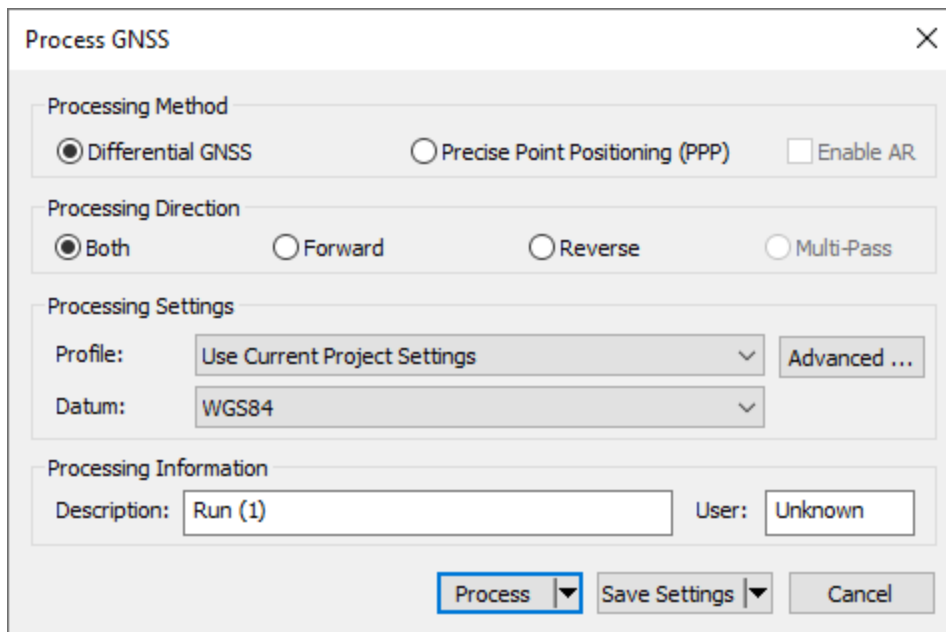
3.5.4   Process Data

PPP and differential processing modes are supported for GNSS-only and GNSS+INS users. Loosely and Tightly coupled processing modes are supported for GNSS+INS users. Precise orbit and clock files will be automatically downloaded if required when selecting the *Process* button on the main processing dialogue.

There is no requirement for GNSS+INS users to process GNSS-only first, as they may launch the Tightly Coupled processing dialog immediately after project creation (*Process | Process TC*). If the user wishes to process loosely coupled, they must first process GNSS-only.

Process GNSS-only:

1. Select *Process | Process GNSS*.

2. Choose the Processing Method.

   Differential GNSS is the default if one or more base station has been added to the project.

Precise Point Positioning (PPP) is the default if no base station has been added to the project.

Enable AR is applicable only to PPP processing and is activated by default if you have an NRT license and the data was collected using a NovAtel receiver.

3. Choose the Processing Direction.

Both processes the data simultaneously forward and backward in time and is the default direction for differential processing.

Multi-pass is the default method of processing PPP data and maximizes float solution convergence by processing data three times sequentially, passing the converging Kalman filter states between passes.

4. Ensure an appropriate processing profile has been set.

Waypoint products are installed with processing profiles for fixed-wing aerial, UAV, ground vehicle, pedestrian, marine, and static applications.

5. Select the *Process* button.

> (i) AR can only be enabled if you have an NRT subscription and the data was collected using a NovAtel receiver.

Process Loosely Coupled [IE only]:

1. Access the Loosely Coupled processing dialog through *Process | Process LC (Loosely Coupled)*.

2. Ensure the *Source File for GNSS Updates* has been set appropriately. The default selection will be a differentially post-processed trajectory (CG file). If the user processed PPP, choose *PPP Combined* from the pull-down.

3. Choose Processing Direction. *Both* is the default for LC processing.

4. Ensure an appropriate processing profile has been loaded for the application and INS used.

5. Ensure the IMU to GNSS antenna lever arm, IMU installation settings and Body to IMU Rotation have been set correctly.

6. Select the *Process* button.

Process Tightly Coupled [IE/IEX only]

1. Access the Tightly Coupled Processing Dialogue through *Process | Process TC (Tightly Coupled)*.

2. Set the Processing Method (Differential, PPP or PPP-AR). Differential is the default processing method if one or more base stations have been added to the project.

3. Set the Processing Direction. The default direction will be loaded from the processing profile that is loaded. Unlike in GNSS-only and LC processing, Multi-pass is a supported processing direction in TC processing and helps maximize attitude convergence for low cost IMUs and for low dynamic applications (e.g. pedestrian, marine).

4. Ensure the IMU to GNSS antenna lever arm and Body to IMU Rotations are set appropriately.

5. Select the *Process* button.

The *Process* option features additional options:

Process without pre-processing:

Using this option skips pre-processing checks prior to processing. It may be necessary to use this option if you would like to bypass a critical pre-processing warning which disables processing.

Solve Lever Arm (Inertial Explorer/Inertial Explorer Xpress only):

Using this option adds the X, Y and Z IMU to GNSS lever arm states to Inertial Explorer's Kalman filter. After processing, the best converged estimate of the lever arm is automatically reported after processing.

Please note that several iterations may be required for the lever arm to converge and Inertial Explorer's ability to estimate lever arm values is dependent on the amount of data collected and vehicle dynamics.

If processing third party IMU data, an IMU error model must first be developed. It is also recommended to create a custom processing profile in order to automatically load all preferred processing settings.

AR can only be enabled if you have an NRT subscription and the data was collected using a NovAtel receiver.

3.5.5   *Plotting and Quality Control (QC)*

Once processing is complete, QC the project using available plots. Under the *Output* menu, choose *Plot Results* to access available plots. Inertial Explorer comes pre-loaded with 3 plot groups:

- Waypoint GNSS QC
- Waypoint GNSS+INS QC (IE/IEX only, meant for those processing TC)
- Waypoint INS QC (IE/IEX only, meant for those processing LC)

The plot groups contain a collection of frequently accessed plots for GNSS-only and GNSS+INS processing. For descriptions of the common plots, see *Common Plots* on page 109.
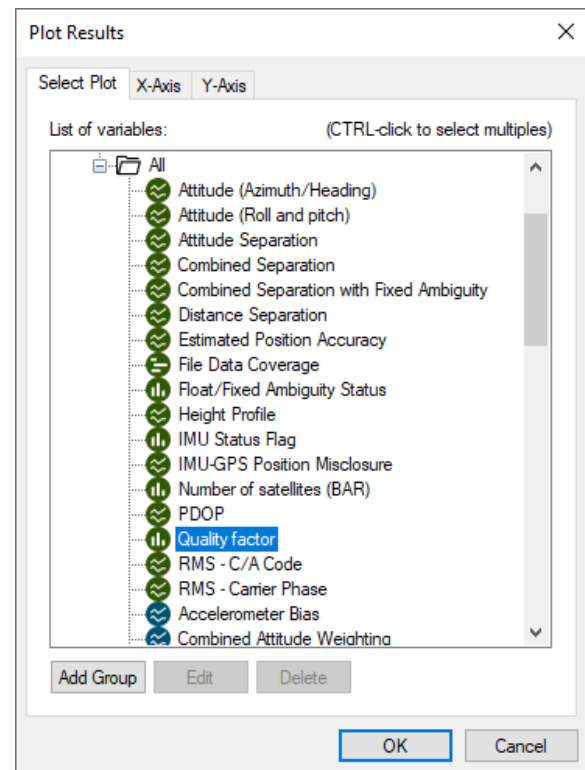
(i)   Consider adding your preferred QC plots to a group using the *Add Group* button. Your custom plot group will appear under the *Grouped Plots* list. When plotting a group, all plots within that group are simultaneously plotted. For more information about how to Add Groups, see *Add Group* on page 107.

3.5.6   Smooth Solution (IE/IEX only)

By default, Inertial Explorer's backward smoother is automatically run after processing. This is needed to produce the best possible solution.

Automatic smoothing can be controlled through an option within the *Solution* tab of *File | Preferences*. If this has been disabled, it is strongly recommended to run the Smoother (*Process | Smooth Solutions*) prior to using the Export Wizard.

3.5.7   Export Final Coordinates

The steps for exporting final coordinates are below.

1.   Select *Output | Export Wizard*.

2.   Specify the source for the solution. *Epochs* outputs the trajectory, while *Features/Stations* exports positions only for loaded features, such as camera marks.

3.   Select a profile.

4.   Click *Next*. The Export Wizard will prompt you for all necessary information depending on the contents of your export profile.

(i)   The Export Wizard requires a geoid when exporting orthometric (MSL) heights. Waypoint's geoids may be downloaded from the NovAtel website at: www.novatel.com/support/waypoint-support/waypoint-geoids/.

3.6   File Menu

The following sections provide information about the features available on the File menu.

3.6.1   New Project

To process a survey for the first time, start a new project. When you start a new project, choose between *Project Wizard* and *Empty Project*.

The Project Wizard is recommended for new users as it will guide you through all the steps of getting started, including data conversion and downloading base station data (if needed). After you are more familiar with the tools and workflow, you may prefer to use the *Empty Project* option.

The following sections discuss these options and step-by-step instructions once you have decided on the method for starting your project.

Project Wizard

The Project Wizard offers you a guided step-by-step way of creating a project. The *Project Wizard* steps are listed below.

1.   Create and name the project

2.   Add the rover data to the project.

> (i) The rover data can be in Waypoint's GPB format or in the receiver's raw format. If the data is in the receiver's raw format, the Wizard converts it to GPB for you.
> If you are a NovAtel SPAN user and you add a raw data file, the Wizard automatically detects the IMU model for conversion to IMR format.

3. Add the base station data to project.

> (i) You can add your own local base station data (in raw or GPB format) or you can have the Wizard download free service data from the Internet.
> Optionally, you can choose to add precise satellite clock & orbit products to your project here. If you have an NRT license activated, TerraStar Near Real-Time precise products will be downloaded.

> (i) Inertial Explorer Xpress does not support adding more than one base station to a project.

Empty Project

Creating an empty project is not recommended for new users as all steps involved with project creation must be done manually. Specifically, the remote GNSS data must be converted to GPB format using the GNSS Data Converter utility and any base station service data must be downloaded through the Download Service Data utility.

The Project Wizard is best for new users as it guides you through each step involved with starting a project. Creating an empty project is usually preferred by advanced users. This is because, for someone familiar with Waypoint's workflow, it may be possible to get started more quickly creating an empty project as opposed to stepping through a Wizard.

How to create a new project using Empty Project

Prior to starting the following steps, the Raw GNSS Converter must be used to convert the remote data to GPB format. If required, the Download Service Data Utility must also be used to acquire base station data. (See *Convert Raw GNSS data to GPB* on page 172 for more information.)

1. Select *File | New Project | Empty Project*.

2. Enter the name and where you would like to save your project.

3. Select *File | Add Master File(s)* to load master files. Select the GPB files collected at the base station(s) and click *Open*.

> (i) Inertial Explorer Xpress allows the inclusion of only one base station per project.

4. Enter the base station coordinates, datum and antenna information when prompted.

5. Select *File | Add Remote File*. Select the GPB file corresponding to the data that was collected at the remote.

6. Enter the antenna information for the remote when prompted. Please note, antenna heights are only relevant to GNSS-only projects, as GNSS+INS projects require input of a lever arm from the IMU to the GNSS antenna (measured to the ARP or Phase Center of the antenna).

7. Ensure an appropriate processing profile is selected.

8. Select *Process | Process GNSS*.

3.6.2   Open Project

This option allows you to open existing projects.

You may choose to open an existing legacy CFG file (versions 8.70 and earlier), or the new PROJ format. If opening a legacy CFG file created in a previous version, a PROJ file will automatically be written and changes made to the project will be saved only to the PROJ file.

How to open a project

1. Choose *File | Open Project* or select *Open Project* on the tool bar. A dialog box appears that asks you to select the name of an existing project.

2. Choose the name of the project and click the *OK* button.

Recent projects

Provides a list of recent projects for quick access.

3.6.3   Save Project

When this option is selected, all project settings are saved to a PROJ file format, which is in xml format and new to version 8.80. The project is automatically saved when processing and thus accessing the save option from the File menu is not typically necessary.

How to save a project

1. Choose *File | Save Project* or select *Open Project* on the tool bar.

3.6.4   Save As

Use the *Save As* command under the *File* menu to create a new project that has identical processing options as the current project. This allows you to change the options in the new project and process the data without losing the solution computed by the original configuration.

How to save as a project

1. Choose *File | Save As*.

2. Enter the name and where you would like to save your project.

> (i)   Entering the name of a project that already exists overwrites the file contents.

3.6.5   Add Master File(s)

Up to 100 base stations can be added to a single project. We recommend adding additional base station data only if each base station is in a distinctly different project area and is at some point the closest in the trajectory.

All data must be converted to GPB prior to adding as a base station. When adding a base station, take care to verify base station coordinates and datum (and epoch, if necessary) as this is critical to absolute position accuracy.

To add a master file:

1. Select *File | Add Master File(s)*.

2. Select the base Station file(s) from the list of available GPB files. Up to 100 base stations can be added to a project. Click the *Open* button.

3. Enter the coordinates and datum of each base station when prompted.

   If you are importing data retrieved from the Download Service Utility, precise coordinates may be accessed through the *Select from Favorites* option under the *Coord. options* pull-down.

   If the datum of any coordinate does not match the processing datum, it will be automatically converted prior to processing.

4. Enter or verify the antenna model and height information and click the *OK* button.

> ⓘ Inertial Explorer Xpress allows the inclusion of only one base station per project.

Master Station Position

When loading a master station, the coordinates that appear in the master coordinate dialog may come from two different sources.

If loading data converted from RINEX, as is the case when obtaining base station data through the Download Service Data Utility, the coordinates that appear initially are scanned from the RINEX header. The coordinates provided in the RINEX header may be precise or approximate, this will depend on the individual RINEX data provider. The RINEX header does not provide any information regarding the datum of the coordinates. As such, the user is required to specify the coordinate datum of each base station loaded.

If loading base station data converted from any other source, the coordinates that appear initially are likely averaged from the unprocessed position records decoded in the raw GNSS data file. The accuracy of this position is typically no better than approximately 2 m horizontal and 5 m vertical. If you select the *OK* button using averaged coordinates, a warning dialog appears to ensure you are aware the coordinates may not be accurate.

Regardless of the source of your base station data, it is important that accurate coordinates are loaded. In differential processing, a vector is solved between the base station antenna and the remote antenna. Any error in the base station position is directly transmitted to the remote position.

To assist in loading precise coordinates, it is recommended that coordinates be selected from the favorites list through the *Select from Favorites* option, which appears under the *Coord. options* pull-down. Coordinates for

select base station networks, such as CORS and IGN, are regularly maintained and accessible through Favorites.

The *Compute from PPP* option, which also appears under the *Coord. options* pull-down, can be used to easily check or survey base station data using the Precise Point Processor. When using this option, the differences between the loaded and computed coordinates are displayed. If the master station has a NovAtel receiver and the user has an NRT subscription, PPP-AR will be used. Note that PPP accuracy is largely dependent on the length of the survey and the quality of the data.

Datum Selection

GrafNav and Inertial Explorer distinguish between base station coordinate datums and the processing datum. Each base station may have a unique coordinate datum. If any base station's coordinate datum is different than the processing datum, it will be automatically converted prior to processing.

Epoch Selection

Users can enter the epoch of their base station coordinates for tracking/reporting purposes. This is important as coordinates change over time due to tectonic plate motion, and as such in any precise application both the datum and epoch of the coordinates should be known.

If entering the epoch of a base station coordinate, it is required that all base stations have the same epoch (if using more than one base station).

Antenna Height

The antenna height applied at the base station depends on where the base station coordinates are referenced. If the coordinates are referenced to some point below the antenna, the vertical offset between the marker and the Antenna Reference Point (ARP) should be entered for *Measured Height*. In this case, the total applied height would then be the addition of the vertical offset defined by the antenna model and the vertical offset between the ARP and the marker from which the coordinates are referenced.

If the base station coordinates are ARP values, the *Measured height* is by definition zero and the total *Applied height* is only equal to the difference between the ARP and the L1 phase center as defined by the antenna model.

If the base station coordinates are L1 phase center values, choose the *L1 Phase Center* option within the *Measured to* options and zero the *Measured to* height.

Antenna Models

The purpose of an antenna model is to:

- Correct for the vertical offset between where GNSS observations are observed (the electronic phase center) and the bottom of the antenna (Antenna Reference Point, or ARP).
- Correct for any difference between the L1 and L2 electronic phase centers, which can be a factor in the success or failure of ambiguity resolution.
- Apply elevation based corrections

Calibrated absolute antenna models published by IGS and NGC in the ANTEX format are supported. If the antenna model is not known at your remote, it is recommended that the *Generic* profile be applied, which does not apply any corrections. In that case, the processed positions are referenced to the antenna L1 phase center, or as best can be estimated without applying the antenna model. The correct antenna model should be selected for best results.

When selecting an antenna model, the *ARP to L1 offset* reflects the vertical difference between the L1 phase center and the ARP (which is the bottom of the antenna). This value comes directly from the antenna model and reduces the processed position from the phase center to the ARP. This value should match any diagram

that appears directly on your antenna, presuming it is an absolute antenna calibration. Antenna heights can be measured to the antenna reference point, phase center, or computed from a slant measurement.

When loading a base station converted from RINEX, the antenna name and radome (if provided) are scanned from the RINEX header and used to automatically load the appropriate antenna profile. It is good practice to ensure the correct antenna model is loaded prior to processing.

> (i) Waypoint does not perform antenna calibration. If your antenna model is not included in the Waypoint software, ask your antenna manufacturer to have the antenna calibrated through IGS.

3.6.6   Add Remote File

Only one remote file can be added to an Inertial Explorer project. The file must be converted to GPB prior to adding it to the project. When selecting the remote GPB file, Inertial Explorer will automatically check for any associated IMU data (*.imr file), DMI data (*.dmr file), heading data (*.hmr file) and mount data (*.mmr) and prompt you whether you would like to add this data to the project as well.

When adding a remote GPB file, ensure the *Measured height* of the antenna is set to zero. Inertial Explorer uses the entered IMU to GNSS lever arm in order to transfer the GNSS position updates to the IMU center of navigation during processing. A vector can be entered from the IMU to any other sensor or point of interest on the vehicle during Export to transfer position data.

How to add a remote file

1. Select *File | Add Remote File*.

   From the list of available GPB files, choose the file collected at the remote station.

2. When prompted, enter the remote station antenna information.

   For GNSS+INS applications (IE or IEX), the *Measured Antenna Height* should be entered as zero, and the *Measured to* setting should be *L1 Phase Center*. In IE or IEX, users are required to enter a lever arm measured from the IMU center of navigation to the GNSS antenna on the main processing dialog. If your lever arm is measured to the ARP, it can be adjusted later in the processing menu.

Compute from Slant

The *Compute from Slant* feature enables the automatic computation of the true vertical *Applied height* required by GrafNav and Inertial Explorer given a slant measurement, the radius of the ground plane edge and the offset from the ARP to the ground plane edge.
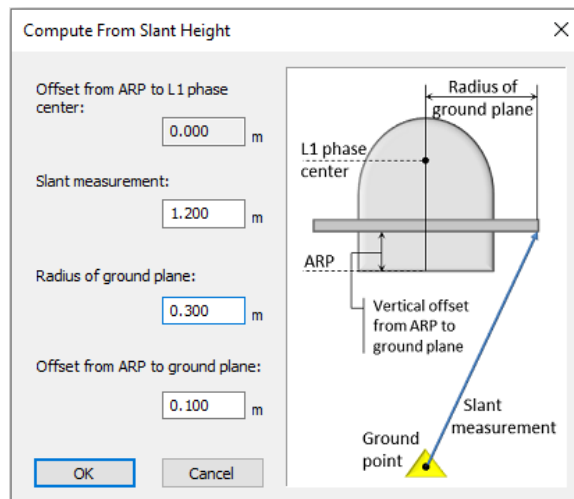
3.6.7   Add IMU File (IE/IEX only)

Only one IMR file can be added to an Inertial Explorer project. This menu item is not often needed as IMR data will be automatically added to the project when adding the remote GPB file, provided it is in the same directory and has the same name as the remote GPB file.

> ⓘ   The IMU file must be in the IMR format before being added.

3.6.8   Add Precise/Alternate Files

The *Precise Files* dialog primarily facilitates the easy download of precise products. Users can choose between *GPS*, *GPS+GLONASS*, and *All GNSS* (sources that provide data for GPS, GLONASS, BeiDou, Galileo and QZSS) sources depending on the signals acquired in data collection.

The *Precise Files* utility also enables a user to add alternate broadcast ephemeris data downloaded through the *Download Service Data* utility. A user may do this to supplement missing broadcast ephemeris data within their project.

Broadcast Ephemeris

The ephemeris file contains Keplerian orbital parameters used to compute satellite positions. Presently, the line of sight component of satellite positions can be computed within an accuracy of approximately 2 m (RMS) using the broadcast ephemeris.

Orbital error is largely removed in differential processing, as the line of sight component is correlated at short and medium baseline lengths (< ~100 km). Therefore, the accuracy of the broadcast orbits is completely sufficient for most projects. A discussion on precise orbits is found in the next section.

Generally, the GNSS receiver includes broadcast ephemeris data with its raw data files. The decoder converts these files into EPP format. Receivers typically output ephemerides at startup, as satellites rise into view, or approximately every two hours.

Prior to processing, all ephemeris information collected at the base station(s) and remote are combined. This minimizes the chance of missing broadcast ephemerides.

In version 8.50 and earlier, if a GPS broadcast ephemeris was missing the satellite could not be used regardless of whether or not a precise ephemeris file had been added to the project. Versions 8.60 and greater are not dependent on the presence of GPS, BeiDou, Galileo and QZSS broadcast ephemerides and any

missing broadcast values can be fixed by adding a precise ephemeris to the project. The same is not true for GLONASS, broadcast ephemerides are required regardless of whether a precise ephemeris has been added to the project. The Download Service Data utility can be used to download a global broadcast ephemeris file in EPP format as well as to download precise ephemerides.

Precise Ephemerides

Precise ephemerides are computed from data collected by ground reference stations around the world. These files are produced by various agencies, including CODE (Center for Orbit Determination in Europe), the IGS, TerraStar and others. The different precise ephemeris products vary in the rate they provide precise clock corrections, the constellations for which data is provided, and their latency. Presently supported products range in latency from approximately 15 minutes to 3 weeks. The difference in accuracy between rapid and final products is marginal, well within the noise of either differential or PPP kinematic solutions.

Presently, precise ephemerides reduce the line of sight component of satellite position error to approximately 2 cm RMS (as compared with approximately 2 m RMS for broadcast orbits). As orbital error is largely canceled in differential processing, adding precise ephemerides to a differential project will only produce observable differences where the baseline length is large (150-200 km). For this reason, adding precise orbits to a differential project is generally considered optional.

Precise ephemerides can be downloaded through the Download Service Data utility or directly through the GrafNav/Inertial Explorer interface. Adding a precise ephemeris file will compensate for any missing broadcast ephemeris data for GPS, BeiDou, Galileo and QZSS satellites. A broadcast ephemeris for each GLONASS satellite observed is required regardless of the presence of a precise ephemeris.

How to download precise ephemeris files

1. Select *File | Add Precise/Alternate Files*.

   The project start and end date are automatically scanned from the GNSS data loaded into the project. This should not need to be set manually.

2. Select *Browse* in order to choose any precise orbits (.sp3), clock files (.clk) or NRT files (.cor) that have previously been downloaded.

   If no files have been downloaded, select *Download* after specifying the source to download from under *Constellation*. Note that multiple precise products for the same day cannot be loaded into one project. The precise orbit (.sp3) and clock (.clk) data will automatically be downloaded and added to your project. This requires an internet connection.

   If you have a license for the NRT feature, NRT correction data (.cor) can be chosen to download into the project. See *Waypoint TerraStar Near Real-Time (NRT) Precise Satellite Clocks and Orbits* below.
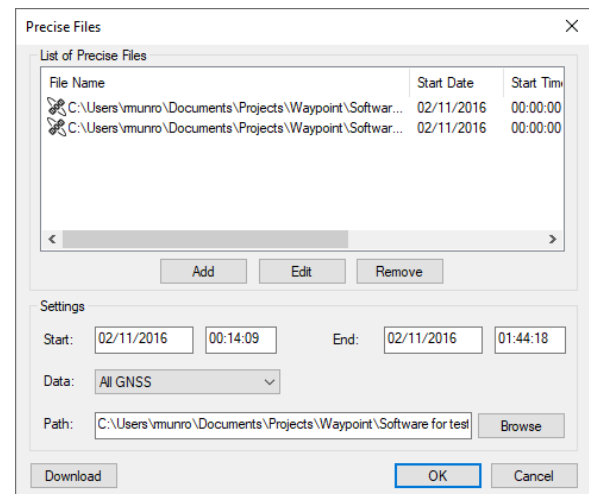
> ⓘ   If your project includes GLONASS or other constellation data, make the appropriate selection under the "Constellation" pull down menu prior to downloading. The default search location for precise products contains only GPS data.

Waypoint TerraStar Near Real-Time (NRT) Precise Satellite Clocks and Orbits

The Waypoint TerraStar NRT feature provides quick access to precise satellite clock, orbit, code bias and phase bias data, which facilitates Precise Point Positioning (PPP) and PPP ambiguity resolution (PPP-AR) in

applications that demand a quick turnaround. NRT clocks, orbits, code biases and phase biases are provided by TerraStar, NovAtel's partner in high precision positioning products and services. TerraStar owns, operates, maintains and controls its global network of GNSS reference stations and the associated infrastructure to ensure maximum operational reliability of its augmentation services for precise positioning. With a long history in satellite-based correction services, TerraStar provides seamless delivery of trusted corrections for demanding applications.

The purchase of an NRT license is required for access to this feature and the PPP-AR feature. NRT correction files are available approximately 15 minutes after data collection, with accuracy similar to that of final precise ephemeris data (see *Precise Ephemerides* on the previous page for more information on precise ephemerides).

Satellite Clock Files

Presently, using the data available in the broadcast ephemeris, satellite clock errors can be predicted within an accuracy of approximately 2 m RMS. Satellite clock error is completely removed in differential processing, as this error is exactly the same at the base and the rover. Thus adding precise clock files to a differential project will have no effect.

Satellite clock files can be downloaded through the Download Service Utility or from *File | Add Precise/Alternate Files*.

3.6.9   Load

The following sections describe the options available from *File | Load*.

GNSS Solution

After processing, forward and reverse solutions are automatically combined if available. Thus, the trajectory output to the map window, and all generated plots, are usually relative to a combined forward/reverse solution. The title bar of the map window and plots clearly indicate which solution is loaded.

If the processing results from a particular direction (forward or reverse) are of interest, individual solutions can be loaded using this feature.
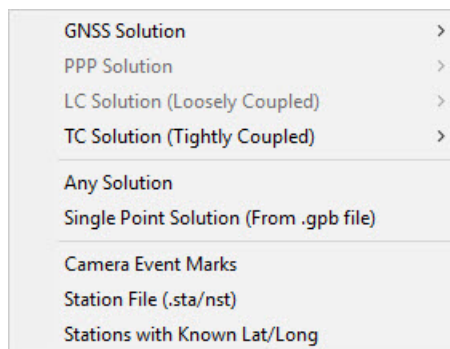
PPP Solution

The differential and PPP trajectory files have, by design, different file extensions. This allows both differential and PPP trajectories to be processed within the same project without overwriting each other. If both types of solutions have been processed, you can control which type of solution is loaded through the *GNSS Solution* and *PPP Solution* options.

LC Solution (Loosely Coupled)

Loads either the filtered or smoothed loosely coupled solution.

> (i)   Loosely coupled processing is not supported in Inertial Explorer Xpress, GrafNav or GrafNav Static.

TC Solution (Tightly Coupled)

Loads either the filtered or smoothed tightly coupled solution.

Any Solution

This option allows any readable trajectory to be loaded into a project. The only requirement is that the trajectory cover the same time range as the data within your existing project. An example of when this feature may be used is when loading a real time trajectory produced from the GNSS decoder.

Single Point Solution (from .gpb file)

This option ensures the trajectory displayed to the map window reflects the unprocessed positions in the remote GNSS data. This trajectory typically represents the real time solution as computed on board the receiver during data collection.

Camera Event Marks

Events from supported GNSS formats are automatically written to a station file (.sta) during conversion of the raw GNSS data to GPB, and automatically loaded into the project and displayed on the map window.

Use the *Load Camera/Event Marks* feature to load external time-tagged events from an ASCII file from one of four supported input formats. When you load events, they must be referenced to GPS time, local H:M:S or GMT H:M:S. The source of the events can come from an aerial camera, sounding equipment or other real-time devices.

How to load camera event marks

1. Under *File*, select *Load | Camera Event Marks*.

2. Choose the file format that matches your input file.

3. Under *File Name*, use the *Browse* button to select the input file.

When features/camera marks have been loaded into a project, they appear as bright blue circles on the map window. If no event marks are present after processing, first check that you have not disabled the display of event marks within the *General* options of the *Display* tab within *File | Preferences*. If *Show feature marks* is enabled, it is likely that the time tags are wrong or no event marks have been loaded. To determine what has been loaded, use the *Feature Editor* by selecting *View | Features*.

File Format

STA File
Most supported receiver formats write features/camera marks directly to the station file. The features load when you add the GPB file to the project. In the event you have deleted features using the Feature Editor and you wish to re-load the original station file, use the *File | Load | Station File* feature.

User#
These formats allow you to import the time and name of each event mark. Optional variables include line number (description) and altitude information.

Time settings

User time type:
Seconds of the week – GPS time ranging from 0 to 604800.

Local H:M:S – Local hours, minutes and seconds (HH:MM:SS.SSSS) in GPS time scale.

GMT H:M:S – GMT hours, minutes and seconds (HH:MM:SS.SSSS) in GPS time scale.

Local time correction:
This is necessary for both Leica and User# formats using *Local H:M:S*. This is the offset, in hours, from GMT. For the Eastern Standard Time zone, this number is 5. For the Pacific Standard Time zone, this number is 8. During daylight savings time, these numbers are reduced by one. An incorrect entry causes the camera marks to be displayed incorrectly or not be displayed at all.

GMT date of first record:
This is necessary for Leica, Ashtech and User# formats implementing H:M:S time-tagging. Enter the date of the first exposure record in month/day/year format. It is not the date in local time, which may differ towards the end of the day. An invalid date results in the marks not being displayed.

Station File (.sta/nst)

The station file (.sta) associated with the remote GPB file are automatically loaded. This file is produced during conversion and contains, among other information, any time tagged events. If properly loaded, these time tagged events are displayed to the map window.

The program automatically loads the STA station file as long as the filename is the same as the remote GPB file. If the station file has a different filename than the GPB file, then load the file through the *File | Load | Station File* feature.

Stations with Known Lat/Long

This option allows you to load and display a file that contains stations with known coordinates. The coordinates are displayed with pink triangles.

How to load stations with known latitude and longitude

1. Select *File | Load | Stations with Known Lat/Long*.

2. Use the *Browse* button to locate the input file containing the points with known positions that you wish to display to the map window.

3. Choose the appropriate file format under the *Lat/Long Format*.

4. Choose an option under *Id String Handling* to tell the program how to separate the ID from the coordinates. The first column usually contains the station IDs.

Lat/Long Format

The following are formats that the coordinates from the file can be in:

Degrees Minutes Seconds
For example: 51° 03' 28.3214"

Degrees Decimal Minutes
For Example: 51° 03.4720'

Decimal Degrees
For Example: 51.0579°

Id String Handling

The settings under this option tell the program how to separate the ID from the coordinates.

Use first continuous word (no spaces)
To be used if the station names are separated from their coordinates by a space.

Comma separation
Use this option if commas separate the IDs from the coordinates.

Use first 'n' columns
If you know which column the coordinates start in, you can enter the number of columns for the program to ignore. Each character is a column.

3.6.10   Preferences

The *Preferences* dialog has several tabs. The following sections provide information about the features available on the Preferences dialog.

Display

This tab allows you to edit what is displayed on the *Map Window*. Disabling features or base stations from here will only prevent them from being displayed to the map window and will not remove them from the project.

General

The following settings are available:

Show feature marks
This option controls whether time-stamped events, such as camera marks, features or stations appear on the map window. Users may wish to disable the display of feature marks if they are continually collected throughout the survey, resulting in hundreds or thousands being decoded. If this is the case, the feature marks will make it difficult to see the processed quality numbers on the map window which can be useful in QC.

Draw White background instead of black
Changes the background color of the Map Window from black to white. This may be preferred when printing generated HTML reports.

Show ARTK marks
ARTK marks indicate where fixed integers have been resolved. Users may or may not want to include these in the map window display if printing generated HTML reports.

Show base stations
When disabling the display of base stations, the Map Window automatically zooms to the extents of the project area covered by the remote GNSS antenna. This can be useful for the QC of multi-base or large scale projects.

Show centroid circle (Inertial Explorer Xpress only)
The circle encompassing a 3 km radius around the project centroid will be drawn on the map window if this feature is enabled. Only GNSS+INS processed points within this radius may be exported.

The centroid is an average of all non-stationary processed coordinates in the project.

Coordinates for Display

The following settings are available:
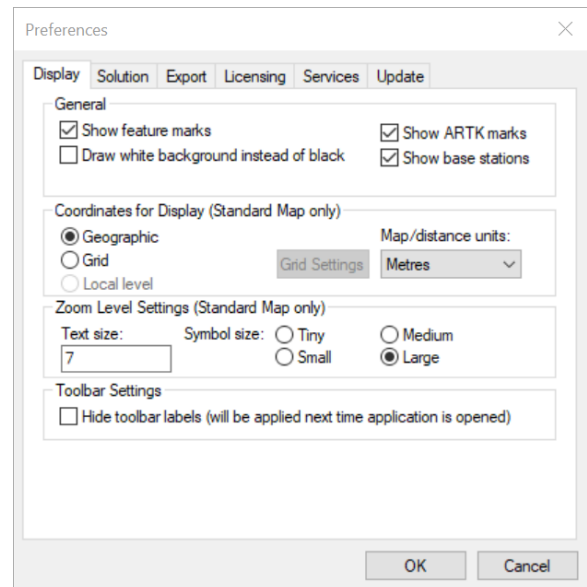
Geographic
Displays the latitude and longitude on the screen. The orientation is such that the positive y-axis is true north.

Grid
Displays the coordinates in the grid selected. By default, the grid applied will be the UTM zone which has been auto-detected from the remote GNSS data.

Several international and regional grids are supported, such as UTM, US State Plane, British Grid, Irish Grid etc. Custom grids can also be defined by selecting *Define Grids* within the *Grid Settings for Coordinate Input* dialog.

Defining a grid allows the grid to be accessed by the Export Wizard. Base station coordinates can also be added directly in grid format as well.

Grid information is stored in the project. Set up a grid for the following reasons:

- Master coordinates can be entered directly in a supported grid.

- The *Map Window* can plot in grid coordinates. See *Show Map Window* on page 71 for more details.

- *Export Wizard* can use a defined grid for coordinate output. See *Export Wizard* on page 115 for details.

New grid definitions can be added by clicking *Define Grid* or via *Tools | Grid/Map Projections | Define*. See *Grid/Map Projection* on page 123 for more information.

Local level (only available if moving baseline processing has been enabled)

ⓘ This option can only be enabled when using GrafNav.

Plots the local level vector if moving baseline processing has been performed. Moving baseline processing should only be engaged if both base and rover are kinematic and the relative vector between them is of interest. Moving baseline processing does not produce accurate absolute positioning results, only accurate relative positioning results.

Map/distance units
Changes the units of the values being displayed for local level or grid coordinates in the *Map Window*.

Zoom Level Settings

This set of options is based on the *Zoom Level* specified.

Text Size
Controls the font size. The *Show Text* option allows text to be seen on the screen for the display of base station coordinate names, ARTK forward/reverse text and the number displayed for feature marks.

Symbol Size
Controls the display of symbols, including processed epochs, ARTK indicators, feature marks and base stations.

Solution

Processing

Default Datum
Allows you to select a default processing datum for all projects. This controls the datum of the processed output. Any coordinates which have not been entered in this datum will be automatically converted to the processing datum prior to processing.

Leica airborne sensor work flow (Inertial Explorer only)
This option enables the Leica IPAS workflow within Inertial Explorer for FCMS and FlightPro users. Engaging this option affects the folder structure created during decoding and processing and will auto-generate a *.sol file after processing.

Apply lever arm correction for FCMS/FlightPro
When using Leica airborne sensor workflow, a lever arm correction is required with certain FCMS/FlightPro versions. When the *Leica airborne sensor work flow* check box is selected, Inertial Explorer detects the need for the correction based on the data from the flight and corrects the lever arm automatically, showing the corrected settings in the user interface. It is recommended to leave this check box selected.

Perform smoothing automatically (Inertial Explorer and Inertial Explorer Xpress only)
With this setting enabled, Inertial Explorer's backsmoother is automatically called following processing. This is recommended for best position, velocity and attitude results.

Default processing profiles
During conversion, the detected processing environment is written to the header of the decoded GPB file from analysis of the unprocessed position records. This allows the manufacturer processing settings for the detected processing environment to automatically load when the process GNSS dialog is first accessed within a project.

GNSS-only and *GNSS+INS* default processing profiles can be specified here. This will disable the auto-detection of the processing profile from the detected processing environment and load a specific profile each time (whether it is a customer created profile or default manufacturer profile).
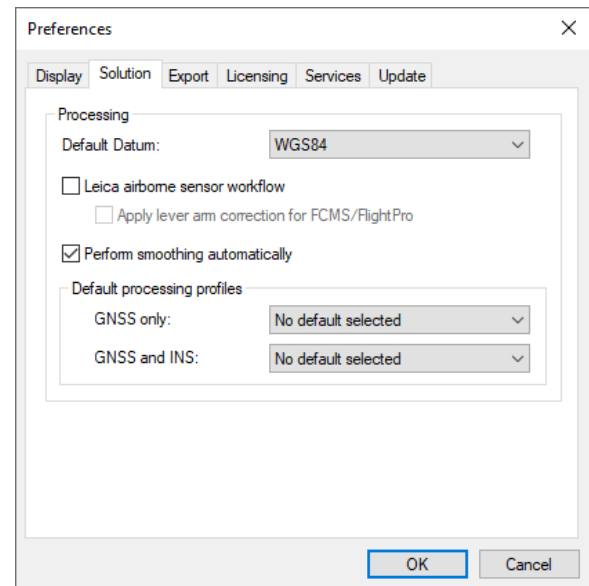
Export

Google Earth

Hold epochs and events to ground
This option plots the trajectory on the ground in Google Earth. This option is recommended when exporting ground vehicle surveys to Google Earth.

Limit epoch output to interval
You can reduce the density of the output trajectory by specifying an interval here. This helps reduce file size and loading times in Google Earth.

Optimize output for trajectory comparison
When exporting to Google Earth, the computed quality numbers as displayed to the map window will also be displayed in Google Earth. When engaging this feature, that behavior is overridden and the color of all processed points will be the same color. This allows easy comparison of trajectories when loading from different projects.

Output MSL height for better compatibility with GE elevation data, using
Google Earth expects orthometric (mean-sea-level, MSL) height values. As such, if *Hold epochs and events to ground* is disabled, the plotted height may be below ground. To mitigate this effect, use the *Browse* button to locate an appropriate Waypoint Geoid (WPG) file for your processing datum. Waypoint geoid files are provided here: www.novatel.com/support/waypoint-support/waypoint-geoids/.
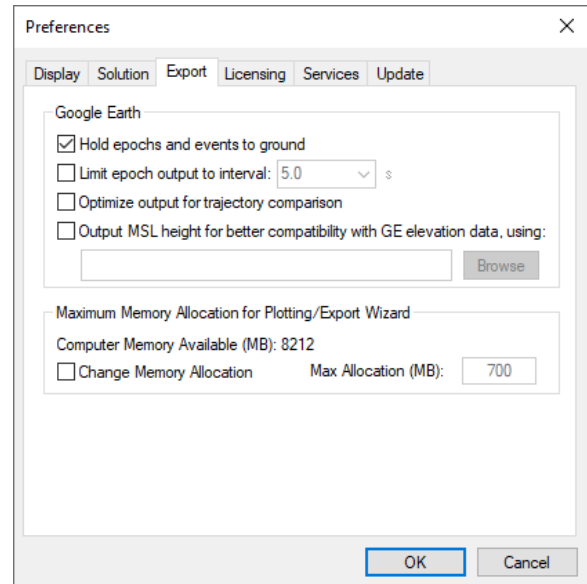
Licensing

Auto-Activate / Auto-Return

On the *Licensing* tab, you can add your Software and/or TerraStar NRT activation IDs for auto activating and returning. If you choose to fill in either activation ID, you must also enter information in the *User Information* field. NovAtel recommends that the user information be as descriptive as possible. This will make it easier to look up where a license is activated using the instructions in *Retrieve Activator Information* on page 40.

Once your activation IDs are entered, click **OK** to save the information entered. For information about how the auto activate and auto return process works, refer to *Auto Activate/Return* on page 35.
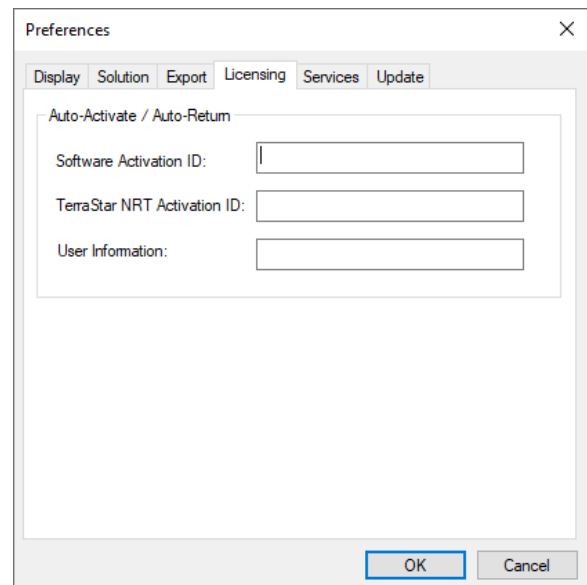
Services

TerraStar NRT Subscription

Download TerraStar NRT precise files (requires valid license)

The option to download TerraStar NRT precise products from the North American server is engaged by default. However, it will have no effect unless a Waypoint TerraStar license has been activated. If an NRT license has been activated, TerraStar precise products will be the default download source whenever precise products are downloaded within Waypoint products. If this option is disabled, publicly available precise products will be downloaded instead. TerraStar NRT subscribers may wish to enable or disable this option for testing purposes, as it conveniently allows download of different precise products within the software.

Server

Users have the choice to download the TerraStar NRT precise files from two different servers, North America or Europe. Choosing the appropriate server can help facilitate faster download times of the products. European Waypoint TerraStar subscribers are encouraged to change their NRT download source to the European server. To change to the European Server, click the Server drop list and select Europe.
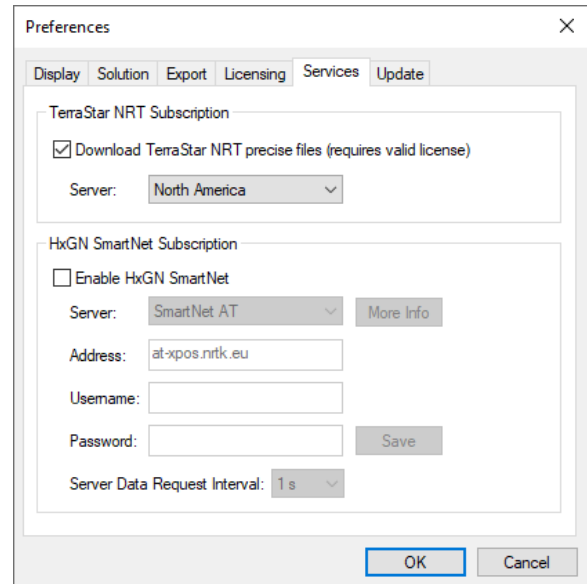
HxGN SmartNet Subscription

If you are a HxGN SmartNet user, you can enter your credentials to gain access to any of your subscriptions through our download utility. We offer the ability to save multiple HxGN SmartNet subscriptions.

To access any HxGN SmartNet options, you will need to select the check box *Enable HxGN SmartNet*.

For more information on any of the HxGN SmartNet servers, select the server of interest and then the *More Info* button to be guided to the HxGN SmartNet web page.

With HxGN SmartNet enabled, you will enter your credentials after selecting the server you have subscribed from the *Server* drop-down menu. Selecting the server will automatically load the server address. Then you will fill in your *Username* and *Password* and click the *Save* button. To add multiple subscriptions, simply change the server and repeat the process.

Additionally, you can specify the data rate of the downloaded RINEX files via the *Server Data Request Interval* setting. Note that the desired data rate of the final GPB file should still be specified by the usual means within the *Download Service Data* utility. The utility will handle any resampling needed to meet your request. This setting allows you to reduce your quota consumption by requesting the data at a lower rate and letting the software interpolate it to a higher rate.

After your credentials have been saved, the download utility will treat the HxGN SmartNet stations as any other service available in our Download utility. For more information on downloading stations, refer to *Download Service Data* on page 128.

Update

Auto-Update

After installation, users are prompted to enable a setting which downloads manufacturer files from the NovAtel server on a bi-weekly basis.

Manufacturer files contain the latest antenna profiles from the National Geodetic Survey, updates to services and stations of permanently operating base station networks (accessed through the Download Service Utility), updated published coordinates for CORS, IGS and IGN base station networks, the latest GPS P1-C/A DCB clock biases (which affects PPP convergence), and any new manufacturer grid or datum conversions. It is recommended to keep these files up to date to ensure the most up to date information available.

Directories for ...

This section shows where various content is located. The directory that contains *All user created or modified profiles, grids, datums, favorites, etc.* is of particular interest if users wish to copy any user created content from a previous version to 10.00. This is the directory where any/all user created files from previous versions should be copied to. See *Copy User Files* on page 17 for more information.
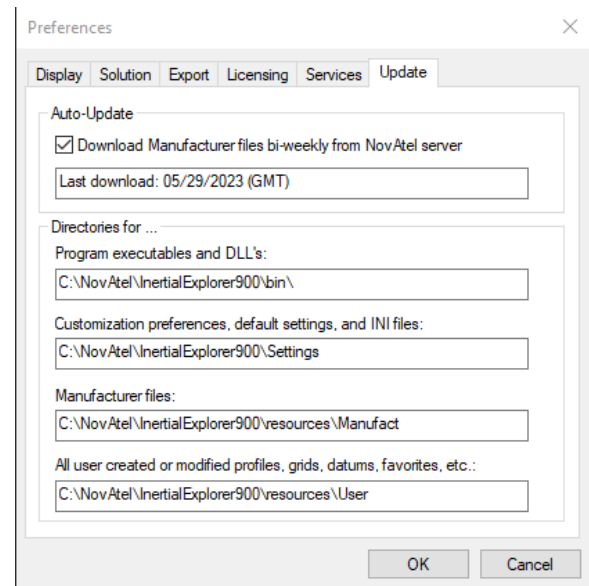
3.6.11 Exit

Exits Waypoint software.

3.7 View Menu

The following sections provide a description of the features available in the View menu.

3.7.1 Project Overview

This window provides a summary of the data in the current project. From here, you can view information regarding the base and remote files, including receiver/antenna types, time coverage, data gaps and the constellations present in each file.

3.7.2   Coordinate/Antenna

Master Station Settings

This option allows modification of the master station coordinates, station name and antenna information. Individual base stations can also be disabled from this dialog.

For more information about the Coordinates, Datum, Epoch, Antenna Height and Antenna Profile, see *Add Master File(s)* on page 52.

Coord. Options

The following options are available from the *Coord. options* pull-down menu.

Select Station From Favorites

Precise coordinates for CORS, IGN and IGS stations are regularly maintained within the manufacturer files. If downloading base station data from one of these networks, you can load the published coordinates using the *Select Station From Favorites* button in the master coordinate dialog. This returns a list of the closest stations to the coordinates loaded.

When selecting a station from favorites, be sure to note the available *Attributes to Apply* at the bottom of this dialog. This provides the ability to copy not only the position and datum information from the favorites, but also the station name, antenna properties (if available) and station velocities. If velocities are selected, the station velocities are applied to the published coordinates and reference epoch to update them to a user-specified epoch. The default epoch is the date of the survey.

Compute from PPP

This feature can be used to compute or check base station coordinates. If used, this feature will check for the presence of precise clock and orbit files required for PPP to deliver accurate results. If no files are present, the best available at the time of download will be downloaded automatically. If a Waypoint TerraStar NRT license has been activated, the Waypoint TerraStar NRT precise products will be downloaded prior to processing the PPP solution. Additionally, if you have a NovAtel receiver with the NRT files, PPP-AR will be used for coordinate determination. The *Computing Coordinates Using PPP* dialog will then report the processed position at the epoch of the data collected, within the base station coordinate datum chosen. The horizontal and vertical difference between the computed coordinate and the coordinate currently loaded on the master dialog will be reported. A user can then decide to accept the computed coordinates or to select *Cancel*, if this was only being used as a check.

Use average position

This will load the average position from the GPB file. This position is often only accurate to several meters and is not of sufficient accuracy for the majority of applications.

Enter grid values

This feature launches the *Enter grid coordinates* dialog, which allows a user to directly enter published grid coordinates, such as UTM and State Plane values. ECEF coordinates can also be entered using this feature.

Enter MSL height

This feature launches the *Enter Orthometric (Mean Sea Level) Height* dialog. It allows a user to directly enter a published MSL height for a base station. When doing so, an ellipsoidal height must be computed from the MSL height, as all position computations are done relative to the ellipsoid. As such, it is required to point to a geoid in WPG format and the ellipsoidal height will be calculated using the interpolated geoid undulation and the entered MSL height. Please see http://www.novatel.com/support/waypoint-support/waypoint-geoids/ to access all of Waypoint's geoids in WPG format.

Save to Favorites

This option launches the *Add to Favourites* dialog, which allows a user to save master station coordinates, datum, epoch, and antenna information in order to easily apply that information in future projects that use the same base station.

Remote Settings

This option lets you customize the remote's antenna information. See *Add Remote File* on page 54 for additional information.

3.7.3   Moving Baseline Options (GrafNav Only)

Enable moving baseline processing if your application involves azimuth determination between two antenna on the same vehicle or relative vector determination between two moving antennas on separate moving platforms.

When moving baseline processing is enabled, GrafNav cannot fix the base station position. Every processing epoch uses a different base station position, which is read from the GPB file. The absolute positioning accuracy of each instantaneous base station position is thus limited to the autonomous positioning accuracy of the receiver used. This is generally no better than 2 m horizontal and 5 m vertical.

Although the absolute positioning accuracy in moving base mode is approximate, this is not of interest to most moving base applications. Only the relative position difference and/or azimuth between the antennas is typically required. When ARTK resolves carrier phase ambiguities in moving base mode, the relative positioning accuracy between base and remote is the same as in stationary base mode.

If moving base is enabled, choose from one of the four Azimuth determination options explained below.
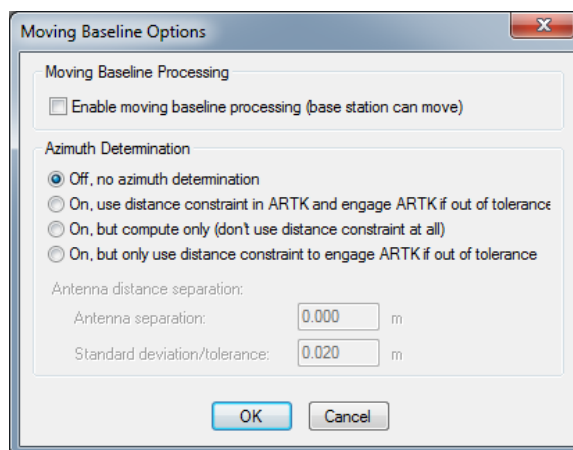
Azimuth Determination Options

Off, no azimuth determination
Use this option if both antennas are on separate moving platforms and the azimuth between the antennas is not of interest (i.e. only the relative position and/or velocity).

On, use distance constraint in ARTK and engage ARTK if out of tolerance
Use this option if both antennas are fixed to the same moving platform and a post-processed azimuth is required. This option requires that you input the surveyed distance between GNSS antennas as it is

used as a distance constraint in ARTK.

On, but compute only (don't use distance constraint at all)
Use this option if the surveyed distance between the antennas is not known, or is known to change significantly during the survey.

On, but only use distance constraint to engage ARTK if out of tolerance
When this option is used, the distance constraint is not applied when resolving carrier phase ambiguities. Rather, it is used only to re-engage when the computed distance disagrees with the surveyed distance significantly (based on the standard deviation applied to the distance constraint).

3.7.4 GNSS Observations

These options are available via *Master* or *Remote*:

View Raw GNSS Data

Opens the master or remote GPB file in the *GPB Viewer*.

View Ephemeris File

Opens the master or remote ephemeris file in the internal ASCII viewer.

View Station File

Opens the master or remote station file in the internal ASCII viewer.

Resample/Fill Gaps using the following options

File Interval
Fills any gaps but does not resample to a higher rate than the file was originally collected at.

Processing Interval
Fills gaps and matches the data rate in accordance with the specified processing interval.

Remote File Times
Produces a new master GPB file with epoch times that match the remote file. Any data gap present in the remote file is also present in the new master GPB file. This method of resampling removes unneeded data logged before, and after, the observation time period at the remote.

ⓘ   Resampling base station data to a lower interval will add noise to the processed trajectory. This noise is negligible if resampling from an original rate of 5 seconds or less, but can add as much as 1-2 cm if resampling from 30 second data. Note, this is often within the noise of a differentially processed trajectory and thus should not be seen as a significant limitation.

Disable

Disables the selected master station from being used for processing. You may want to disable individual baselines from a multi-base project when trouble shooting poor multi-base processing results.

Remove

Removes the master file completely from the project.

3.7.5 Forward and Reverse Solutions

GNSS / PPP Message Log

These files display all messages generated by the processing engine. Inertial Explorer outputs a forward message log (.fml/.fsl) and a reverse message log (.rml/.rsl), depending on the processing mode (differential or PPP). Possible messages reported here are listed below.

Types of messages written to the message log files

- Times at which ARTK was engaged and the reasons for its engagement. These messages are preceded by +++.

- The satellite constellations (GPS/GLONASS/BeiDou/Galileo/QZSS) that will be used in processing and within ARTK

- Any satellites with no ephemeris information.

- The antenna types detected for the base stations and remote files

- The GLONASS fixing receiver type mode

- Base satellite drop outs

- Epochs of less than 4 common satellites between the master and remote.

- Periods of poor satellite geometry.

- The occurrence of cycle slips. This log gives a time and record of these slips that mean problems in kinematic data.

- Data errors that cause filter resets or the rejection of satellites. These messages are preceded by $$$.

- Entering static and kinematic modes.

- Events resulting from significant changes in the satellites' geometry. These include changes in the base satellite and the rising or falling of satellites above or below the elevation mask.

- The omission of satellites, baselines or time periods from processing.

GNSS Summary

These summary files (.fss and .rss) display some basic processing settings and the statistics for ARTK fixes and static sessions. Other items reported in this summary are listed below.

Static/ARTK summary report items

- Final solutions for all static sessions, as well as the type of solution obtained.

- Time and place at which ARTK engaged successfully, as well as the corresponding statistics. Such information is useful for evaluating whether or not ARTK resolved ambiguities correctly.

- Master station coordinates, antenna summary for base and rover, and the processing mode.

- Satellite usage information pertaining to static sessions.

- Slope, horizontal and corrected ellipsoidal distances for all static sessions.

- Program completion information.

IMU LC / TC Message Log (IE/IEX only)

These files display IMU messages generated by the processing engine. Inertial Explorer outputs a forward message log (.fll/.ftl) and a reverse message log (.ril/.rtl), depending on the processing mode (Loosely Coupled or Tightly Coupled). For information on file formats see *IMR File* on page 201, *DMR File* on page 203 and *HMR File* on page 205.

3.7.6   Processing Summary

This file provides a statistical summary of the processing results. It can be used for reporting and quality checking purposes. A list of the items reported in this file include:

- Solution type (forward/reverse/combined)
- Summary of the number of epochs in the remote GPB file processed, missing and epochs with poor measurement residuals
- Summary of measurement RMS values (L1 Phase, C/A code and L1 Doppler)
- Breakdown of quality number percentages
- The RMS of the forward/reverse position separation, including separate statistics where both solutions are fixed
- Percentages of standard deviations that fall within given intervals
- Percentage of epochs with poor satellite geometry (DD_DOP > 10).
  Note: DD_DOP is approximately equal to PDOP^2.
- Baseline distance summary

The *Processing Summary* can be added to the end of an output text file created through the *Export Wizard*. See *Export Wizard* on page 115 for information about the *Export Wizard*.

3.7.7   Features

The *Feature Editor* window lists all of the features loaded into the project. In addition to viewing features, the feature editor can also be used to:

- Edit Station feature names and time-tags. For camera marks, the line number can be inserted into the *Desc/Info* field.
- Re-number stations and camera event marks.

> ⓘ   Changes made to features are saved automatically to an NST file. To revert back to the original station information, use *File | Load | Station File*.

Columns on the Features Editor window

The following is a list of the columns displayed on the Features Editor window.

Name
The name of the feature. The symbol next to the name indicates the type of feature loaded. Examples include camera marks and stations. The symbol appears gray if the feature has been disabled.

Time
This is the feature's GPS capture time.

Week
This is the GPS week that the data was captured.

Desc/Info
Describes the feature or line information for the camera mark.

Remarks
Some GNSS files will have remarks that are saved from the data collection. These will be simple or abbreviated descriptions that relate to the specific measurement.

Buttons on the Features Editor window

The following is a list of the options that are available with the buttons on the right-hand side of the *Features Editor* window.

Remove

Removes the selected stations. Multiple stations can be selected and removed. You might consider disabling a feature instead of deleting it.

Edit

Edits the station name, time-tag, description and remarks.

Select All

Selects all features. Use this prior to *Edit Selected* when you want to apply global edits to all features.

Edit Selected

Edits multiple selected features.

Re-Number

Re-number a selection of stations. Numbering can be performed starting from the bottom or the top of the list. You can specify the starting number and the increment value. To decrease numbers, use a negative number.

> (i) To select a continuous block, hold down the *Shift* key while clicking on features. To select individual features, use the *Ctrl* key.

3.7.8   ASCII File(s)

The *View ASCII File(s)* option allows you to view any of the ASCII files generated by the software using the ASCII file viewer. Examples of these files include the following:

- Message logs (FML and RML)
- Static summaries (FSS and RSS)
- Station files (STA)
- Ephemeris files (EPP)
- Legacy Configuration files (CFG)
- Project files (PROJ, these XML files are readable in ASCII)

3.7.9   Binary File(s) (IE/IEX only)

The *View Binary File(s)* option launches the Waypoint binary file viewer where IMR, HMR, DMR, MMR, PVB, and other binary files used within Waypoint software may be opened for viewing. This viewer may also be used to save the contents of a file to ASCII for further troubleshooting or analysis.

3.7.10   Raw GNSS Data

This option launches the GPB Viewer. The GPB viewer allows the viewing and editing of raw GNSS data that has been converted to Waypoint's format. This viewer is also launched by double clicking a converted GPB file within Windows Explorer. See *GPB Viewer Overview* on page 167 for more information.

3.7.11   Show Map Window

Prior to processing, the map window displays the unprocessed positions within the remote GPB file. These positions usually reflect the real time position as logged by the remote receiver.

After processing, the map window displays the processed results, color coded by quality number. Quality numbers, which range from 1-6, are meant to convey a general indication of solution quality. A description and the approximate accuracies associated with each quality number is provided in the table below. The Q/C plots should be accessed for a more detailed analysis of solution quality. See *Common Plots* on page 109 for descriptions of commonly accessed plots.

The information displayed to the map window is fully customizable from the *Display* tab within *File | Preferences*. Users can choose whether or not to display feature marks, ARTK marks and base stations.

> ⓘ The accuracies given are only guidelines. Quality numbers are meant only to provide a high level indication of solution quality. We highly recommend accessing the quality control plots for a more in-depth analysis.

Table 2: GNSS Quality Number Description

Quality	Color	Description	3D Accuracy (m)
1	Green	Fixed integer	0.00 – 0.15
2	Cyan	Converged float or noisy fixed integer	0.05 – 0.40
3	Blue	Converging float	0.20 – 1.00
4	Purple	Converging float	0.50 – 2.00
5	Magenta	DGPS	1.00 – 5.00
6	Red	DGPS	2.00 – 10.00
Unprocessed	Grey	Has not been processed	N/A

Satellite

The Satellite Map window displays the positions on a satellite image or a road map. To change the map image, right click on the Map Window, click *Map Style* and then select *Satellite* or *Road*.

Positioning the cursor on a processed epoch and clicking with the left mouse button accesses a summary of the processing results for that epoch. The time, quality number, number of satellites, standard deviation, forward/reverse separation and other statistics are displayed.

If you have a scroll-wheel on your mouse, you can use it to zoom in and out by scrolling forwards and backwards over the area of interest.
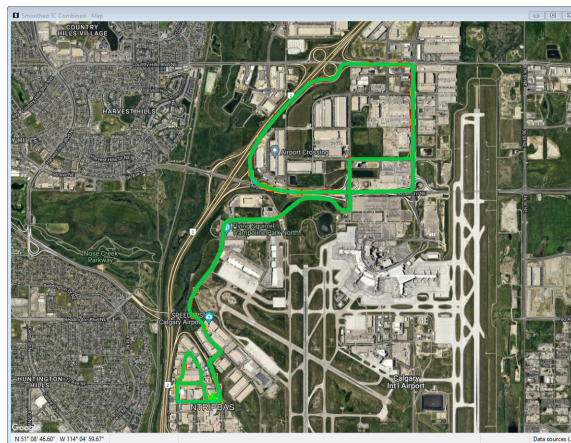
Click the right mouse button to access the map window options.

The *Map style* option changes the map window background to satellite view (*Satellite*) or road map (*Road*).

The *Reset zoom* option restores the map view to the default orientation and zoom level for the project.

In order to improve map window performance and reduce bandwidth consumption, the software will cache downloaded tiles for re-use as needed.
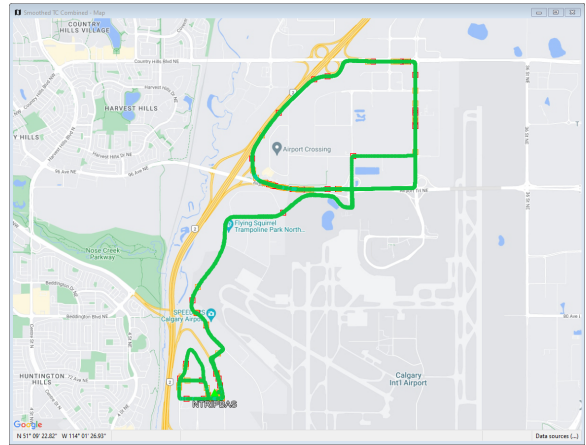
Standard

The Standard Map window displays the positions on a black background.

Positioning the cursor on a processed epoch and clicking with the left mouse button accesses a summary of the processing results for that epoch. The time, quality number, number of satellites, standard deviation, forward/reverse separation and other statistics are displayed.

If you have a scroll-wheel on your mouse, you can use it to zoom in and out by scrolling forwards and backwards over the area of interest.

The *Save to HTML* option generates an HTML file containing a bitmap version of the Map window. These HTML and BMP files are saved to the *HTML* folder contained within the project folder.

See *Tools Menu* on page 121 for additional interactive mapping tools.

3.8   Process Menu

The following sections provide descriptions of the features available in the Process menu.

3.8.1   Process GNSS

The Process GNSS dialog is intended to provide a one page startup where the processing method, direction, options and datum can all be conveniently accessed.

Processing Method

Differential GNSS

Differential processing can be selected if base station(s) have been added to the project. This method of processing provides access to ARTK, where carrier phase ambiguities may be fixed for high accuracy applications.
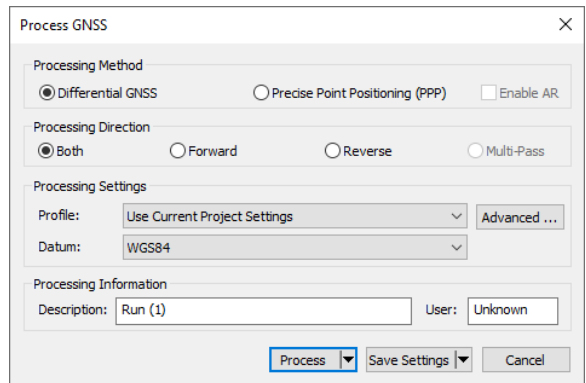
Precise Point Positioning (PPP)

PPP is an autonomous positioning method where data from only the remote receiver is used. If base station data has been added to the project, it will not be used when processing PPP. By design, both differential and PPP trajectories can be processed within the same project without over-writing each other.

The PPP processor requires dual frequency data, single frequency PPP is not supported.

Upon selecting *Process*, pre-processing checks test whether precise ephemeris and clock data have been added to the project, which are required to remove meter-level error sources. If the project contains only broadcast orbit and clock corrections from the combined ephemeris data (.EPP files), the pre-processing checks will warn of this through the *No Precise Files* pre-processing warning.

If it is your intention to process a PPP trajectory without applying any precise corrections, you can do so by deselecting the *Try to fix* option at the bottom of the PPP Pre-processing dialog and then select *Continue*. Users may wish to do this as a quick check on the quantity and quality of collected data, prior to precise ephemeris files or base station data becoming available.

If the *Try to fix* option is selected when you select *Continue*, the Download Service Utility is called to automatically download the best available source of precise and ephemeris data given the detected constellations in the remote data file.

PPP With AR Enabled

PPP-AR is an enhanced version of PPP that utilizes the TerraStar C-PRO corrections for faster convergence times with ambiguity resolution. Any survey collected after July 4th, 2019 can benefit from the faster convergence. With the faster convergence times you can use shorter surveys to obtain similar or better performance than our legacy PPP filter, making PPP a more viable option.

> (i)   PPP-AR can only be used with NovAtel receivers and an NRT subscription.

Processing Direction

Both

When processing *Both* directions, independent forward and reverse solutions are processed and automatically combined. This method of processing is the default for differential processing.

Combining forward and reverse solutions maximizes solution accuracy and assists in quality control. Depending in part on baseline length, satellite geometry and number of satellites available, forward and reverse solutions may achieve different solution types (fixed/float) for different parts of the survey.

When both directions are combined automatically after processing, inverse variance weighting is applied to ensure the direction with the lower estimated errors receives the most weight in the combined trajectory.

Position differences between forward and reverse directions can be accessed from the *Combined Separation* and *Combined Separation (fixed)* plots after processing. The latter plot shows the differences in positions only where both have fixed integer solutions. This plot will help detect incorrectly fixed ambiguities.

Forward and Reverse

Changing the processing direction to *Forward* or *Reverse* is normally done only if a problem is detected after processing *Both* directions. The *Advanced* dialog can be accessed to customize processing options prior to reprocessing.

Multi-Pass

This method of processing is available when processing GNSS-only PPP or TC (PPP or differential). Multi-pass processing maximizes convergence by passing converging Kalman filter states sequentially between

processing directions. This benefits PPP processing, as float carrier phase ambiguities are estimated, and heading convergence for low cost IMUs and low dynamic applications (e.g. pedestrian, marine). Differential GNSS-only processing does not benefit from multi-pass processing, and is thus not an available selection in the processing mode, due to ARTK (fixing carrier phase ambiguities).

Processing Settings

Profile

Processing profiles are available for aerial, ground vehicle, marine, pedestrian and UAV applications. The processing profile which matches the detected processing environment during decoding of the raw measurement data to GPB is automatically loaded the first time you access the Process GNSS dialog. Users can change their default processing profile, which turns off the auto-detection of the processing profile, within the *Solution* tab of *File | Preferences*. Users may wish to change their default profile if a custom profile has been developed or edits have been made to the manufacturer profiles. These profiles load processing settings that have been empirically developed to work well for each application, including changes to the default elevation mask, ARTK options, measurement weighting and more.

Processing profiles are particularly helpful for new users, as adjusting individual processing settings from the *Advanced* options are often unnecessary in order to generate a high quality result. For advanced user's, processing settings can be created or customized.

Advanced...
Depending on the processing method selected (differential or PPP), selecting *Advanced* provides access to all available processing settings.

> ⓘ When AR is enabled, many measurement settings cannot be edited due to the functionality of the filter.

> ⓘ In Inertial Explorer Xpress, the UAV profile is always loaded when initially accessing the processing dialogs.

Datum

The processing datum is directly accessible from the *Process GNSS* dialog for both differential and PPP processing. If any base station coordinates have been entered in a different datum than the processing datum, they will be automatically converted prior to processing.

Processing Information

Description

The processing description automatically appears as *Run (1)* for the first differential processing run or *PPP (1)* for the first PPP processing run. The counter within the parentheses automatically increases each time a processing run is performed. The description of the processing runs can be edited (optional).

User

You can enter your name or initials here. This can be helpful if multiple users will be processing the same data on the same computer.

General (Differential Settings)

Process Data Type

Defines the type of data used for processing.

Automatic
Chooses between dual frequency, single frequency and C/A only depending on what measurements are in common between the base and remote.

C/A code only
Only C/A code measurements are applied in this method of processing which is limited to meter-level accuracy.

Dual frequency carrier phase
Dual frequency processing should always be used for best results if both base and remote provide dual frequency data. Ambiguity resolution is faster, more reliable and possible at longer baselines lengths than single frequency processing. For long baselines (>7 km by default), ionospheric processing is automatically engaged, helping to preserve post-processed accuracy with increasing baseline length.

Single frequency carrier phase (Differential GNSS processing only)
Single frequency processing uses L1/B1/E1/L1CA measurement only from GPS and GLONASS, BeiDou, Galileo and QZSS if available. While ambiguity resolution can still be successful on short baseline lengths, this method of processing is generally associated with decimeter level applications. As the ionospheric error cannot be directly measured and removed, as in dual frequency processing, post-processed accuracy quickly degrades with increasing baseline length.
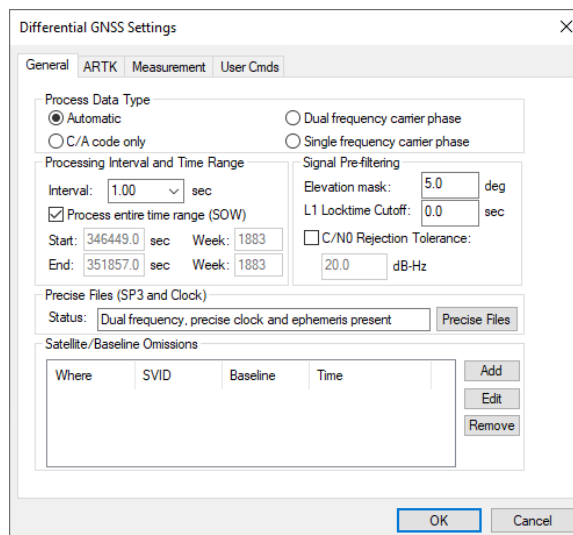
Processing Interval and Time Range (SOW)

The data rate of the remote GPB file is used as the default processing interval. However as only common data between the base station and remote can be processed, you will need to ensure the base station(s) were also logged or resampled to the same interval in order to output a trajectory at this interval. Pre-processing checks will output a warning if the master data rate is detected to be less than the remote and will automatically resample the base station data to the remote interval to correct the issue should you select *Continue* with the *Try to fix* option engaged on the pre-processing dialog.

By default, all common data between master and remote is processed but a specific time range in GPS seconds of the week can be entered here. The start and end processing times can also be set by right clicking on the Q/C plots.

Signal Pre-filtering

Elevation Mask
Satellites below this elevation (relative to the horizon) are ignored. Common elevation masks for differential kinematic processing are 10-12 degrees. Static processing generally benefits from a higher elevation mask (15 degrees).

Low elevation signals are more affected by multipath and tropospheric error, and are more likely to be affected by cycle slips due to signal blockages and/or signal attenuation by the antenna. Thus, pre-filtering low elevation signals is generally beneficial to post-processed accuracy. Increasing this value too high may cause satellite geometry to become poor which can affect the performance of integer carrier phase determination.

L1 Locktime Cutoff:
This is the number of seconds that continuous carrier phase tracking is required before measurements will be used. Lowering this value will help to maximize GNSS position availability following a total loss of carrier phase lock. However, using low values increases the likelihood of an incorrect ambiguity fix. This is because the quality of carrier phase measurements may be suspect within the first few seconds the receiver achieves carrier phase lock.

C/N0 Rejection Tolerance
Most often, pre-filtering GNSS signals by elevation mask and L1 locktime cutoff is effective. For specialized applications, introducing an alternative or additional pre-filtering method based on the signal to noise ratio may also be effective.

This option is not engaged by default as not every receiver provides a C/N0 value, and different receivers may output this value at different stages of signal processing. Care should be used if applying this option.

Precise Files (SP3 and Clock)

Precise clock and orbit files can be downloaded by accessing the *Precise Files* button. Adding a precise ephemeris file will help mitigate residual orbital error on long baselines. Precise clock files are not needed in differential processing as this error cancels completely. However, as both files are required should the advanced tropospheric state be engaged or if a Precise Point Positioning (PPP) solution is later computed, both precise files can be added here. Alternately, an NRT correction file can be added instead of the SP3 and clock files.

Satellite/Baseline Omissions

Pre-filtering options will often remove noisy or problematic data prior to the processing stage. During processing, automatic outlier detection routines work to automatically fix errors when large measurement residuals are detected. Failing all of this, if a problematic measurement or satellite can be identified, usually from repeated warnings during processing regarding a specific satellite prior to a Kalman filter reset occurring, the *Omit Satellite Info* dialog can be accessed to manually enter satellite omissions.

Satellites to Omit

All Satellites
Disables all satellites from being used.

Only specified satellite
Disables individual satellites from individual constellations.

Baselines to Omit

Omit satellite for all baselines
Applies the satellite omission to all baselines in the project.

Only selected baseline
Applies the satellite omission only to the specified baseline (applies to multi-baseline projects only).

Time Period

Omit for entire data set
Applies the omission to the entire processing time range.

Use specified time range
Applies the omission to a specific time period, entered in GPS seconds of the week.

General (PPP Settings)

The options found in the General tab of the PPP processing settings are explained in the Differential General tab. See *General (Differential Settings)* on page 76. The one exception is *Allow processing without precise files*.

> ### Allow processing without precise files
> This option removes the restriction where measurements will not be used if precise clock and ephemeris data is unavailable. This enables a user to process PPP using only broadcast ephemeris data for the purposes of a quick check on the quality and quantity of data processed prior to precise products or base station data becoming available.
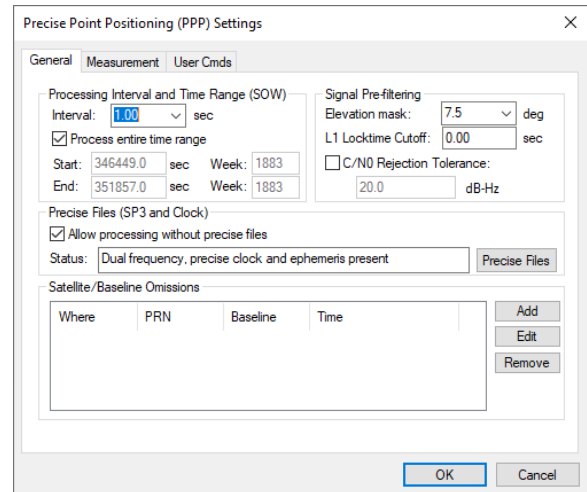
ARTK Options (Differential GNSS processing only)

ARTK (AdVance RTK) is NovAtel's method of resolving integer carrier phase ambiguities. ARTK is engaged by default and should be attempted in high accuracy applications, whenever cm level results are required.

Dual frequency ARTK provides fast, reliable and robust performance. However, in high multipath environments or where the satellite geometry is marginal, the possibility of an incorrect ambiguity fix exists. This is why it is important to access Inertial Explorer's quality control plots which will help detect errors.
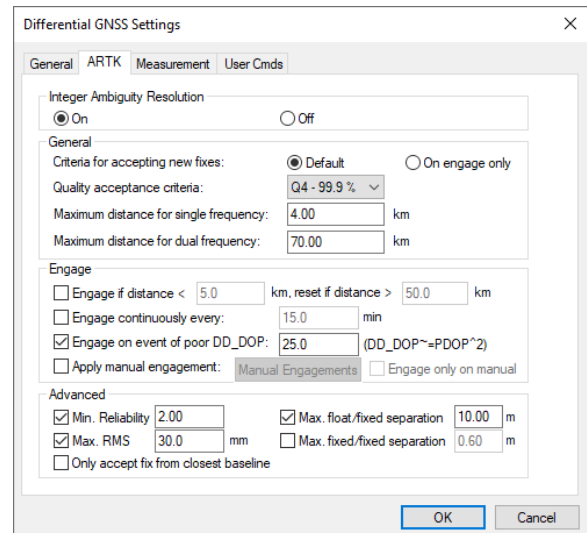
> (i) Both single and dual frequency ARTK require at least 5 satellites, but 7 or more are preferable.

Integer Ambiguity Resolution processing option settings

> ### On
> Engages ARTK for both single and dual frequency data processing.
>
> ### Off
> Disables ARTK. This will produce a float solution.

General

> ### Criteria for accepting new fixes
> ARTK can be used in *Default* or *On engage only* modes. These modes are described below.

Default

When ARTK is used in default mode, it is constantly re-checking its solved ambiguities when the satellite geometry changes (i.e. when new satellites come into the solution or when individual satellites are lost). Thus it is possible, even under open sky conditions where no loss of lock occurs, that ARTK will accept a new set of integer ambiguities when there is a change in satellite geometry. This may result in a position jump where the new ambiguities are accepted.

Using ARTK in default mode is thus mostly preferred for ground vehicle applications, as this method provides a high level of solution accuracy over the entire length of a trajectory.

On engage only

This method ensures ARTK engages only at startup, when a complete loss of lock occurs, or after a period of poor satellite geometry. This method is generally preferred for aerial applications as it ensures that new ambiguity fixes are not accepted in the middle of a flight line, where position jumps may be problematic.

Quality acceptance criteria

This is the confidence level required in residual testing for an ARTK fix to be accepted. Using lower quality acceptance criteria increases both the likelihood of achieving a fix and the possibility the fix may be incorrect. Conversely, increasing the quality acceptance criteria helps reduce the likelihood of incorrect ambiguity fixes, but also the chance that no fix is achieved when conditions are marginal for ambiguity determination.

The default criteria applied in all manufacturer processing profiles is the highest possible setting, Q4 (99.9%). This is set purposefully conservative to help guard against the worst-case scenario of an incorrect set of ambiguities being accepted. In this case, the standard deviation of the solution will be cm-level, however there may be meter-level error in the solution. It is important to view the *Combined Separation with Fixed Ambiguity* plot to help identify any incorrectly fixed solutions.

The quality acceptance criteria provides a level of control over ARTK performance. However advanced settings can also be applied, including the minimum reliability, maximum RMS, maximum float/fixed separation and maximum fixed/fixed separation.

Maximum Distance

The distance tolerance for engaging ARTK for both single and dual frequency can be defined here. The default values applied are high, and therefore are more often lowered than increased.

If your project involves a long flight to or from the project area, and your base station is operating in the project area, it is generally beneficial to lower the distance threshold to 30 km or less. This will prevent ARTK from engaging itself unnecessarily far from your project area, which increases the likelihood of an incorrect ambiguity fix.

Engage Options

These options control when ARTK is engaged.

Engage if distance < tolerance1, reset if distance > tolerance2:

The first tolerance is used to automatically re-engage ARTK on approach to any new base station. The remote must exceed the second tolerance for ARTK to re-engage when re-approaching the same base station. This option, specifically the first tolerance, is useful in multi-base, corridor-type projects.

Engage continuously every:

Engages ARTK at regular intervals. This option does not check other criteria, such as baseline length or data quality. Thus, it should only be used in slow moving or monitoring applications.

Engage on event of poor DD_DOP:

It is possible to maintain a fixed integer solution through an event which causes poor satellite geometry, provided carrier phase lock is maintained on four or more satellites. When satellites are re-acquired,

their carrier phase ambiguities are not automatically re-established as fixed integer solutions. Thus, it is possible that following a period of poor geometry, more satellites in the solution have float ambiguities than fixed. This will not necessarily result in degraded accuracy, but re-establishing all satellites with fixed ambiguities is generally beneficial to maintaining high accuracies.

Apply Manual Engagement

A manual ARTK engagement forces Inertial Explorer to re-establish carrier phase ambiguities. Introducing a manual engagement is one technique to recover from an incorrect or drifting ambiguity fix. These instances (incorrect or drifting ambiguity fixes) can be identified from the forward/reverse separation plots. If the *Engage only on manual* setting has not been enabled, Inertial Explorer will compute a float solution only until a manual ARTK engage time is reached, at which point Inertial Explorer will attempt to resolve integer carrier phase ambiguities.

Advanced

These options provide advanced users more control over ARTK performance and more tools when reprocessing problematic surveys. By default, conservative values are applied in all manufacturer processing profiles only to provide sanity checks on the values returned by ARTK.

Min. Reliability:

The reliability of an ARTK fix is the ratio of the second best RMS and the best RMS. It indicates how much better, statistically, the best solution is from the second best solution. High reliability values indicate the best RMS is significantly better (lower) than the second best RMS, and thus a high degree of confidence can be placed in the solution. This option provides direct control over the minimum reliability ARTK will accept as a pass.

Max. RMS:

An RMS is computed for every possible ARTK fix within a given search area. This RMS, output by Inertial Explorer in units of mm, represents the mathematical fit of the solution or how well the carrier phase measurements in the solution agree with each other. Low values (mm level or sub-mm) represent well fitting solutions, or measurements that agree very closely. Large values (cm level) indicate poorer fitting solutions that are more suspect. This option provides direct user control over the maximum allowable RMS for an ARTK fix to be considered a pass.

Max. float/fixed separation:

Using this option forces the float solution to converge within a specified distance prior to a fix being accepted. This value is usually dependent on the time used by ARTK to fix. If only seconds of data are used, the float solution is likely to be meters away from the fixed. This would be normal and not indicative of a problem. If several minutes of data are used prior to fixing, the float solution may have converged to within a decimeter-level value. Nonetheless, fixed ambiguities with excessively large float/fixed separate values are suspect and large values may indicate heavy multipath conditions.

Max fixed/fixed separation:

This option is of significance when ARTK is used in *Default* mode. In this mode, ARTK is constantly re-checking its carrier phase ambiguities as the satellite geometry changes. When a new fixed integer solution is obtained, the position computed with the new set of fixed ambiguities is compared to the position computed from the previous set of fixed ambiguities and the difference is reported as the *fixed/fixed separation*. Fixed solutions with large fixed/fixed differences may be suspect, and users can directly control how different a new set of fixed integer ambiguities can be from the current. It is recommended not to set this value too low, as it may prevent Inertial Explorer from fixing.

Only accept fix from closest baseline:

In multi-base processing, ARTK uses data from all base stations within the distance tolerance under the *General* ARTK options and chooses the best fix (statistically). As such, the closest base station will not necessarily be the one which has fixed ambiguities. This option is available should users desire or

require to only accept fixed integer solutions from the nearest baseline. This option is not engaged by default as in general it does not produce best results.

Measurement

Measurement Standard Deviations

Sets the measurement standard deviations applied to code, carrier and Doppler measurements.

> #### Code (Not with AR enabled)
> Controls the measurement weighting applied to the double differenced C/A measurements. Regardless of what value is entered here, if ARTK is used to fix integer carrier phase ambiguities, the C/A measurement standard deviation will not significantly impact results. This is because when ambiguities are fixed, the strength of the solution comes from the carrier phase. The C/A measurement weighting can affect float solution convergence and is one of the most effective setting available for optimizing float trajectories.

> #### Carrier phase (Not with AR enabled)
> Controls the measurement weighting applied to the double differenced carrier phase measurements. This value is automatically increased if ionospheric processing is engaged. Also, an additive PPM value is applied to account for increased noise as the baseline distance increases.

> #### Doppler
> Doppler is the instantaneous rate of change of the carrier phase signal as measured in the receiver. Doppler is used to calculate instantaneous velocity. Inertial Explorer assigns a relatively conservative measurement weighting of either 1.0 m/s or 0.25 m/s depending on the receiver manufacturer.

Inertial Explorer uses a conservative weighting as the quality of Doppler measurements vary significantly from one receiver manufacturer to another. Nonetheless, if a large number of Doppler errors are reported to the processing dialogs and message log files, consider increasing the weighting after viewing the *RMS - Doppler* plot or disengage the option to *Use Doppler for velocity determination* within the *Measurement Usage* settings.

> #### Outlier Detection Level (Not with AR enabled)
> Inertial Explorer attempts to automatically reject satellites or measurements when large measurement residuals are detected. If a large residual is detected, Inertial Explorer systematically rejects each satellite individually and recalculates the position and residual. If the new residual is significantly lower than the original residual, the satellite is automatically removed from the solution at that epoch. Inertial Explorer's sensitivity to high measurement residuals is controlled through this setting.

Measurement Usage

> #### Dual code/carrier clocks (PPP only) (Not with AR enabled)
> This option engages the use of separate clock states for the code and carrier measurements. Whether this option should be engaged is completely dependent on receiver design. It is most often needed for

Trimble receivers, so this option is automatically engaged if the remote receiver is detected to be Trimble. If this option is not used when needed, typically, results are obviously degraded.

Use Doppler for velocity determination

If engaged, Doppler is used to derive instantaneous velocity. If many Doppler measurement errors are output to the Inertial Explorer processing dialog, it may indicate the Doppler measurement quality of your receiver is very poor. In this case, it is recommended you disable this option or increase the measurement SD upwards.

Disable baselines when distance becomes greater than (Differential processing only)

This option is used to automatically disable base stations according to baseline length. This is an effective means of managing base station data use in large project areas.

Limit usage to nearest # baselines (Differential processing only)

This option determines the maximum number of base stations used simultaneously. In the initial release of Version 9.00 and earlier versions, this value was internally set to 8. You can now significantly speed up processing by lowering this value, as this will reduce the computational load. Compared to using a value of 8, Waypoint's testing shows that processing times can be reduced by up to 75% when using the new default of 4, and up to 95% when using 1. Like most settings, changing this value can impact the results for better or worse, although testing has shown that the results are nearly identical with 4, and very comparable with lower values. For most applications, a value of 2 is the recommended minimum in order to facilitate a smooth transition between Kalman filter states when base stations change, but corridor-like applications have been tested successfully with the minimum value of 1.

Use tropospheric error state (PPP processing only) (Not with AR enabled)

As no base station data is used to reduce correlated errors, such as tropospheric delay, this must be solved as an additional state within the PPP filter. The tropospheric spectral density controls how fast Inertial Explorer allows the tropospheric state to change. *Medium* is suitable for most projects, but *High* may work better if very fast and frequent changes in elevation are expected in your survey. *High* allows the tropospheric conditions to change more rapidly within the filter.

Ionospheric Processing (Differential processing only)

Ionospheric processing requires dual frequency data. It helps maintain GNSS positioning accuracy with increasing baseline length. The ionosphere can be a significant error source for L1 only processing as it is highly variable and can change rapidly.

Ionospheric processing essentially removes the ionospheric delay as an error source, however does so at the cost of higher measurement noise. Thus, best results are achieved on short baseline lengths when ionospheric processing is disabled. However when the baseline distance becomes large, the benefits of correcting for the ionosphere out-weigh the increased noise and best results are achieved when enabling this option.

In order to handle both scenarios, Inertial Explorer has an *Automatic* setting that will turn on or off ionospheric processing depending on the length of the baseline detected in the project. Prior to processing, the unprocessed positions in the remote GPB file are compared with the base station position. If more than 10% of the trajectory exceeds the distance tolerance, ionospheric processing is engaged.

In addition to *Automatic*, ionospheric processing can also be explicitly turned on or off.

Constellation Usage

Inertial Explorer supports GPS, GLONASS, BeiDou, Galileo and QZSS within the differential and PPP processors.

GPS, by default, is always engaged in PPP and differential processing and does not appear in the list of constellations you can enable/disable. If data from other constellations are detected within the project, they will appear here and may be omitted from the project by deselecting the check box.

ⓘ Waypoint software offers the ability to switch the secondary frequency used in processing with a user cmd. This can be changed for both differential processing and PPP processing using the commands SECONDARY_FREQ_SRC and PPP_SECONDARY_FREQ_SRC respectfully. For which signals are used by default and as replacements, refer to *Table 3: Secondary Frequency Used* below.

Table 3: Secondary Frequency Used

		Default		SECONDARY_FREQ_SRC = 'L5'	
		Primary Signal	Secondary Signal	Primary Signal	Secondary Signal
GPS	L1	X		X	
	L2/L2C		X		
	L5				X
GLONASS	L1	X		X	
	L2/L2P		X		
BeiDou	B1I	X*		X*	
	B2I		X*		
	B3I				X
	B1C	X*		X*	
	B2A		X*		
	B2B		X*		
Galileo	E1	X		X	
	E5a				X
	E5b		X		
QZSS	L1	X		X	
	L2C		X		
	L5				X

*For each slot (primary or secondary), only one signal will be used per constellation. In differential processing, the software will automatically choose by scanning the remote and base station data to determine which signal is more prevalent. In PPP processing, B1I will be preferred over B1C for any satellite tracking both. Similarly, B2B will be preferred over B2A.

User Cmds (Not available in IEX)

User commands only need to be added if it enables special functionality for something that is not directly available through the GUI. Any user command entered which is also available as a GUI option will override the GUI setting.

When opening an older project in a new version, any unrecognized commands will appear within the GNSS user commands. They can be deleted but otherwise will not cause an error or a change in results.

User commands can be used to change commands that are set by the other option tabs, or set commands that are not handled by the other option tabs.

3.8.2   Process LC (Loosely Coupled) and TC (Tightly Coupled)

> (i)   Loosely coupled processing is not supported in Inertial Explorer Xpress, GrafNav or GrafNav Static.

This window provides access to most settings related to IMU processing.

Update Data
Use this option to select the GNSS file from which Inertial Explorer obtains updates. In most cases, the differential combined solution is suggested. However, you may specify an alternate file by selecting *External trajectory* from the drop-down menu and clicking the *Browse External* button.

File Name
Displays the selected file that will be used for updates.

Process Settings

Profile
A processing profile is automatically loaded based on the detected processing environment (airborne, UAV, marine, ground vehicle, pedestrian) when converting the raw GNSS data to GPB format and the type of SPAN system used. If the automatically detected processing profile is incorrect it can be changed by accessing the pull down menu.

Filter Profiles
This option, enabled by default, will only show profiles associated with the SPAN IMU in use. If using third party IMU data, this option should be disabled in order to gain access to custom processing profiles.

Datum (TC processing only)
Choose the processing datum for all processed output here. If any base stations have been entered in a different datum, the coordinates will be automatically converted to the processing datum. Users may change their default processing datum in the *Solution* tab of *Preferences* window. See *Solution* on page 62.

Advanced...(LC Processing)
This button provides access to all IMU processing settings.

Advanced GNSS (TC Processing)
This button provides access to all GNSS processing settings. Refer to *Process GNSS* on page 73 for information.

Advanced IMU (TC Processing)
This button provides access to all IMU processing settings.

IMU Installation (IE/IEX only)

Read rotations and lever arms from IMR file
If using a NovAtel SPAN system, the IMU to GNSS lever arm and body to IMU rotation may be set during data collection. If this has been set and the necessary log (INSCONFIGB) is present in the raw data, this information is imported automatically to Inertial Explorer.

Vehicle Profile
This button accesses the Vehicle Profile Manager. It allows the primary lever arm, secondary lever arm, body to IMU rotation, vehicle boresight, gimbal lever arm, DMI lever arm, and GNSS heading offset to be saved to a vehicle profile. This facilitates quick and easy loading of important project parameters that are specific to each survey vehicle.

It is not necessary to save vehicle profiles if using a NovAtel SPAN system as this information can be retrieved directly from the raw data and imported automatically. Vehicle profiles are intended to assist non-SPAN customer workflow.

Lever Arm Offset (IMU to GNSS Antenna)

To perform GNSS updates accurately, enter the 3-D offset, in meters, from the IMU sensor array's navigation center to the GNSS antenna. This offset vector must be entered with respect to the body-frame of the vehicle, as *Figure 1: Body Frame Definition for Lever Arm Offset* on the next page shows.

You must also specify whether the Z value applies to the antenna's reference point (ARP) or L1 phase center. To specify ARP, you must select an antenna model when you add the remote GPB file to the project. In this case, the antenna model's offset value is applied to the Z value to raise the Z value to the L1 phase center.

ⓘ   Save lever arms for future access using the *Vehicle Profile* button.

Read rotations and lever arms from IMR file
If the lever arm and body to IMU rotation values are written to the header of the IMR file, then use this option to extract them.

Figure 1: Body Frame Definition for Lever Arm Offset
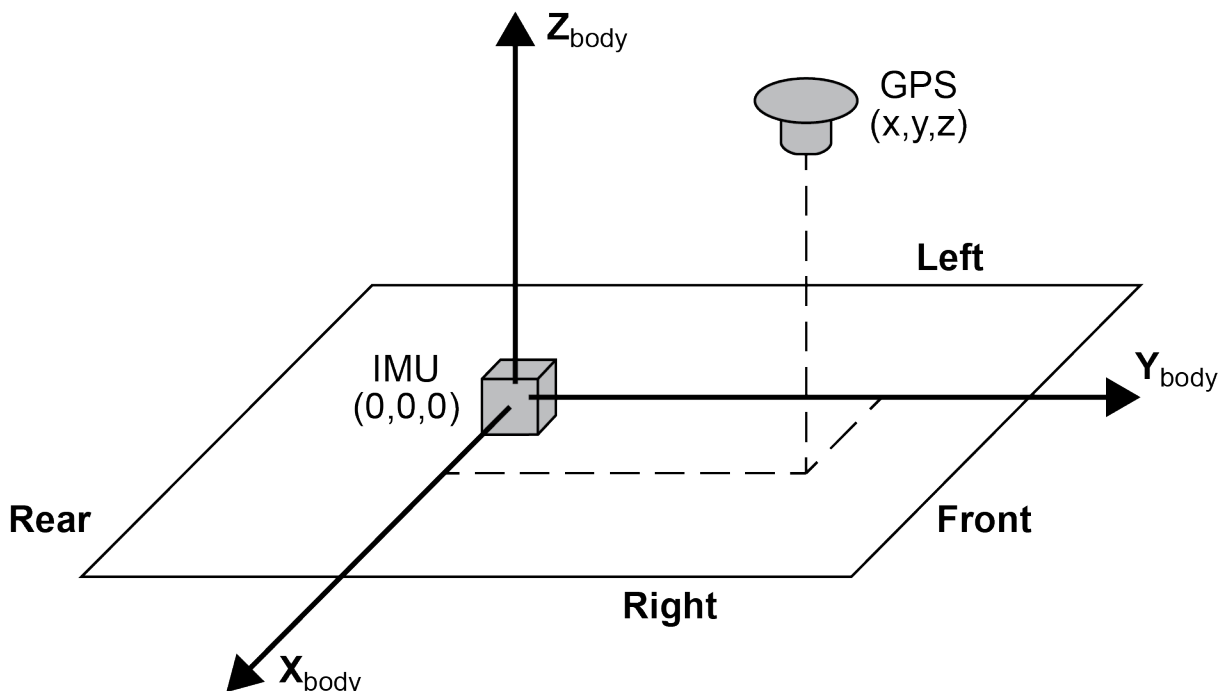
The IMU is the local origin of the system and the measurements are defined as the following:

X: The measured lateral distance in the vehicle body frame from the IMU to the GNSS antenna.

Y: The measured distance along the longitudinal axis of the vehicle from the IMU to the GNSS antenna.

Z: The measured height change from the IMU to the GNSS antenna.

> All measurements are from the navigation center of the IMU to the GNSS antenna.

Body-to-IMU Rotations (Rotate Vehicle Frame into IMU Frame) (IE/IEX only)

Many typical IMU installations have the surface of the IMU directly attached to the floor of the vehicle so the sensor frame of the IMU and the body frame of the vehicle are more or less aligned. In these installations, the roll, pitch and yaw of the vehicle are directly sensed by the IMU. Some IMUs are installed in a tilted position with respect to the body frame of the vehicle. If the tilt between the IMU frame and body frame is known, Inertial Explorer compensates so that the attitude information produced is with respect to vehicle body frame, not the IMU sensor frame.

The order of rotations employed is R_z, then R_x, followed by R_y, in decimal degree units.

GNSS Heading Offset (IE/IEX only)

This value may also be referred to as the "Reference to Aircraft Rotation" and is meant for customers that have backwards-pointing LIDAR applications or other specialized applications where the IMU cannot be rotated to the vehicle frame through body to IMU rotations. This option applies a correction (as entered in degrees) to GNSS Course Over Ground (COG) values in order to allow kinematic alignments to succeed when the IMU is intentionally not aligned to the vehicle frame. This option has no effect if a static alignment is performed.

Advanced IMU (IE/IEX only)

This button provides access to all IMU processing options.

Alignment (IE/IEX only)

Method for Initial Alignment

In INS processing, small changes in velocity and orientation are integrated in order to derive position, velocity and attitude from a starting point. As such, it is a relative positioning method and the initial integration conditions must be known. Alignment is the process of solving these initial integration constants.

The initial position and velocity of the IMU are usually derived from Inertial Explorer's GNSS processor. Initial roll and pitch are derived from the accelerometer measurements and initial heading is derived from gyroscope measurements.

IMUs of tactical grade or higher are capable of static alignment. However MEMS IMUs, or any IMU with a gyro bias larger than the Earth rate (15 deg/hr at the equator), are not capable of deriving a reliable heading from gyro measurements alone. In these cases, the GPS Course-Over-Ground (COG) must be used to help Inertial Explorer determine the initial azimuth of the IMU.

Click the *Options* button to open the *Align Options* dialog. See *Align Options* on the next page for information about the settings available on this dialog.
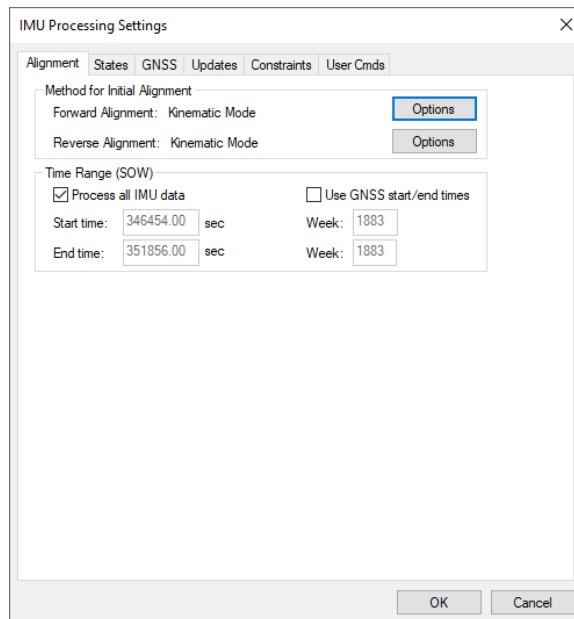
Time Range Options

Process All IMU Data
If this option is enabled, the software obtains the beginning and end times from the raw binary IMU file. These times are in GPS seconds of the week.

Use GNSS start/end times
When selected, IMU processing will start and end based on a time range set under the *General* tab of the GNSS processing options menu.

Start Time
Forward alignment will begin at the entered time (GPS SOW). Reverse processing will end at this time.

End Time
Reverse alignment will begin at the entered time (GPS SOW). Forward processing will end at this time.

Align Options

Alignment Method

Automated Alignment (Recommended)
Automated alignment scans the raw IMU data in order to determine whether a static alignment can be attempted. If no usable static alignment is detected, a kinematic alignment is applied when the vehicle reaches the minimum speed set within the auto/kinematic align tolerance. If static data is detected, a static coarse alignment is attempted for the duration of the detected session length.

Static alignment
Static alignment uses the sensed gravity vector components to estimate roll and pitch. It uses sensed Earth-rotation rate to provide an initial estimate of the yaw of the IMU. As such, only IMUs with gyro biases much less than the Earth rate (15 deg/hr at the equator) are capable of reliable static alignment.

Kinematic alignment
When no static data is detected, a kinematic alignment will be used. The GNSS Course-Over-Ground (COG) will be used as an initial approximation of the forward pointing IMU axis. As such, it is important when using a kinematic alignment that the IMU be mounted Y-forward, X-right and Z-up. If it is not possible to mount the IMU in this fashion, appropriate body to sensor rotations should be entered. If intentionally misaligning the sensor and vehicle frames, use the GNSS Heading Offset to correct the GNSS COG used in the alignment process. Kinematic alignment requires that the IMU be traveling relatively straight and level for at least 4 seconds.

Alignment Options

Minimum Speed
Specifies the minimum speed that the system must be traveling before kinematic alignment is attempted. This value should be lowered for low dynamics applications such as pedestrian surveying. Minimum speed is not considered for static alignments.

Heading SD Tolerance
Specifies the tolerance below which the heading standard deviation must fall before the alignment routine will move into navigation mode. Lower this value if the software is not achieving a good alignment. Raise this value if the software is not aligning at all. This value is tested for both static alignments and a kinematic alignments.

Initial Static Alignment Duration
Specifies the length of time the system must be stationary for static alignment. If you do not know this value you can check the GNSS velocity plot.

Manually Set Initial Position/Heading

This dialog allows the user to manually set the initial position and heading for a static alignment. It is particularly useful for IMU-only processing or denied GNSS environments. The position and heading values entered should be known to a good degree of accuracy.

The *Start Time* will automatically be loaded depending on the start/end time in the IMR file.

The *Initial Position* is to be entered in DMS format with ellipsoidal height. The *Standard Deviations* values are mandatory. Enter small values if the accuracy of the input position is well known. The *Marker to IMU Lever Arm* values are optional. They are intended to be used if the unit is starting near a known point. The lever arm must be entered in the local level (ENU) frame. A compass or magnetometer may be used, for example, to determine the East and North directions.

Initial Heading is to be entered in decimal degrees along with its standard deviation. If the heading is well known, enter a small value for standard deviation. The initial heading can be gathered using a compass or magnetometer, for example.

(i) Positive heading rotation is clockwise from North

The *Copy from <opposite> direction* button may be used to copy the input parameters from the opposite direction for alignment (i.e. from forward to reverse or vise versa). This is useful if the beginning and end of the survey are on an identical position and identical orientation.

States (IE/IEX only)

Error Model

Error models consist of initial standard deviation and spectral density values which are indicative of IMU sensor quality. They help control the extent to which Inertial Explorer weights GNSS and INS measurements during processing.

Inertial Explorer comes pre-configured with error models for all SPAN IMUs. These are automatically selected when loading an appropriate processing profile for the application (aerial, ground vehicle, marine and pedestrian) and SPAN system used. Inertial Explorer also comes pre-configured with a handful of error models developed for third party IMUs as well as generic error models that can be a useful starting point when attempting to develop your own new error model for a non-SPAN IMU. See *Edit Error Model Values* on the next page for information about the settings you can change in the Error Model.
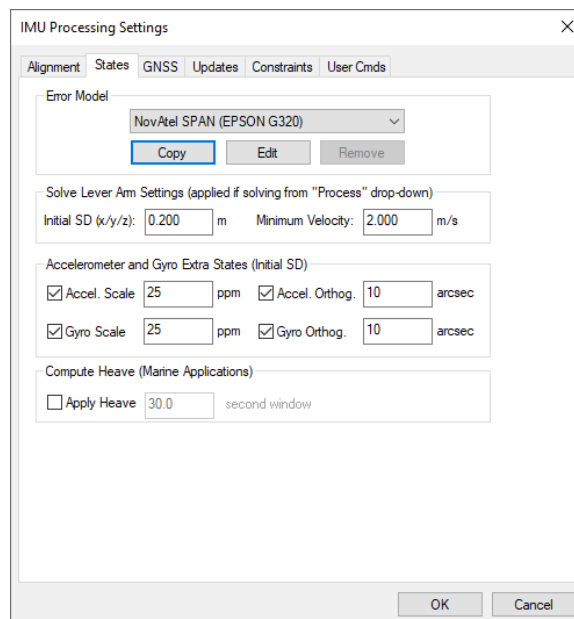
Solve Lever Arm Settings

These values are applied if using the *Solve Lever Arm* feature under the *Process* pull-down menu on either the TC or LC processing dialog.

Inertial Explorer's ability to observe the IMU to GNSS lever arm is largely dependent on the length of data collection, quality of GNSS data and vehicle dynamics. This feature is not meant as a substitute for measuring the lever arm but rather for checking or troubleshooting purposes.

Initial SD
This value reflects the uncertainty in the lever arm measurement.

Minimum Velocity
The lever arm state will not be updated unless this minimum velocity has been reached. A minimum value of at least 1 m/s is suggested (but not required) to help avoid the possibility of the IMU to GNSS lever arm state diverging under very low dynamics.

Accelerometer and Gyro Extra States

These options add scale and/or non-orthogonality states to the Kalman filter for the accelerometer and gyroscope measurements. They are often needed by MEMS sensors to account for errors in the manufacturing process.

Compute Heave (Marine Applications)

> (i) Heave is not supported on Inertial Explorer Xpress.

For marine users who wish to apply heave compensation to the computed ellipsoidal height, use this option to engage Inertial Explorer's low-pass filter. The algorithm requires that a window size reflecting the period of the wave motion be entered. The smaller the window size, the more responsive the filter will be to the wave motion. If using this option, the computed ellipsoidal height and the heave compensated height can be viewed from the *Height Profile* plot. The computed heave value can also be viewed from the *Heave* plot.

After processing with *Apply Heave* enabled, you can access heave compensated ellipsoidal and orthometric heights from the Export Wizard. The *Height Profile* plot will display the processed ellipsoidal height together with the heave-compensated ellipsoidal height in order to show the effect of the heave window used. The longer the window used the smoother the marine heave compensated height will be (i.e., less responsive to changes).

Edit Error Model Values

Error model editing is only necessary when developing your own error model for a new IMU. Note that when working with MEMS sensors, it may also be necessary to enable accelerometer and gyro extra states in order to achieve a reasonable level of performance in addition to error model tuning.

Initial Standard Deviation Values

The following mathematical quantities are available:

Accel Bias
These values represent the initial uncertainties in the a priori knowledge of the constant bias errors in the accelerometer triad. If these bias values were left at zero, meaning that they are unknown, then the standard deviation values entered here should reflect this uncertainty. The processor then computes the biases on-the-fly. These values should be entered in m/s^2.

Gyro Drift
These values refer to the initial uncertainty of the a priori knowledge of the sensor drift in the gyroscopes. If the biases are left at zero, then enter standard deviations values here that reflect this. The program attempts to compute reasonable values during processing. All values should be entered in degrees/sec.

Spectral Densities Values

Generally speaking, the lower the grade of the sensor, the larger the spectral densities that should be used for processing. As previously discussed, the spectral densities add noise to the covariance propagation process prior to filtering. Therefore, the higher the densities, the greater the weight that is placed on the GNSS updates during filtering. The following mathematical quantities are available:

ARW (Angular Random Walk)
Angular Random Walk, in degrees, becomes a covariance when multiplied by some time interval, δt. If the sensor triad is problematic in terms of providing an accurate attitude matrix, or if initial alignment is poor, then you may need to introduce large spectral density values here. These spectral components add noise to the computed Kalman covariances for ARW, which, in turn, forces the processor to rely more heavily on the GNSS position and velocity updates. As a result, large errors in the direction cosine matrix are compensated for.

Accel Bias
Accelerometer bias densities, when multiplied by the prediction time interval, act as additive noise to the accelerometer bias states. As such, larger values here may help to compensate for large biases in the accelerometers.

Gyro Drift
Gyroscope drift densities similarly act as additives to the covariances computed for the gyroscope drift states. In the case of inexpensive units, larger values here may be necessary.

VRW (Velocity Random Walk)

Velocity spectral densities are noise densities that account for modeled velocity effects during each Kalman prediction. Increasing this value permits more emphasis to be placed on the GNSS update data, but may also lead to an increase in error growth during outages. For this reason, these values should be determined as part of the tuning process. The default values are recommended unless dealing with a trajectory of unusually high dynamics, such as a race car, in which case these may need to be reduced by an order of magnitude.

Position

Position spectral densities are noise densities that account for modeled position effects during each Kalman prediction. Apply all of the considerations mentioned above for the velocity spectral densities.

GNSS (IE/IEX only)

Variance Factors Applied in GNSS Residual Testing

Inertial Explorer performs residual testing using a standard least squares approach on every type of update applied within our Kalman filter. Phase updates are only applied when there are a minimum of two satellites available in TC processing.

Updates are accepted only if the computed residual is within the set tolerance. The larger the variance factor tolerance, the less likely an update is to be rejected by residual testing. For this reason, large values are typically applied in aerial processing profiles in order to reduce the chances of false rejection and lower thresholds are applied in ground vehicle profiles in order to lessen the likelihood that a biased update will be accepted. It is safe to use large values in clean GNSS environments where the quality of GNSS data is good, however lower values (1-3) are recommended when surveying in challenging GNSS environments.
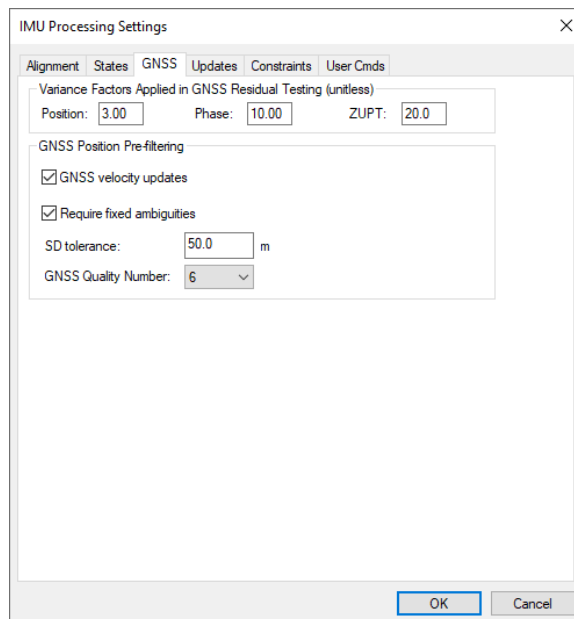
GNSS Position Pre-filtering

GNSS velocity updates

GNSS velocity updates are important, especially when a kinematic alignment is performed. As such, this option is normally engaged. However, for any special applications where GNSS velocity updates are to be rejected, they can be disabled here.

Require fixed ambiguities

If using a high precision IMU and when surveying in urban conditions with some challenging GNSS data, this option may be useful in achieving the best possible results. This option is not recommended for most systems (MEMS or tactical grade IMUs) as any GNSS updates (even one derived from float ambiguities) are generally beneficial in observing IMU sensor errors.

SD tolerance

If the position update returned by the GNSS processor is larger than this value, it will not be passed to the IMU filter. By default a large threshold is used as Inertial Explorer relies on variance factor testing to determine whether a GNSS position update should be applied or not.

GNSS quality number

The GNSS processing engine assigns a quality number to each processed epoch between the values of 1 to 6, 1 being the best. By default Inertial Explorer does not use the GNSS quality number in pre-filtering

as instead it relies on GNSS variance factor testing in determining whether a GNSS position update should be accepted. If you wish to enable a lower prefiltering tolerance, enter it here.

Updates (IE/IEX only)

Automated ZUPT Detection Tolerances

These settings control the software's ability to detect periods of zero velocity.

Raw Measurement
The raw gyro measurement threshold. This value may need to be raised for lower-grade sensors (i.e. MEMS) to accommodate the noisier measurements.

Velocity
The GPS velocity threshold. Potential ZUPTs are rejected if the GNSS-derived velocity exceeds this value.

Period
Length of time span over which measurements are averaged.

External Position/Velocity/Attitude Updates (IE only)

A binary PVA file can be input to Inertial Explorer if external position updates are available. See *PVA File* on page 207 for the format of this file. Input of this binary file is the recommended approach if large numbers of external updates are available. Two types of updates are supported by the PVA file: absolute coordinate and relative coordinate updates. Absolute updates are position updates within a defined reference frame, and the relative updates provide the translation vector between two points in time.

Absolute Updates

Absolute updates are typically formed from either a robotic total station or with an optical or LIDAR sensor and ground control. Inertial Explorer needs these updates and the IMU center. If the positions are with respect to another sensor location, then a lever arm with the offset can be set.

Relative Updates

Inertial Explorer can accept relative position updates that have been measured by an external sensor, such as a camera-array and/or LIDAR sensor. For the photogrammetric case, knowledge of scale (or depth) is important, which becomes difficult with monocular vision systems. Therefore, stereo vision systems with sufficient base (camera separation) is suggested. In the case of LIDAR, a sufficient number of surfaces that are perpendicular to the direction of travel need to be present, or preferably estimated accuracy values will compensate for geometry variations. Regardless of the input source, the relative position inputs will have varying accuracy, depending on the number and geometrical distribution of matched points. Thus, computing representative standard deviations is highly recommended.

Relative updates are measured vector components between two timed events, which are determined by an external system that is time-synchronized with the navigation system. Basically, the sensor measures the relative motion and orientation between the two epochs, which are generally 0.2 s to 2 s apart. The best data-rate for the formation of the updates and the best rate for input into Inertial Explorer may differ, where Inertial Explorer may benefit from a lower rate. The problem with very short intervals is that the noise (measurement error) can be a significant portion of the vector length. Therefore, an external pre-processor may need to accumulate high-rate measurements to a lower rate like 1 Hz, which is suitable for Inertial Explorer.

The coordinate system supported for the relative updates is local level frame. The input y-axis is aligned to true-north, x-axis to east and z-axis to up. The local level vector frame changes as the rover position moves, and for the update the local level frame is computed at the update time. It is critical that the local level frame is recomputed for each update.

Manually Enter Updates (IE only)

Inertial Explorer also accepts input of individual ZUPTs and CUPTs through the *Manually Enter Updates* button. This feature is more convenient for customers that want to manually enter a small number of such updates as opposed to having to format your own binary file. This feature also supports loading of ZUPTs and CUPTs from an ASCII file, however this feature is limited to supporting a maximum of 1000 updates. For this reason, using the binary PVA file is encouraged when large numbers of external updates exist.

> #### Zero Velocity Updates (ZUPTs)
> Inertial Explorer automatically detects ZUPTs by analyzing the GNSS, IMU and, if available, DMI data. This is true for both loosely and tightly coupled processing. As such, the manual entry of ZUPTs is generally not necessary, except in cases of poor data quality. Nonetheless, individual ZUPTs can be added here or loaded from an ASCII file.

> #### Coordinate Updates (CUPTs)
> External coordinate updates can be very beneficial to GNSS/INS post-processing in areas of denied GNSS signal reception if they can be properly time tagged. This dialog can be used to add individual time coordinate updates or load from an ASCII file.
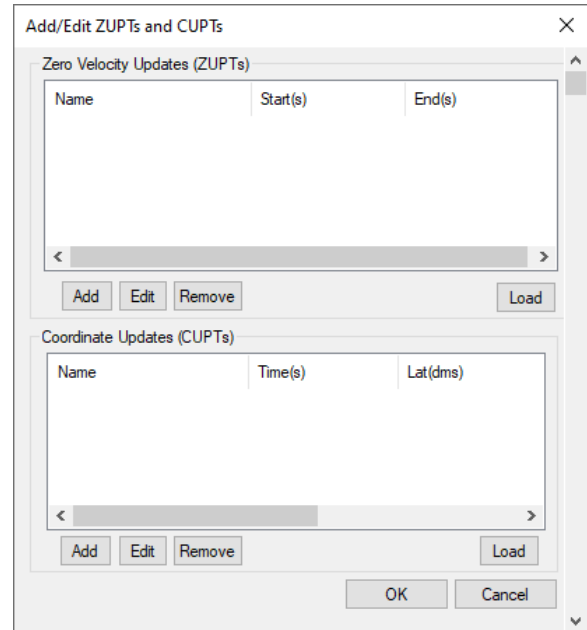
Gimbal Mount

> (i) Gimbal mount updates are not supported on Inertial Explorer Xpress, GrafNav or GrafNav Static.

If using a gimbal mount, the IMU to gimbal center lever arm can be entered here. This should be entered in the vehicle frame (Y-forward, X-right, Z-up) with the origin at the IMU center of navigation. This causes Inertial Explorer to shift it's output from the IMU to the Gimbal Center.

MMR files are automatically produced by the SPAN data converter and contain the rotations of the stabilized gimbal platform. This is required in order to properly compensate for the changing IMU to GNSS lever arm during operation of the gimbal unit.

Distance Measuring Instrument (DMI)

> (i) DMI updates are not supported on Inertial Explorer Xpress, GrafNav or GrafNav Static.

If logging DMI data, the NovAtel SPAN decoder will automatically write a DMR file which contains time stamped DMI measurements. If a DMR file is detected during project creation, it is automatically loaded into the project and thus does not have to be explicitly set here.

DMI Options

ⓘ A typical DMI will either output an accumulated tick count or a measured speed. If accumulated tick counts are recorded, Inertial Explorer converts them to a velocity update using knowledge of the ticks/rev, wheel circumference, and estimated wheel circumference scale factor. If speed was recorded, then the software applies the update directly as a velocity update.

Detect ZUPTs from DMI sensor

This option is off by default as Inertial Explorer already has two layers of ZUPT detection; analysis of the raw IMU measurements and using available GNSS data. This option therefore is generally not needed and if the DMI used does not function well at low velocity, it can actually be harmful.

If however a high resolution DMI is used which works well at low velocity and if ZUPTs will be observed during periods of extended GNSS outages, this option can be very beneficial in helping to observe ZUPTs.

Measurement standard deviations

The standard deviation associated with the DMI measurements depends on the DMI being used. As such, this value may need to be determined empirically.

Wheel circumference

The default value is 1.96 meters if no value is detected from the raw GNSS data or set during conversion. Inertial Explorer computes a DMI scale factor to account for varying wheel sizes during data collection, however the best estimate possible of the wheel circumference should be input.

Heading Updates

If using the NovAtel dual antenna ALIGN system and requesting HEADING2B logs, an HMR file is automatically produced during data conversion which can be input to Inertial Explorer here. The secondary lever arm must also be set if using it in *Dual GPS Antenna System* mode.

Heading updates are most useful in assisting auto/kinematic alignment in low dynamic applications such as marine surveys. When a kinematic alignment is used and heading updates are available, Inertial Explorer will extract the initial heading of the vehicle from the HMR file.

The HMR data format is described in *HMR File* on page 205.

Constraints (IE/IEX only)

Non-Holonomic Vehicle Constraints

Vehicle constraints help optimize positioning performance in fixed wheel and land-vehicle applications where GNSS signal conditions are poor or completely denied for significant periods. Pedestrian GNSS+INS surveys may also benefit from these constraints.

The vehicle constraints implemented in Inertial Explorer apply a zero velocity update with the specified standard deviation about the X and Z vehicle body axes at 1 Hz. For best results in fixed wheel and land-vehicle applications, the vehicle boresight should first be computed as the constraints are applied in the vehicle frame. In the absence of GNSS updates, application of vehicle constraints can significantly limit IMU error growth.

Apply Vehicle Boresight

Even when carefully mounting the IMU in the vehicle, a small rotational difference exists between the IMU frame and the vehicle frame. Should output be required in the vehicle frame, or if vehicle constraints will be applied to maximize positioning performance in fixed wheel or land-vehicle applications, the Body->Vehicle boresight should be applied.

Compute Boresight

In order to estimate the boresight using Compute Boresight, first process a survey normally and generate the smoothed combined output. For best observability of the vehicle boresight, the survey should contain long, straight and flat sections of data. The *Compute Boresight* button will estimate the vehicle boresight from the smoothed and combined output and populate the dialog with the rotation angles. Reprocess the survey to apply the boresight in Inertial Explorer's computations.

Compute vehicle boresights on-the-fly
New in 8.90 is the ability to compute the boresight on-the-fly. This feature replaces the more involved process of using the *Compute Boresight* button. We recommend incorporating this functionality into your work flow. If the survey does not contain proper convergence periods, enter in boresight values from previous surveys.

> (i) When computing boresight values, the data used cannot include extended periods of reversing as the computed boresight will obtain a 180 degree rotation. This also means that the *Compute vehicle boresights on-the-fly* option cannot be used with data sets that have extended periods of reversing.

Rotate processed output to vehicle frame
Selecting this option will rotate the processed attitude to the estimated vehicle frame. Note that if you have just computed the boresight, you will need to reprocess the solution after selecting this option. Re-processing after deselecting this option will apply the boresight computation to the IMU->GNSS lever arm translation and DMI computations but will leave the processed/re-processed output in the body frame.
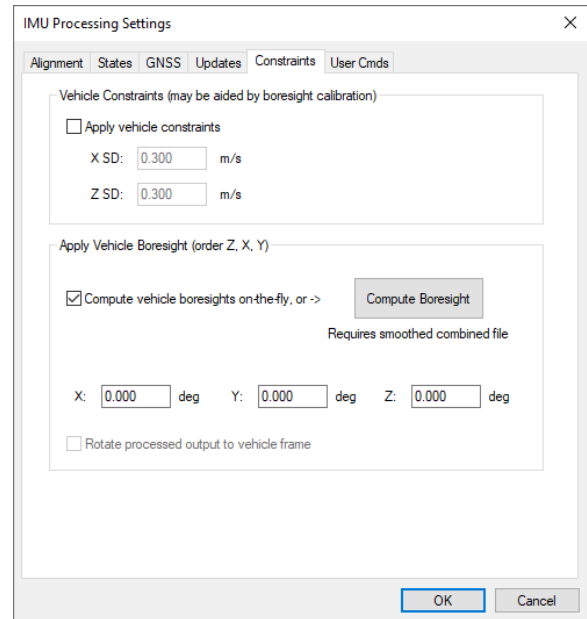
3.8.3   Pre-Processing Messages

Unless specified otherwise, pre-processing checks are conducted before processing begins. If there are any warnings or critical errors, a dialog will appear to describe the issues present. There are three different message types.

- Critical errors – which will cause a poor solution or prevent processing

- Warnings – which may cause a processing error

- Informative messages – typically will not bring up the pre-processing window as these are generally minor and are just for your knowledge

Table 4: Critical Errors

Message Name	Description
Remote Antenna Setting	When processing with IMU data, you cannot have the remote antenna settings set to the ARP. With IMU processing, you must enter a lever arm in the processing window and select whether the lever arm is measured to the L1 phase center or to the ARP. For this reason, the *Measured height* must be zero and the *Measured to* must be to the L1 Phase Center. By default, the processing dialog will fix this if the *Try to fix the issue* box is checked.
Master Coordinate	When you load a master station, an average single point position is computed. If you enter coordinates that have a large discrepancy to those coordinates, a warning is provided. In this case, before processing, you should review the master station coordinates to ensure that you have entered them properly. You can open the coordinates to review under *View | Coordinate/Antenna*.
Corrupt IMR	This message is typically caused by incorrect file formatting through a third-party application. If you are using a third-party application, review how the file is converted. If you get this issue using the Waypoint Convert tool, contact support at support.novatel@hexagon.com.
Empty IMR	This warning notifies you that the IMR file in the project is empty. This is most likely due to third party conversion tools. Verify that the data has properly been converted to the IMR file.
IMR All Zero Measurements	This typically occurs when not using the provided convert tool to convert to the IMR format. Changes to the external application used for conversion to fix the issue are typically required to fix this issue. If you see this issue with a SPAN system using the Convert tool, there could be a problem with your raw data collection. Contact support (support.novatel@hexagon.com).
IMR Blunder Measurements	Before processing, the Waypoint software checks to ensure that the IMU values in the IMR file are within a reasonable range. If you get this error, the IMU scale factor is likely incorrect. A less likely cause could be from the raw data collection. If it is the latter, contact support (support.novatel@hexagon.com).
Processing Datum Error	If you selected the Leica workflow for processing in your preferences, your project must be processed using WGS84. Change the selected processing datum to WGS84 to continue.
Ephemeris Error	No ephemeris, precise or broadcast, is present in the project. While precise ephemeris will work as a substitute for most constellations, GLONASS data usage requires the broadcast ephemeris. Use the Download Service Utility to download both precise and broadcast ephemeris, see *Download Service Data* on page 128 for more information.

Message Name	Description
No NRT file for PPP-AR	An NRT file is required to perform PPP-AR processing. Without an NRT file, the processor will use the legacy PPP engine. By default, the dialog will try to download the NRT files needed when the *Try to fix the issue* box is checked.
Not a NovAtel receiver	PPP-AR only supports NovAtel receivers for processing. Without a NovAtel receiver. the processor will use the legacy PPP engine.
Invalid NRT file for PPP-AR	PPP-AR can only be used if your data was collected after July 4th of 2019 as this is when the new corrections began being supplied. Any survey completed before this date will not be able to use the PPP-AR functionality and will use the legacy PPP filter instead.

Table 5: Warnings

Message Name	Description
Data Rate	When processing differential GNSS, the remote and master station data rates should match. If the master station has a lower data rate than the remote, only the common epochs can be processed. By default, the pre-processing dialog will try to fix the issue by resampling the master station. If you want to keep the master station at the lower rate, uncheck the *Try to fix the issue* box.
Dual Clock	Many Trimble receivers use different clocks for their phase and C/A measurements. For this reason, the Waypoint software needs to compensate for the additional possible errors in the solution. By default, the pre-processing dialog will automatically turn the feature on if needed. You can disable the feature from being turned on by unchecking the "*Try to fix the issue*" box.
IMR Large Gaps	Large data gaps (3 or more missing epochs) can sometimes appear in your solution. If they are at the beginning of the survey, the processing time can be adjusted accordingly. If they are in the middle of the project, there are no adjustments that can be made. To check when the data gaps occurred, open the IMR file using the binary viewer under *View* or by double clicking the file. If you repeatedly see this warning, check your raw data collection and contact support at support.novatel@hexagon.com.
L2C Present	This is a message to notify you that there are L2C measurements present in the GPB file. L2C signals have offsets that need to be applied. These offsets differ not only between receiver manufacturers but also possibly between firmware versions. If ARTK continuously fails, this may be due to an improper L2C offset. More information on how to adjust this offset can be found in *Edit GPS L2C Phase Correction* on page 170.
Too Many Small Gaps	When processing with differential GNSS, only the overlapping times can be output as common data is needed for computations. This message warns you that there are many data gaps that could impact your solution. If these data gaps impact your solution, you can use the Download utility to get a new master station (see *Download Service Data* on page 128).
Time Range	You will receive this warning when the time range supplied by the master station does not cover the entire time range of the survey. By selecting this message, you can see how much time is missing. If it is only a few seconds, you can ignore this message. However, if there is a large time period missing, and it is not intended, we recommend downloading a new master station using the Download utility (see *Download Service Data* on page 128).

Message Name	Description
IMU to GNSS Lever Arm	This error appears if you have not entered any values for your lever arm. The lever arm values should not be zeros. Enter the proper lever arm values or solve for your lever arm values if you do not know the values.
Secondary Lever Arm	This error appears if you have not entered lever arm values for your secondary antenna. The lever arm values should not be zeros. Enter the proper lever arm values or solve for your lever arm values if you do not know the values.
Missing GLONASS Broadcast Ephemerides	The GLONASS broadcast ephemeris are always required to use GLONASS in a project. The frequency number for the GLONASS SVIDs are required and are only found in the broadcast ephemeris. Therefore, the precise ephemeris cannot replace the broadcast for GLONASS. You can download the broadcast ephemeris to fix the issue. For more information on how to download the broadcast ephemeris, see *Download Service Data* on page 128.

Table 6: Informative Notices

Message Name	Description
Ephemeris Check	Some satellites are missing broadcast or precise ephemerides and cannot be used in processing. You can use the Download Service Utility to download global GNSS precise and broadcast ephemeris, see *Download Service Data* on page 128 for more information. Note that GLONASS must have broadcast ephemerides to be used in processing process.
IMR Small Gaps	If there are small data gaps (1 or 2 IMU epochs), this warning will appear. Typically, this is seen at the beginning of a survey for which the processing time can be adjusted. If they appear in the middle of the solution, you can generally ignore the warning as a couple of small gaps should not impact the solution. In the case that you get a processing failure with this warning, there are raw data collection issues that need to be resolved, as there are too many small data gaps for the filter to handle.
No Precise Files	When processing with PPP, you require precise files to get a proper solution. By default, clicking continue will download the files and add them to the project. If you want to continue without downloading the precise files and use the broadcast ephemeris data, clear the *Try to fix the issue* box.
Processing Time Interval	The processing interval cannot be at a higher rate than the remote data collection rate. Before processing, the Waypoint software will automatically set the processing rate to match the remote data collection rate.
Master Data Gaps	When processing with differential GNSS, only the overlapping times can be output as common data is needed for computations. Therefore, if your master station has a data gap then you cannot obtain a solution for the missing time period. You can fix this by downloading a different master station using the download utility (see *Download Service Data* on page 128) or by using PPP.
IMR Time Reversals	This warning notifies you that the IMR file has times that run backwards in time and the solution will fail when processing. You will not see this issue with SPAN data as the converter knows how to handle these cases. Only third party IMU users will see this issue. If you are repeatedly seeing this issue , there is likely a raw data collection or data conversion issue.
IMR Record Repeats	In most cases, processing should be able to handle repeat records in the IMR file. If you are continuously getting this error or processing is failing, there is likely an issue with either your raw data collection or your data conversion. Contact support at support.novatel@hexagon.com.

3.8.4   *Processing Window*

This window appears during processing and shows position, status, progress and any high priority messages output by the processing engine.

Click the *View* button to customize the fields displayed during processing. See *Notifications* below for descriptions of variables which can be monitored during data processing.

The values in *Plot Results* on page 107 differ in the manner in which they are computed depending on the mode of processing being performed.

If the GNSS is being processed, then the values displayed are those computed in the Kalman filter. However, during the IMU processing, the values displayed reflect those calculated in the IMU Kalman filter, using the GNSS information as updates. Ideally, these values should agree. When they do not, monitor the position and velocity misclosure.

The Processing window is updated twice a second.
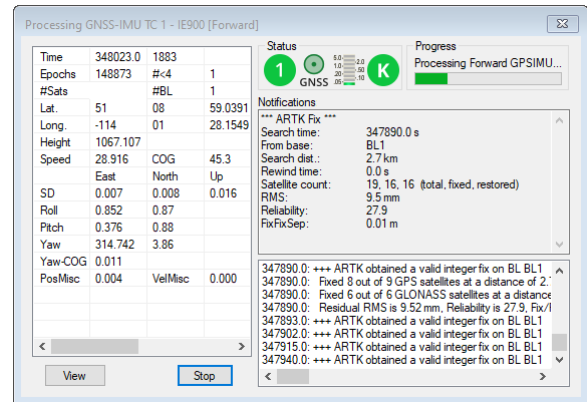
Status

The Status section of the processing window reports the instantaneous quality number. Quality numbers are meant to provide a high level indication of solution quality and are further described in *Table 2: GNSS Quality Number Description* on page 72.

If integer carrier phase ambiguities have been fixed, a green circle with the word *Fixed* will be shown immediately to the right of the quality number. The ARTK statistics of the fix will be shown in the *Notifications* window below. If integer ambiguities have not been fixed, a blue circle with the word *KAR* (Kinematic Ambiguity Resolution) will be shown instead.

The instantaneous estimated position error will be shown on a meter immediately to the right of the fixed/float ambiguity status.

Immediately to the right of the estimated position error is the static/kinematic processing mode. If the data is processed in kinematic mode, a green *K* will be shown, otherwise if the data is processed in static mode a red *S* will be shown.

Progress

The Progress box graphically displays how much of the data has been processed and how much remains.

View

In the left-hand window, various parameters are available for display via the *View* button. The list of available parameters is given in *Table 9: Processing Window Parameters* on page 102.

Notifications

The *Notifications* window displays all information pertaining to the last ARTK fix. Descriptions of these messages are found in *Notifications Windows Messages* on the next page.

Table 7: Notifications Windows Messages

Message	Description
Search time	Time at which ARTK engaged.
From base	Specifies which base station ARTK used to fix ambiguities. This will often be the closest base station in multi-base projects.
Search distance	This is the baseline distance when ARTK was first engaged.
Rewind time	When ARTK achieves a fix, the integer carrier phase ambiguities (data quality permitting) can be applied backwards in time to the moment ARTK was engaged. The rewind time reports the number of seconds ARTK was able to restore integer ambiguities backwards from the engage time.
Satellite Count	The number of satellites used by ARTK. The *total*, *fixed* and *restored* numbers are reported. *Total* represents the number used in the float solution. *Fixed* indicates the number which achieved fixed integers at the restore time. *Restored* indicates the number of satellites where it was possible to restore backwards in time (see *Rewind time*)
Fix Type	Will either be reported as GNSS Fixed or GNSS Fixed/Verified.
RMS	The RMS of an ARTK fix represents the mathematical fit of the carrier phase measurements. Low RMS values (3 mm or less) represent very good fitting solutions. While this does not guarantee a correct solution, it is a good indication. High RMS values (above 20 mm) may still be correct but the chances of an incorrect fix are higher. Regardless, the *Combined Separation with Fixed Ambiguity* plot can be accessed to help identify incorrect ambiguity fixes.
Reliability	Reliability is a unitless value that indicates how much better the best ARTK fix is from the second best. This is determined by dividing the RMS of the second best fix by the RMS of the best fix. High reliability values (above 3) indicate a high probability the fix is correct as the best ARTK fix appears much stronger than the second best.
FloatFixSep	This is the distance between the fixed integer solution and the last float solution prior to achieving a fix. Large values (meter level) can be expected where ARTK uses only several seconds of data, as the float solution will not be well converged. Unusually high float/fixed separation values of 5 m or more may be suspect.
FixFixSep	This is the distance between the position computed with a previous set of ambiguities and the position computed with newly accepted fixed ambiguities.

Table 8: Notifications for Static Processing

Message	Information
RMS	Similar to the RMS computed for an ARTK fix, the RMS of a fixed static solution represents the fit of the carrier phase measurements.

Message	Information
Reliability	See *Reliability* for ARTK fixes in *Table 7: Notifications Windows Messages* on the previous page for a definition. The reliability for long fixed static solutions may be reported as *N/A*, which indicates that only one fix was within the search area. Thus, there was no second best RMS in order to use in computing reliability.
Frequency	Reported as *single* or *dual* to indicate whether an L1 only or L1/L2 solution was computed.
Time	The length of time used by the fixed integer solution in hh:mm:ss format.
Type	Fixed static solution type used. *Continuous* looks for the best continuous block of cycle slip free data to use within the fixed integer solution. *NewFixed* (multi-sat) uses all of the data, although it may reject some sections of data for individual satellites.

Table 9: Processing Window Parameters

Parameter	Description
Attitude	Displays information such as the Roll, Pitch and Yaw values and standard deviations. Also provides the Yaw-COG separation.
Baseline Data (MB)	Displays the distance, carrier phase RMS and number of satellites for each baseline.
Baseline Distance	Distance separation for projects containing only one base station.
DOPs	Displays DD_DOP, PDOP, HDOP and VDOP.
Estimated Accuracy	The instantaneous north, east and height standard deviation of the remote position.
Geographic Position	Displays the instantaneous position and ellipsoidal height of the remote.
Measurement RMS	The RMS of the code and phase measurements are displayed, together with their standard deviation (measurement weight) in the Kalman filter.
Speed/COG	Speed of the vehicle is displayed with the Course-Over-Ground (COG), computed between consecutive measurement epochs.
Status Flags	Provides the number of satellites and number of baselines.
Time/Epochs	Displays time in seconds of the week, as well as a continuous count of epochs processed. The GPS week number is also shown.
Pos/Vel Misclosures	Provides the misclosures for the position and velocity.
Channel Data B/L	Allows for selection of baseline for which to display channel information.

3.8.5 Combine Solutions

The *Combine Two Solution* dialog does not typically need to be accessed within a project as forward and reverse solutions are automatically combined when processing in both directions (or when using multi-pass PPP processing). If, however, a user has reprocessed one direction only and then they wish to re-combine forward and reverse directions, or if a user wishes to plot the difference between two processed trajectories

(i.e. PPP vs Differential), this can be done through the Combine dialog and does not require knowledge of Waypoint file extensions.

In order to plot the difference between two processed solutions within the project, first choose the two solutions from the *Solution 1* and *Solution 2* pull-down lists and then *Combine*. Only a list of available solutions is accessible within the pull-down lists. As an example, if a user wanted to compare the combined PPP solution to the combined differential solution, choose *PPP Combined* as *Solution 1* and *Differential Combined* as *Solution 2* (or vice versa) and then select *Combine*. After combining the two trajectories of interest, plot the combined separation to view the difference in north, east and height as a function of time.

However, before exporting ensure that either the differential (.cg) or the PPP (.cp) solution is loaded, as the Export Wizard accesses whichever solution is presently loaded. One way of re-loading combined results is to choose the *Differential/PPP forward* and *Differential/PPP reverse* solutions from this dialog and clicking the *Combine* button.
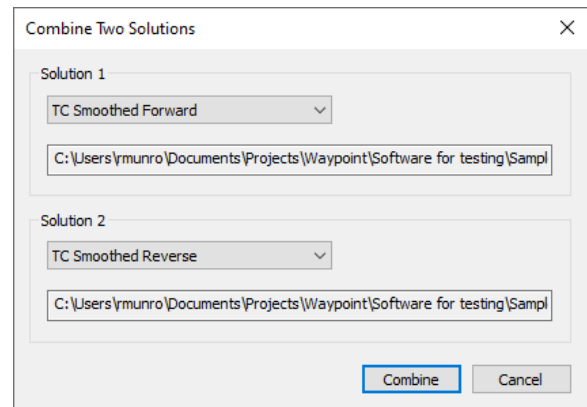
3.8.6   Smooth Solutions (IE/IEX only)

Inertial Explorer is capable of combining processing directions and/or performing back smoothing on an inertial trajectory.

Smoothing greatly improves position quality over GNSS data gaps. The benefits of smoothing are not limited to improving position quality however; velocity and attitude are also back-smoothed. Even if no GNSS data gaps are observed, smoothing will always generate the highest quality trajectory possible.
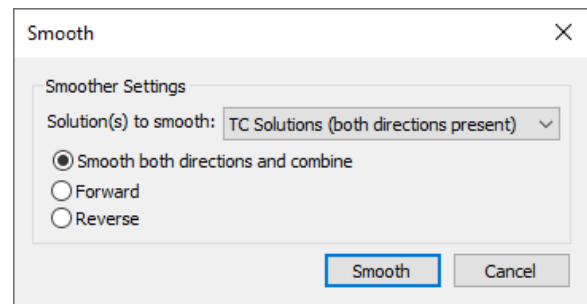
Smoother Settings

Smoothing can be performed in just one direction, or both. Much like GNSS and GNSS-IMU processing, it is recommended that smoothing be performed in both directions. Smoothing both directions will also generate the combined smoothed trajectory.

3.8.7   Solve Boresighting Angles

ⓘ   Solving boresighting angles is not supported on Inertial Explorer Xpress, GrafNav or GrafNav Static.

Inertial Explorer offers the ability to compute the boresight angle between the IMU and a frame imaging system. We use an external bundle adjustment's omega, phi and kappa Euler angle values to compute the angular difference between the systems. Once these values have been computed they can then be saved for future projects to use when exporting the omega, phi and kappa values so your trajectory angles are for the camera system. All the boresight related data will be saved in an ASCII BSI file which should not need to be modified.

What You Need to Get Started

- A data set flown over a targeted calibration field with four flight lines in opposing directions (e.g. north, south, east, add west) and four to six photos in each line.

- Imagery must have 60% overlap along each line (stereo photography is highly desirable) and a minimum of 20% side lap between lines.

- The imagery must have tie points and a minimum of four control points, although more can be very helpful.

- Scale is not so important, but should match typical flying scales. Very large scales (<1:8000) may result in less accurate boresighting angles due to increased influence by GNSS positioning errors.

- GNSS and IMU data that contains camera event marks. Images must have been properly time tagged by the GNSS-IMU system.

- A GNSS-only processed solution initially.

- A valid bundle adjustment solution using these tie and control points as well as the GNSS/camera center positions. Although using the GNSS position is not necessary, it is highly suggested to decorrelate the image position and attitude.

- Exported omega, phi, kappa in a format compatible with this module.

> (i)   The naming convention used for the photo IDs must match that used in Inertial Explorer.

- A fully processed Inertial Explorer project with a forward, reverse, combined or smoothed IMU solution loaded.

Refer to *Mathematical Equations Used with Boresighting* on page 240 for the mathematical equations used by boresighting.

Show

This drop-down menu is linked to the window below it and gives viewing access to the values listed below.

Navigation values
The roll, pitch and heading values, along with their associated standard deviations, are displayed for each loaded camera event. The coordinates of the IMU at the time of the event are also displayed. These values are generally transferred from Inertial Explorer directly and correspond to the IMU values interpolated at camera event times.

Photo E/O values
The omega, phi and kappa values, along with their associated standard deviations, are displayed for each loaded camera event. These values are produced externally in a photogrammetric package.

Matches/residuals
Before the computations begin, choose whether or not to include the observations associated with a camera event in the least squares procedure by right-clicking on the event. After the least squares procedure has finished, the window is updated with the final residual values at each camera event. Additional information, such as quality indicators and computed omega, phi and kappa values are also displayed.
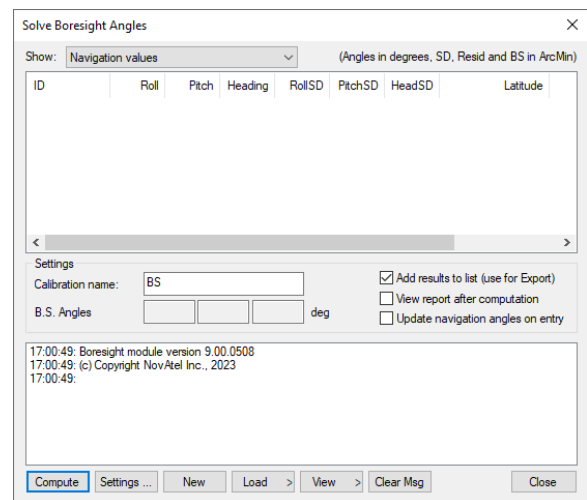
Settings

The following features are available:

Calibration name

Enter a name to distinguish calibration runs from one another. Inertial Explorer keeps a history of calibration runs, so a unique identifier is helpful when trying to recover previous results. This is useful for using multiple systems and/or tracking stability over time.

Boresight Angles

Upon successful completion of the calibration procedure, the final values for the computed boresight angles are displayed here.

Add results to list

When this option is enabled, the last values computed by the program are stored so that they are easily accessible by the *Export Wizard*.

View report after computation

Enabling this option forces the software to launch the boresighting report upon successful completion of a calibration. The contents of the report are discussed later on.

Update navigation angles on entry

When this option is enabled, Inertial Explorer loads the latest navigation values for the camera events into the boresighting module.

Message Window

This window provides valuable insight on the status of the current calibration. Whenever input data is being loaded, read the messages to ensure the expected number of camera events have been read in. After the calibration procedure is complete, the final boresighting values, as well as the number of iterations needed to arrive at them, are displayed.

The following options are available via the buttons along the bottom of the *Solve Boresight Angles* window:

Compute

Assuming all the required input data has been loaded, click this button to begin the iterative least squares procedure. The *Message Window* contains pertinent information regarding the success or failure of the procedure.

Settings…

This button gives access to the *Boresight Settings* window, which is useful for configuring many parameters used in the boresight calibration. See *Boresight Settings* on the next page for information about the setting on this window.

New

This button clears any stored data from previous calibration runs in order to start a new one.

Load

Use this button to load the required navigation and exterior orientation input data.

The navigation data can be obtained either by loading the latest set of roll, pitch and heading values computed by Inertial Explorer, or by an external file which contains this information for each camera event. Alternatively, if such information is available, there is the ability to provide the module directly with the omega, phi and kappa angles required to rotate the ground system into the IMU frame. Obtaining the attitude angles directly from Inertial Explorer is by far the most common usage.

The exterior orientation parameters for each photo must be supplied by an external file. This file should contain the omega, phi and kappa angles required to rotate the ground system into the image system.

View

This button gives access to the post-calibration report. The report contains relevant boresight calibration information, as well as a list of all the input data provided for each camera event. The bottom of the report displays the boresight values and residuals from the final iteration.

> ⓘ This report can be viewed through either NotePad or the internal Inertial Explorer ASCII viewer. This button also gives you access to the calibration history. For each calibration run, the final boresighting results are saved, assuming the *Add results to list* option is enabled.

Clear Msg

This button clears the *Message Window* of any messages currently displayed.

Boresight Settings

Axes/System Definition

System

The selection made here defines the ground coordinate system to which the omega, phi and kappa values are oriented. Normally, they are referenced to a map projection which is defined in the *Grid/Map Definition* settings.

Order

This setting defines the order in which the omega, phi and kappa angles are to be applied during the transformation from the ground system to the image or IMU system. Only the omega-primary, phi-secondary and kappa-tertiary rotation order is supported.

Axes

Use this setting to define the orientation of the image system. The most commonly used system is the conventional frame, where the x-axis points forward, the y-axis points left, and the z-axis points upwards. The frame defined here determines the composition of the R_c matrix.

Grid/Map Definition

The options made available here depend on the system definition chosen. If the input angle was provided with respect to a map grid, then the selection made here determines the convergence value, α, used to form the R_g matrix. In addition, grid users are given the opportunity to enter the average ground height in order to maximize accuracy.

Measurement Weighting

The selections made here determine the composition of the variance-covariance matrix used in the least squares procedure to derive the final boresighting values. Choose to enter a set of constant standard deviation values to apply to all measurements, or have the values derived from either the navigation SD values, the photo SD values (if provided), or a combination of both.

The other setting here pertains to the outlier tolerance. The value specified here determines at which point a measurement is removed from the least squares procedure.

Display Units

These options pertain to the values displayed in the *Solve Boresight Angle* window and determine which units are used when writing to the *Boresight Report* file. These options also allow the number of decimal places to which all values are displayed or written to be modified.

3.9   Output Menu

The following sections provide information about the features available in the Output menu.

3.9.1   Plot Results

Plots are organized into a *Grouped Plots* category and an *All*"category. The *All* category provides access to individual plots, while the *Grouped Plots* category contains 3 manufacturer plot groups and any custom created plot groups. The manufacturer plot groups include groups of commonly accessed plots for GNSS-only processing, GNSS+INS TC processing, and GNSS+INS LC processing. When accessing a grouped plot, all plots within the group are plotted and opened with the Map Window within your default web browser.

Many plots support different units. For example, you can plot the *Combined Separation*, which shows the difference between forward and reverse solutions in meters or feet. The *Distance Separation*, or baseline distance, can be plotted in units of kilometers, miles or meters. In order to change units on a plot, first select the plot from the list and then access the *Y* axis tab. This tab has a *units* pull down list which shows supported units for the selected plot. After changing units, your preference is remembered for all projects.

Individual plots can be viewed by double clicking a plot in the list, or by selecting the *OK* button after selecting a plot. Up to two plots can be selected simultaneously by using the Ctrl key in combination with a left mouse click prior to selecting the *OK* button. Further, if a group of plots has been created using the *Add Group* button, all plots within the group are plotted simultaneously.

Add Group

You may wish to create a custom group of plots for the purpose of plotting the entire group at once. For example, if after processing you always want to see the *Combined Separation*, *Number of Satellites (BAR)*, *PDOP* and *Estimated Position Accuracy*, these four plots can be added to a custom group.

When you click the *Add Group* button, a second dialog appears that allows you to provide the group a name and add plots to your group. There is also an option for launching an HTML report that includes the grouped plots and the Map Window.
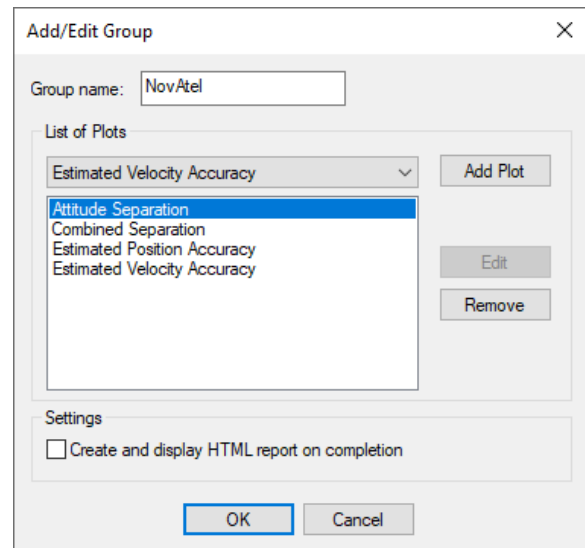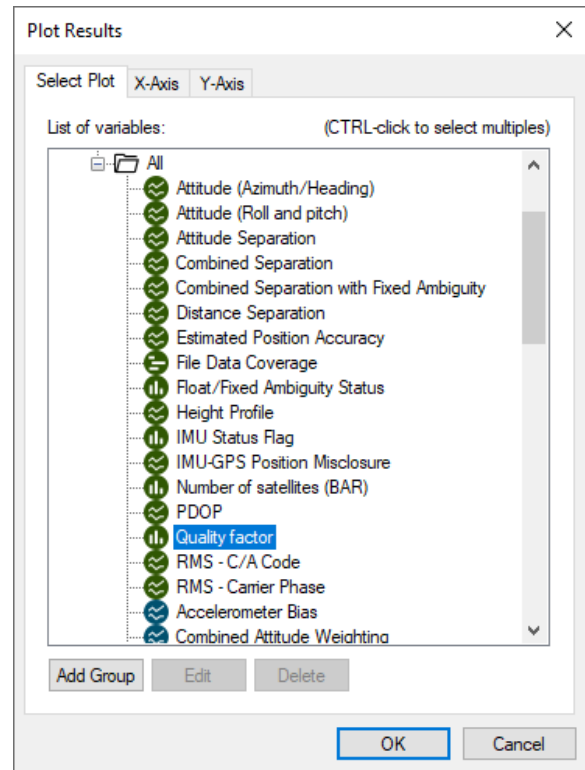
Plot Options

When you right click on a plot, a menu of options appears.

Properties

Allows access to the X and Y axis properties, X and Y axis labels, plot title and the plot settings.

Copy

Copies the plot to the clipboard as a bitmap (BMP), allowing you to paste the image into another application such as Microsoft Word or PowerPoint.

Save to HTML

Copies a BMP version of the plot into an HTML file, which opens upon completion. The HTML and BMP files are saved to the project folder under a directory called *HTML*.

Refresh

Reloads the selected plot.

X-Axis (Time)...

The X-Axis options are described below.

> ***Auto-scale***
> Shows the entire time range of the data.
>
> ***Set Minimum***
> Makes the current time the X-axis minimum.
>
> ***Set Maximum***
> Makes the current time the X-axis maximum.
>
> ***Select X-Range***
> Previously used settings of the X-axis are stored here.
>
> ***Apply to All***
> Scales the X-axis of the other opened plots to facilitate analysis.

Y-Axis (Value)...

The Y-Axis options are described below.

> ***Auto-scale***
> Shows the entire value range of the data.
>
> ***Set Minimum***
> Makes the current value the Y-axis minimum.
>
> ***Set Maximum***
> Makes the current value the Y-axis maximum.
>
> ***Select Y-Range***
> Previously used settings of the Y-axis are stored here.
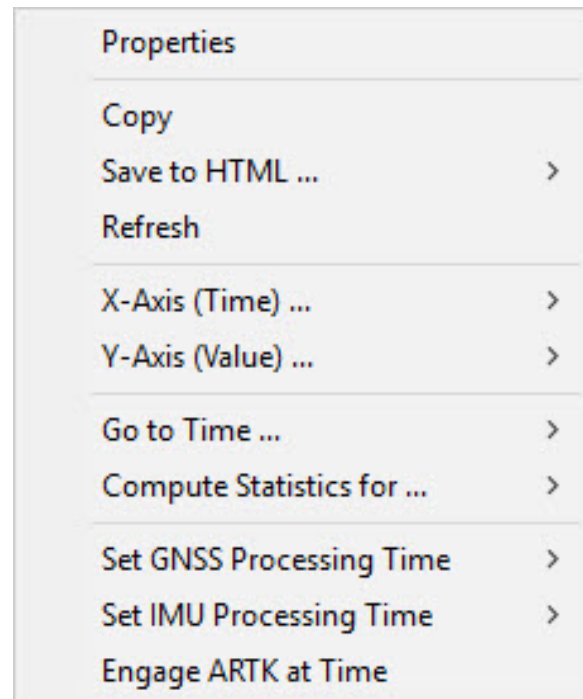
Apply to All

Scales the Y-axis of the other opened plots to facilitate analysis.

> ⓘ In order to apply the Y-axis to all plots, the maximum and minimum values must be manually specified, that is, not auto-scaled.

Go to Time…

Gives you the option of finding the nearest available time in the forward or reverse message logs, or finding the nearest epoch on the *Map Window*.

Compute Statistics for…

Calculates useful statistics for either the entire valid processed time range, or, if it has been adjusted, only the time range being plotted. Statistics include RMS, standard deviation, average, maximum and minimum. Note that this feature is only available for plots where meaningful statistics can be computed.

Set Start Processing Time

Makes the selected time the start time for GNSS data processing.

Set End Processing Time

Makes the selected time the end time for GNSS data processing.

Engage ARTK at Time

Engages ARTK at the selected time.

Common Plots

Table 10: Common Plots

Plot	Description
Accuracy	
Estimated Position Accuracy	Plots the standard deviation of the east, north and up directions as well as a 3D (labeled *trace*) value.
	This plot is a good summary of other factors in your survey, including the float/fixed ambiguity status and satellite geometry. This is because SD values of fixed solutions are generally much lower than float solutions, and spikes in DOP caused by loss of satellite signals are typically correlated with spikes in estimated position accuracy. Please note that the estimated error plot contains no knowledge of any systematic error (such as biased base station coordinates or incorrectly fixed integer ambiguities), and as such the values reported are only (by definition) estimates.
Estimated Attitude Accuracy	This plot shows the standard deviation computed in the GNSS/INS Kalman filter in terms of roll, pitch and heading.

Plot	Description
Measurement	
RMS – C/A Code	Plots the RMS of the double differenced C/A residuals for all satellites used in the solution. High C/A residuals often indicate high multipath. Also plotted is the standard deviation applied to the C/A measurements within the Kalman Filter. This value comes in part by the a priori value set in the *Measurement* tab. In dual frequency carrier phase processing, where ARTK is used to resolve integer carrier phase ambiguities, the C/A code does not heavily influence solution accuracy. Thus the standard deviation assigned to the measurements is not important, provided it is not overly optimistic. Adjusting the C/A measurement standard to a value more representative of the size of the actual residuals (while still being conservative) will benefit float solution convergence.
RMS – Carrier Phase	Plots the RMS of the double differenced carrier phase residuals for all satellites used in the solution. Carrier phase noise increases as the baseline length grows due to factors such as residual ionospheric and tropospheric error. Further, if ionospheric processing is used, the carrier phase noise will increase noticeably (although it should still be cm level). Thus, while values at or below 1 cm may be typical for short baselines (1-2 km), values of 2-4 cm are typical for longer baselines (10-40+ km). If large differences are found in the *Combined Separation (fixed)* plot, the RMS of the carrier phase can be a very helpful plot in determining which direction (forward or reverse) resolved the carrier phase integers incorrectly. When doing this, ensure to load each solution (forward and reverse) separately prior to plotting the carrier phase RMS, in order to ensure you are viewing the carrier phase residuals for each direction separately. Large ramping trends are strong indications of incorrect ambiguities.
RMS-L1 Doppler	Plots the RMS of the double differenced Doppler residuals for all satellites in the solution. Inertial Explorer uses Doppler to compute instantaneous velocity. Also plotted is the measurement weighting applied to the Doppler measurements within the Kalman filter. As the quality of the Doppler measurements varies very significantly between receiver manufacturers, Inertial Explorer applies a somewhat conservative default measurement weight. Therefore it is common to see that the actual Doppler residuals are much lower (better) than the weight applied in our filter, although the opposite is also sometimes true depending on receiver type. A discrepancy between the actual magnitude of the Doppler residuals and the a priori measurement weighting will lead to an inappropriately high (or low) estimation of GNSS velocity. Some receivers output such noisy Doppler values (on the order of 5 m/s) that it will actually cause Kalman Filter resets, significantly degrading positioning accuracy. Thus if you see very large residuals in this plot, we recommend disabling Doppler from the *Measurement* tab of the GNSS processing options.

Plot	Description
Satellite Lock – Cycle Slips	This plot launches a dialog that provides access to cycle slip plots for all GPB files within the project, or a user defined GPB file. Each satellite in the GPB file is plotted as a function of time and is color coded by elevation. See the bottom of the plot for a legend. Cycle slips for individual satellites are represented as a vertical red tick mark on the plot. It is normal for cycle slips to occur on low elevation satellites (< 10 degrees) due to signal blockages or due to attenuation by the GNSS antenna. Cycle slips on high elevation satellites may be expected if surveying in a challenging GNSS signal environment and are thus not necessarily an indication of a problem. However, if the plot shows many cycle slips on L1 or L2 in aerial survey applications where good signal tracking is expected, it can help diagnose receiver or antenna problems that can significantly limit post-processing performance. If you are getting poorer than expected post-processing performance, checking the quality of L1 and L2 signal tracking at the remote and base stations is a good first step in determining the cause.
Individual Satellite Statistics	Provides access to satellite code residuals, phase residuals, elevation angles and C/NO values for individual PRNs.
Raw IMU Data Values	Use this plot to see the raw gyroscope and accelerometer measurements as they appear in the IMR file.
Separation	
Combined Separation	Plots the north, east and height position difference between any two solutions loaded into the project. This is most often the forward and reverse processing results, unless other solutions have been loaded from the *Combine Two Solutions* dialog. Plotting the difference between forward and reverse solutions can be an effective QC tool. When processing both directions, no information is shared between forward and reverse processing. Thus both directions are processed independently. When forward and reverse solutions agree closely, it helps provide confidence in the solution. To a lesser extent, this plot can also help gauge solution accuracy. However, if there is a common bias in both forward and reverse solutions (for example, due to inaccurate base station coordinates or due to a large residual tropospheric error), it will never be seen in the combined separation plot. Large differences in the combined separation plot may be a result of different solution types (fixed/float) or different levels of float solution convergence between the processing directions and thus not a direct indication of a problem. It is important to also consider solution status (fixed/float) when evaluating forward/reverse differences. This is why the *Combined Separation with Fixed Ambiguity* plot can sometimes be more helpful.

Plot	Description
Combined Separation with Fixed Ambiguity	Similar to the *Combined Separation* plot, however only the position differences between forward and reverse processing are plotted where both solutions have fixed integer ambiguities. Fixed integer solutions are associated with high accuracies (cm, or cm-level accuracies depending on other factors). Knowing this, there is an expectation of cm level differences between forward and reverse fixed integer solutions. If large differences (decimeter or meter level) are obtained, an incorrect ambiguity was very likely obtained in one or both directions. In this event, loading each solution into the project individually and plotting the *RMS - Carrier Phase* can be useful in determining which processing direction the problem occurred. See the description for the *RMS - Carrier Phase* plot for more information.
Attitude Separation	This plot shows the difference between the forward and reverse solutions in terms of roll, pitch and heading. A zero separation is ideal, as it indicates matching solutions in the forward and reverse IMU processing. Spikes at the beginning and the end of the plot are common, as they indicate the periods of alignment.
Quality Control	
PDOP	PDOP is a unitless number which indicates how favorable the satellite geometry is to 3D positioning accuracy. A strong satellite geometry, where the PDOP is low, occurs when satellites are well distributed in each direction (north, south, east and west) as well as directly overhead. Values in the range of 1-2 indicate very good satellite geometry, 2-3 are adequate in the sense that they do not generally, by themselves, limit positioning accuracy. Values between 3-4 are considered marginal and values approaching or exceeding 5 are considered poor. If PDOP is poor in your survey, try reprocessing with a lower elevation mask (however care should be taken when lowering this value below 10 degrees).
Float/Fixed Ambiguity Status	This plot indicates where the processed solution is fixed (in one or both directions) or float. If both forward and reverse solutions achieved a fix, the plot shows a value of 2 and is plotted in bright green. If either the forward or reverse achieved a fix, but not both, a value of 1 is plotted. The value will be plotted cyan if the fixed direction is forward and blue if the fixed direction is reverse. If neither direction achieved a fix, a value of 0 is plotted which appears red on the plot. This plot can be helpful to view in conjunction with the *Combined Separation* plot, as it will help determine if large values in the forward/ reverse separation are expected or not, depending on solution status in each direction. That said, the *Combined Separation with Fixed Ambiguity* plot is recommended to quickly check for the presence of incorrect ambiguity fixes.
Number of Satellites (BAR)	Plots the number of satellites used in the solution as a function of time. The bar plot displays the total number of satellites (GPS, GLONASS, BeiDou, Galileo and QZSS). It does not distinguish between how many satellites are tracked from each constellation.

Plot	Description
Number of Satellites (LINE)	Plots the number of satellites used in the solution as a function of time. The number of GPS satellites, GLONASS satellites, BeiDou satellites, Galileo satellites, QZSS satellites and the total number of satellites are distinguished with separate lines.
File Data Coverage	Plots the coverage of each GPB file in the project, or a user specified GPB file, as a function of time. This plot indicates whether the data has been converted as static or kinematic (by different color codes) and shows the presence of any detected complete losses of carrier phase lock by vertical bars. This plot is useful in determining whether any base station data does not overlap with the time range collected by the remote receiver.
Coordinate Values	
Distance Separation	This plot shows the distance between the master and remote. For multi-base distance separation, see *Plot Multi-Base* on page 115.
Height Profile	Plots the ellipsoidal height of the remote as a function of time.
Velocity Profile	Plots the north, east and up velocity. Also plots the horizontal speed.
IMU	
Accelerometer Bias	This is the apparent output in acceleration when there is no input acceleration present. It is computed by the GNSS/INS Kalman filter and the effects may be sinusoidal or random. It is plotted in terms of the X (right direction), Y (forward direction), and Z (up direction) of the vehicle body. Generally, they should stabilize after the alignment period and agree when processed in both directions.
Attitude (Azimuth/Heading)	Plots the heading and GNSS COG (course-over-ground) that was computed from the GNSS/INS processing. Effects of a crab angle is visible in this plot if the GNSS COG bears a constant offset from INS heading. The *IMU Heading COG Difference* plot shows the difference between these two heading values. Note that any transitions between a heading of 359 degrees and 0 degrees shows up as a vertical line.
Attitude (Roll and Pitch)	Plots the roll and pitch values from GNSS/INS processing. In airborne data, it is common to see roll values between 30 degrees and pitch values of around 10 degrees, depending on the flight pattern of the aircraft itself.
Body Frame Acceleration	This plot shows the components of acceleration in the vehicle body frame. Not available in Inertial Explorer Xpress.
Body Frame Velocity	This plot shows the components of velocity in the vehicle body frame. Not available in Inertial Explorer Xpress.
DMI Scale Factor	This plot presents the DMI scale factor, as computed by the Kalman filter. It should be loaded separately for forward and reverse processing to ensure that the same scale factor is computed in both directions. Ideally, the plotted line should be horizontal, indicating a constant scale factor. Not available in Inertial Explorer Xpress.

Plot	Description
DMI Residual	This plot presents the difference between the computed displacement or velocity and that reported by the DMI. Not available in Inertial Explorer Xpress.
DMI Analysis Tool	This tool allows DMI users to view the raw data measurements found in their DMR file. They can use the options available here to find an appropriate scale factor that will make the DMI data fit best with the values computed from the GNSS-IMU data. Not available in Inertial Explorer Xpress.
Estimated Accelerometer Bias Accuracy	This plot shows the estimated standard deviation of the accelerometer bias. It is plotted in terms of the X (right direction), Y (forward direction), and Z (up direction) of the INS body. Not available in Inertial Explorer Xpress.
Estimated Gyro Drift Accuracy	This plot shows the estimated standard deviation of the gyro drift rate, which generally decreases with time. It is plotted in terms of the X (right direction), Y (forward direction), and Z (up direction) of the INS body. Not available in Inertial Explorer Xpress.
Gyro Drift Rate	This is the apparent change in angular rate over a period of time, as computed by the GNSS/INS Kalman filter. The effects are usually random. It is plotted in terms of the X (right direction), Y (forward direction), and Z (up direction) of the INS body. Generally, they should stabilize after the alignment period and agree when processed in both directions.
IMU Angular Rates	This plot shows the gyroscope rate of change of attitude in the X, Y and Z axes of the IMU body with the drift removed. This plot is used to check the gyros.
IMU Status Flag	Shows the status of IMU processing. Specifically, this plot provides indication of the type of update, if any, being applied at each epoch.
IMU-GPS Lever Arm	This plot presents the body-frame components of the lever arm offset between the IMU and GNSS antenna. If the offset was manually entered, then this plot has constant horizontal lines. If left to be solved by the Kalman filter, this plot shows the computed values.
IMU Heading COG difference	This plot is the difference between the IMU heading and the GNSS course-over-ground values. Effects of crabbing shows up as a direct bias in this plot. Not available in Inertial Explorer Xpress.
Velocity Separation	Plots the difference between the East, North and Up components of velocity computed during forward and reverse processing. Requires that both directions be processed and combined. Not available in Inertial Explorer Xpress.
IMU-GPS Position Misclosure	This plot shows the difference between the GNSS solution and the mechanized INS positions obtained from the GNSS/INS processing. This is a good analysis tool used to check the GNSS/INS solution as well as checking INS stability. Large jumps or spikes may indicate a bad INS solution, whereas separations nearing zero confirms the GPS solution.

3.9.2   Plot Multi-Base
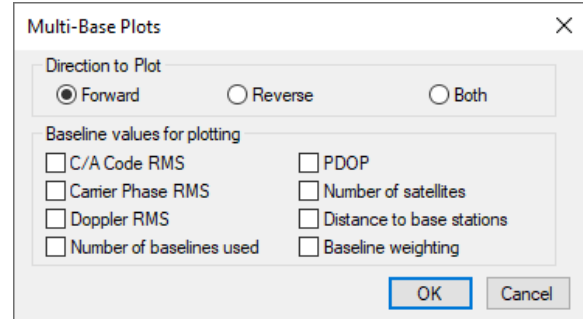
Multi-base plots are not available in Inertial Explorer Xpress.

Multi-base plots are available if more than one base station has been added to your project. In this case, the multi-base plots are often more helpful than the main plots, as they distinguish results from each baseline.

The multi-base plots contain many of the same plots as the main plotting options and therefore only the plots unique to multi-base are described in the following table.

Table 11: Common Multi-base Plots

Plot	Description
Baseline Weighting	Plots the relative weighting applied to each baseline. This is largely dependent on the distance to each base station.
Number of baselines used	Shows the number of base stations used as a function of time.

3.9.3   Export Wizard

The Export Wizard facilitates customized ASCII exporting of processed results. Manufacturer profiles are included with the installation, however they can be edited and new profiles can be created.

When creating or editing an export profile, you can choose from over 150 source variables. Units, precision, column width, field separators, and header/footer information can all be customized.

You can choose to export all processed epochs, interpolated results for features/stations (such as camera marks) or static sessions. The Waypoint application will try to auto-detect which *Source* to use given the data in your project. For example, if more than 80% of the remote file is static, the *Source* will default to *Static Sessions*. If more than a handful of features are loaded into the project, the *Source* will default to *Features/Stations* as this is presumably the data of interest.

How to create a new Export Wizard profile

1. Click the *New* button and type a unique name for the profile.

   Alternatively, it may be quicker to modify a copy of an existing profile that contains most of the variables required.

2. In the *Define Profile* window, add the desired variables from the *Source Variables* list. All source variables are organized under various headings from a pull down list.

   After selecting a variable, click *Add* to add the variable to the bottom of the list or *Insert* to add the variable above the highlighted variable in the list. See the table in *Output Variables* on page 233 for a list of variables available for output.

3. After you are finished adding all the necessary components of the profile, click the *OK* button to save the profile.

Tips for creating an export profile

- To create a profile that does not have spaces between variable entries and the record is based on column width, follow these steps:

  1. Go to the *Define Profile* window.

  2. Click the *Field Separator* button.

  3. Select *None* under *Separation Character* to remove any field separators in the file.

  > The same procedure can be used to have the output be space or comma delimited.

- To change the file by adding a header/footer of a specific format, the *Header/Footer* button in the *Define Profile* window allows you to add headers/footers from a predefined text file. If specific characters are needed to designate the start and end of a text file, strings of characters can also be added to the beginning and end of the file.

- For formats that require no decimal points to be shown in the file, like SEGP1 and Blue Book, the decimal points can be removed by going into the chosen variable, clicking the *Format* button in the *Define Profile* window, and enabling the *Do not print decimal point* option.

- If you need a text string label to designate the type of record being printed/read, for example, $--GLL, *81*, open up the *Miscellaneous* variable category and add the *User Text String* variable. Change the format of the string by entering the text needed for the label and select the *Fixed Width* option if the format is dependent on column width.

- Review the *Header/Footer* button. You can put in your own header file and display datum/projections information, column descriptions and titles. A special character can also be inserted at the start of each header line making it easier for other software to skip past the header. At the bottom of the file, you can add errors/warnings of any problems that were encountered and processing summary information.

> ⓘ The table in *Output Variables* on page 233 describes the many variables that you can include in your output profiles. Not all variables are available for use with each source.

How to use the Export Wizard

1. By default, the export file name is the same name and directory as the project file (.proj), except with a .txt extension. The file name and directory of the export file can be changed using the *Browse* button.

2. Ensure the *Source* has been set correctly according to what you would like to export.

    Choosing *Epochs* produces an output record for each common measurement epoch for the entire trajectory.
    Choosing *Features/Sessions* exports results, linearly interpolated between the nearest two epochs, for any camera marks, features or stations loaded.

    Static Sessions is accessible provided static sessions have been collected. Choosing this option exports the final post-processed (best converged) solution for each static session.

3. Choose an export profile and select *Next* to start the Wizard. Depending on the variables in the profile, the Wizard will prompt you for any needed information. For example, if the chosen export wizard profile contains orthometric heights, you will be prompted to locate a Waypoint geoid file (.wpg).

4. Click *Finish* on the last page of the Wizard. If *View ASCII output file on completion* was selected on the last page of the Wizard, the text file will open within the internal ASCII viewer.

Creating an Output File

The following is an example of the Export Wizard dialogs that appear when exporting *Epochs* using the *Geographic* profile.

Note that when exporting *Features* or *Static Sessions*, or when choosing a different export profile, you may see different dialogs. This is because the Wizard only prompts you for the required information according to your selections.

Select Output Coordinate Datum

The first page of the Wizard provides an opportunity to apply a datum transformation during export. This is required if the datum you wish to export to is not the same as the processing datum.

Filter Output/Estimated Accuracy Scaling

Results can be filtered using either the quality numbers or combined (3D) standard deviation. An example of when it is useful to filter by quality number is when only fixed integer solutions are to be exported. In that case, apply a value of 1 for the quality number filter.

This dialog also provides an opportunity to scale the standard deviations output to a higher confidence interval. By default 1-sigma values are output. However due to the conservative measurement weighting applied to code, carrier, and Doppler measurements, they are not by nature overly optimistic.

IMU Epoch Settings (GNSS+INS only)

Limit Exported Time Range
The time range to export can be changed here. Multiple time ranges may be entered.

Epoch Interval Options
The *Binary Trajectory Interval* displays the interval at which the IMU data was processed. It is the smallest interval that can be output without interpolation. The *Time Interval* option will export data at the input interval. It may be set to a value as small as 0.001 seconds (1000 Hz). Any value smaller than, or not a multiple of, the *Binary Trajectory Interval* will require interpolation of data. The *Distance Interval* option will output data whenever the input distance threshold is met/exceeded.

Transfer IMU Coordinates
Allows for the coordinates of the IMU, calculated via the IMU Kalman filter, to be transferred to an alternate sensor's location.

Note the orientation of the frame in which these coordinates must be entered.

Rotation
Allows for the attitude to be rotated into a user-defined frame.

Export Definition Complete

The last page of the Wizard provides a summary of the file name and path where the file will be written and the *Source* to be exported. The export variables within the profile are also summarized. Optionally, the output file can be viewed after export by selecting *View ASCII output file on completion*.
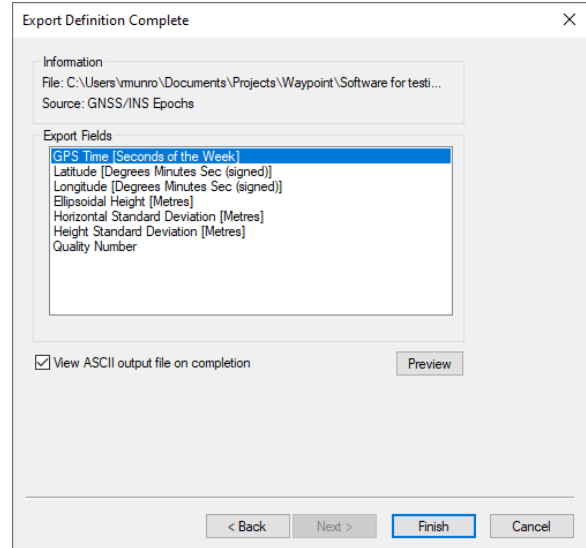
3.9.4   Build HTML Report

Creates an HTML file containing a bitmap version of any plot that is currently open, including the Map Window. These HTML and BMP files are saved to the *HTML* folder contained within the project folder. The HTML file also contains information regarding the processing run(s) used to generate the plots.

3.9.5   Export to Google Earth

Writes a compressed Google Earth (KMZ) file to the HTML sub-directory and automatically opens it in Google Earth.

3.9.6   Export to RIEGL POF/POQ (IE/IEX only)

Selecting this option launches the *Export RIEGL* dialog which supports the conversion of Inertial Explorer's native binary output to RIEGL POF (Position & Orientation file) format. The POF file format is supported by third party software manufacturers and as such is a convenient way to integrate Inertial Explorer into a larger workflow. Use the *Other Export Options* feature to optionally scale Inertial Explorer's estimated position and attitude errors.
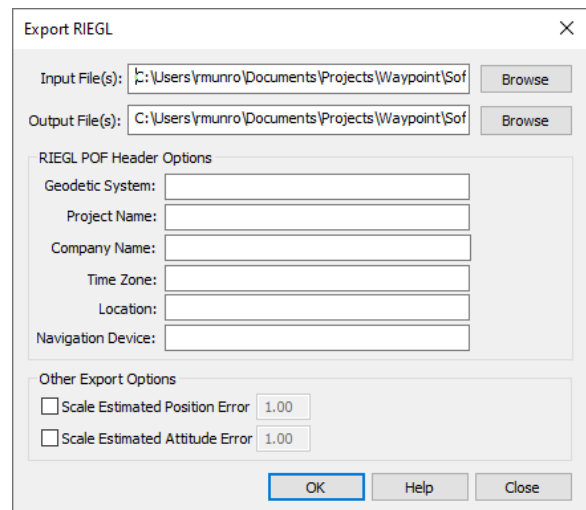
3.9.7 Export to SBET (IE/IEX only)

Selecting this option launches the *Export SBET* dialog which supports the conversion of Inertial Explorer's native binary output to Applanix SBET binary format. The Applanix SBET file format is supported by many third party software packages and thus this utility is a convenient way to integrate Inertial Explorer into a larger workflow. The utility supports outputting GPS or UTC time stamps, scaling of Inertial Explorer's estimated position and attitude error and rotation of the computed attitude into the IMU frame rather than the vehicle frame (as required for processing IMU data in Inertial Explorer).

3.9.8 Export to Waypoint Legacy Format

This option converts your Waypoint trajectory files to the binary format defined by 8.60 and previous versions of the software. It is useful if you have a workflow catered to the legacy file formats, including the CMB or SBTC/SBIC file formats.

ⓘ This tool converts the trajectory currently loaded in the map window. Load the desired trajectory before converting to Waypoint legacy format.

3.9.9 Export to DXF

DXF is a file format read by various CAD packages. This utility outputs the contents of the map window to DXF format.

Output File Name

Specify the name and path of the DXF to be created.

Output Components and Options

The following options are available:

> ***Stations/Features***
> Outputs any stations or features loaded.
>
> ***Baselines/Static Sessions***
> Outputs baselines between all the static sessions. The color of the baselines will be the same as it appears in the Waypoint application and is determined by the quality factor.
>
> ***Epochs***
> Outputs the trajectory and is only useful for kinematic data. Color is determined by the quality factor.
>
> ***Join Epochs***
> Joins a line between epochs.

Symbol Sizes

These settings govern the size of the features and stations in the DXF file. *Automatic* is suggested for a trial.

Datum

Allows you to choose between the processing datum or the input datum.

The grid options are available under the *Select Grid System* tab. For UTM, State Plane or any other zone-dependent grid, check that the zone number is correct because the default is likely wrong.

3.10   Tools Menu

3.10.1   Find Epoch Time

This feature makes it easy to find an epoch on the Map window provided the GPS time in seconds of the week. When used, it circles the epoch in red and if necessary changes the zoom level so that it is in the middle of the Map window.

3.10.2   Time Conversion

This tool converts GPS seconds of the week to hh:mm:ss format (GMT), provided a GPS week number. Alternatively, hh:mm:ss (GMT) can be converted to GPS seconds of the week, provided a month, day and year has been specified.
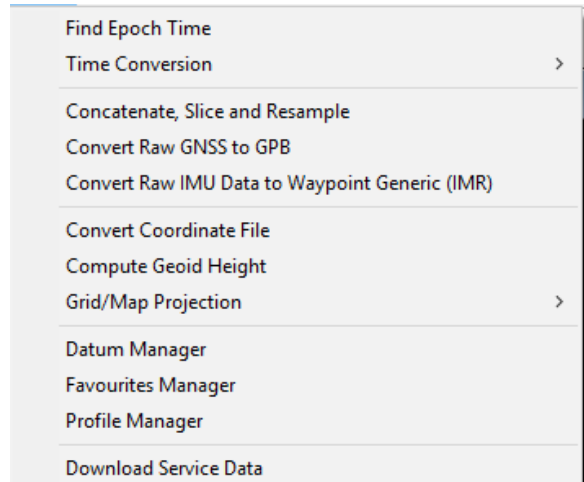
3.10.3   Concatenate, Slice and Resample

See *Concatenate, Slice and Resample Files* on page 171.

3.10.4   Convert

Raw GNSS to GPB

You must convert your raw GNSS data files to GPB prior to adding them to an empty project. It is not necessary to convert your raw GNSS data prior to creating a new project if using the New Project Wizard. See *GNSS Data Converter Overview* on page 172 for more information regarding this utility.

Raw IMU Data to Waypoint Generic (IMR) (IE/IEX only)

IMU data must be converted to IMR format in order to be processed by Inertial Explorer. Use this utility to perform this conversion.

This option does not need to be used by NovAtel SPAN customers. All NovAtel data (including all raw GNSS and IMU data) is automatically converted within the Raw GNSS Data Converter.

3.10.5 Convert Coordinate File

This tool takes an ASCII file containing a list of coordinates as an input and outputs an ASCII file to a different datum or format. You can use this utility not only to convert between datums, but also to change the format of a file. For example, you can convert an input list of coordinates from geographic to ECEF, or a list of coordinates with ellipsoidal heights or MSL.

The *Use first continuous word* option is the default. If the station names contain spaces, select *Use first 'n' characters*. The sign conventions used for geographic coordinates is positive for the northern and eastern hemispheres and negative for the southern and western hemispheres.

Additional options seen on the screen just before generating the output file include the following:

> **Include column header**
> Conserves the header information from the input file.

> **View output files after conversion**
> Automatically opens the output file after clicking *Finish*.

> **Input grid coordinates in southern hemisphere**
> Only necessary if the input data has grid coordinates from a project area that is in the southern hemisphere.

> **Do not apply datum transformation to height**
> This option is useful for outputting orthometric heights because no datum transformation are applied in this case.

> **Output map scale factor and convergence**
> This options allows for the output of the map scale factor and convergence when outputting in a grid format.

3.10.6 Compute Geoid Height

Geoid files are required when exporting Mean Sea Level (MSL) heights. Geoid files contain a grid of undulation values that represent the difference between ellipsoidal and MSL height. To calculate MSL height from ellipsoidal height at any geographic position, an interpolated geoid height (undulation value) is subtracted from the ellipsoidal height. A Lagrange interpolation method is used.

Waypoint software supports a proprietary WPG geoid format. All publicly available WPG files can be found here: www.novatel.com/support/waypoint-support/waypoint-geoids/. Waypoint software also provides utilities to create WPG files from ASCII files and other known formats in order to create custom or local geoids.

Every project requires ellipsoidal base station heights. This is because the geoid is a complicated mathematical surface and all data processing needs to be performed relative to the ellipsoid. However, the

Enter MSL Height feature on the *Master Coordinate* dialog permits you to work directly with published MSL heights. This works by back-calculating an ellipsoidal height provided an MSL height and a geoid file.

Regardless of how you have entered your base station coordinates (i.e. if you have directly entered an ellipsoidal height or if you have used the *Enter MSL height* feature), the Export Wizard will prompt you for a geoid if your export profile contains MSL heights.

The *Compute Geoid Height* dialog allows you to calculate geoid height for individual coordinates. If you have a list of coordinates to convert from ellipsoidal to MSL (or vise versa), use the *Convert Coordinate File* on the previous page feature. The *Geoid Info* button will access basic properties of the WPG file, including the datum, vertical datums and geographic boundaries.

3.10.7   Grid/Map Projection

Grid/map projections are supported in several ways including the following:

- The *Enter Grid Values* feature within the *Coord. Options* pull-down list on the Master Coordinate dialog allows you to enter base station coordinates in any defined grid, including ECEF.

- You can output final coordinates in a map projection of your choice. See *Preferences* on page 60 and *Show Map Window* on page 71 for additional information.

- Several grids, like UTM, TM, and US State Plane, have been pre-defined in the software. However, you can also add your own by selecting *New* within the *Define Grids* dialog as shown on the right.

- Use the *Transform Coordinates* tool under *Tools | Grid/Map Projection* to convert between geographic coordinates and grid coordinates.
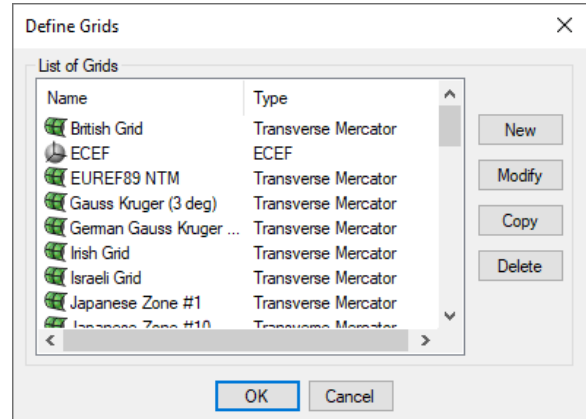
Transform Coordinates

This tool transforms coordinates for a single point from geographic to grid, or vice versa.
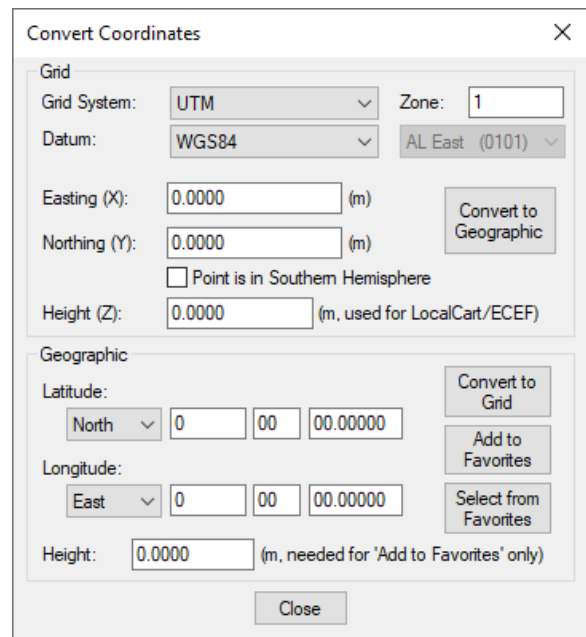
> (i) Use the *Add to Favorites* button to save a converted coordinate for easy retrieval in future projects.

3.10.8   Datum Manager

Datums

This feature allows custom datums to be added, or existing datums to be enabled or disabled.
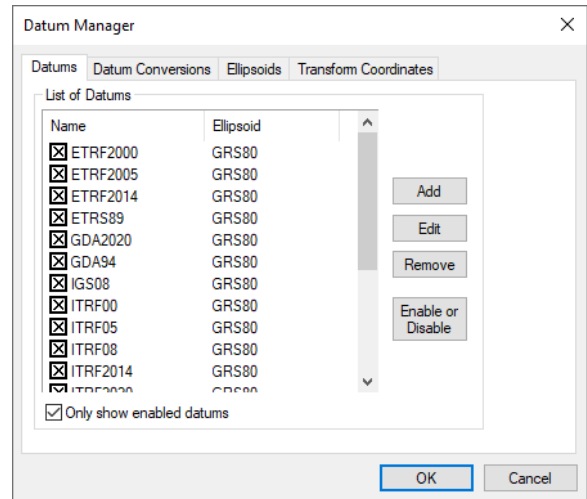
Datum Conversions

This tab allows you to view, edit or add conversions between datums.
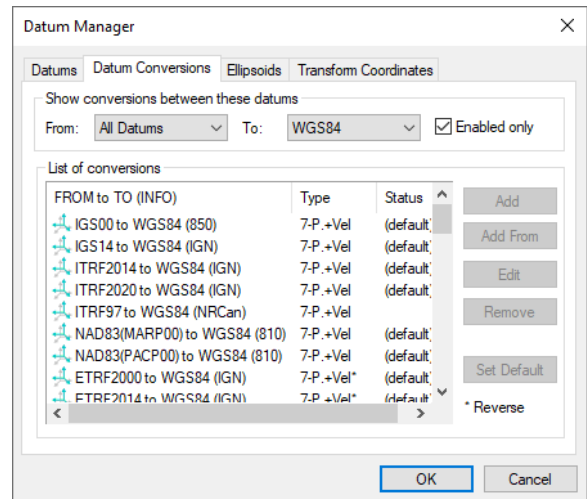
Ellipsoids

This tab allows you to view the *a*, *b* or *1/f* values for a particular ellipsoid. You can also add new ellipsoids.
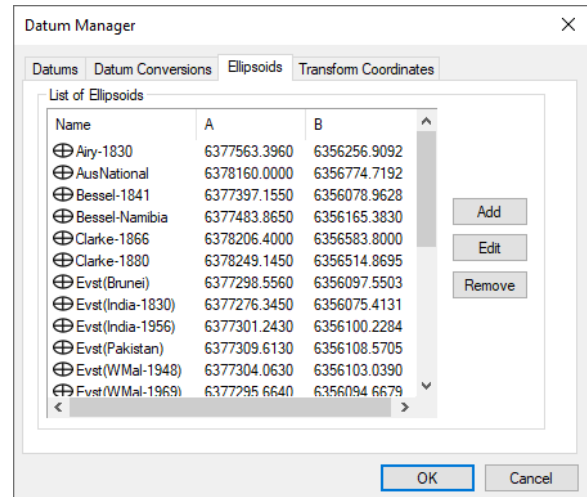
Transform Coordinates

Use this tab to transform individual points from one datum to another. If you have a list of points to convert, use the *Convert Coordinate File* utility under the *Tools* menu. Points can also be loaded from favorites and after conversion saved back to favorites.

It is generally not necessary to convert base station coordinates to a common datum prior to processing, as this is done automatically for any base stations that have their coordinates entered in a different datum than the project datum.
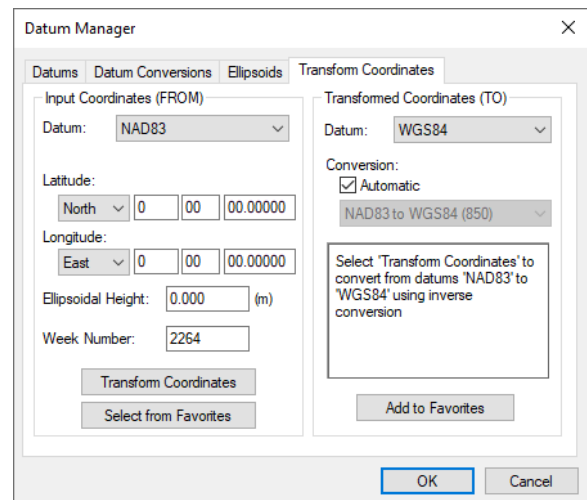
> (i) Specifying the week number of the coordinate effects the final result if using a 14-parameter conversion.

3.10.9 *Favourites Manager*

The Favourites Manager is used to store known coordinates for GNSS reference stations. This permits easy retrieval without the risk of data entry errors through the *Select From Favourites* feature of the master coordinate dialog, which is accessible under the *Coord. Options* pull-down.

The Favourites Manager comes pre-loaded with coordinates for the CORS, IGS and IGN permanently operating reference networks. The CORS(2011) and the CORS(ITRF2014) groups contain published coordinates for the CORS (Continually Operating Reference Station) network from the National Geodetic Survey. This is a large network of stations, most of which are found in the United States.

The CORS(2011) group provides access to published NAD83(2011) coordinates at epoch 2010 as well as station velocities. The CORS(ITRF2014) group provides access to published IGS08 coordinates at epoch 2010.0 as well as station velocities.

The IGN group provides published RGF93 coordinates from a reference epoch equal to the last time they were updated within the Waypoint manufacturer files, which should be within a month of the present date provided you have current manufacturer files. This service provides good coverage within France and the Island of Corsica.

The Favourites Manager and the Download Utility are complimentary in the sense that the latter provides access to base station data through anonymous FTP and the former ensures precise coordinate and datum information is loaded into your project.

Both utilities (the Favourites Manager and the Download Utility) are updated on a monthly basis by Waypoint support staff in order to ensure the list of stations and coordinates are kept current. The Waypoint application will attempt to automatically download the latest manufacturer files on a bi-weekly basis to ensure they are up to date.

In addition to pre-loaded favourites for specific networks, users can create their own favourite groups in order to store their own surveyed base station locations.

The following options are available in the *Favourites Manager* via the buttons on the right-hand side:
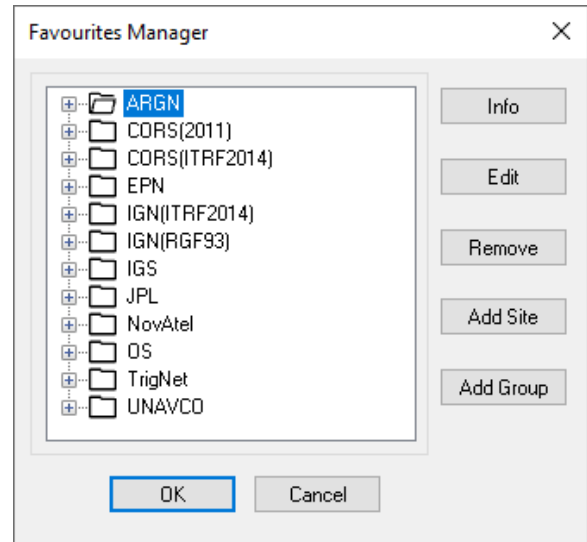
Info
If clicked while a group is highlighted, this returns the total number of sites contained within the group.

If clicked while an individual site is highlighted, the position, velocity and datum are displayed.

Edit
Use this option to modify the information related to a station, including coordinates, antenna information and station velocities.

Remove
Use this option to remove an individual site or an entire group.

Add Site
Use this option to add a new site into any group.

We recommend creating a custom group prior to adding your own sites.

Add Group
Use this option to add a new group.
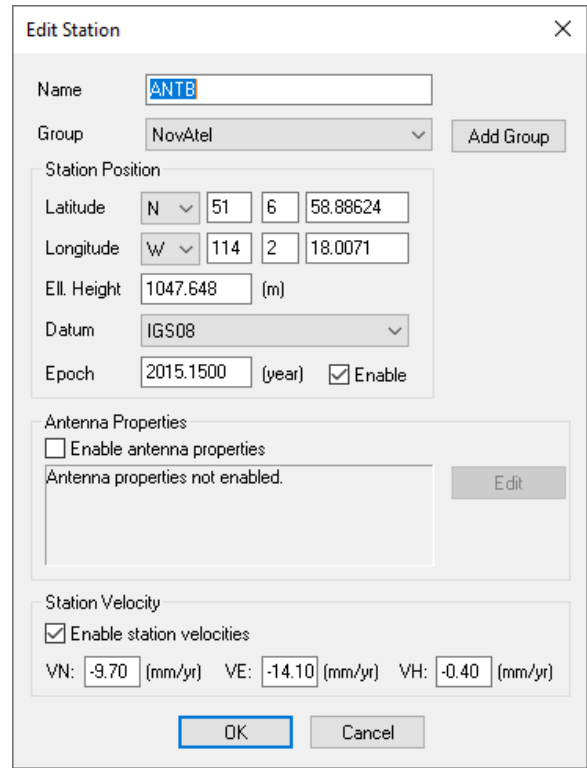
3.10.10   Profile Manager

The profile manager allows new profiles to be created or existing profiles to be edited.

When creating a custom processing profile, you must include an Environment and IMU Name. If you are creating a GNSS profile, select N/A for IMU Name. This will ensure that the profile is accessible from the appropriate processing dialogs.

Project/Profile Tools

New from Project
Creates a new profile using the current project's settings.

New from Selected
Creates a copy of the currently selected profile for editing.

Edit
Use to edit the profile name and settings.

Delete
Deletes the selected profile.

New from DefOpt
Used to convert older profile formats (versions 8.70 and earlier) to the new profile format.
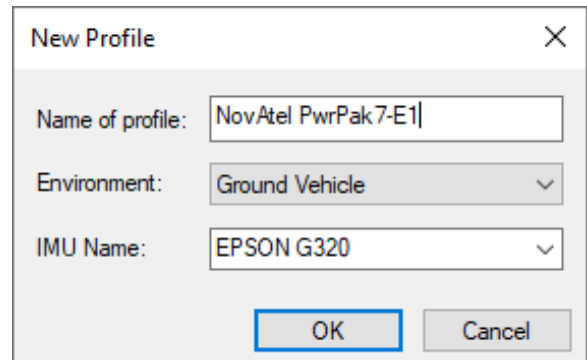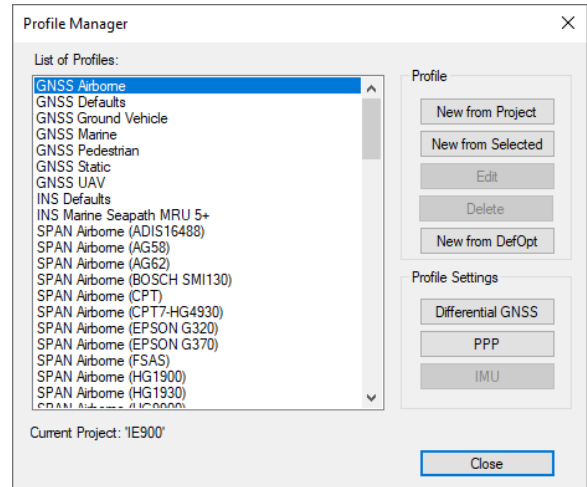
Profile Settings

Differential GNSS
Use to view (if default) or modify the differential settings.

PPP
Use to view (if default) or modify the PPP settings.

IMU
Use to view (if default) or modify the IMU settings.

3.10.11 Download Service Data

The Download Service Utility facilitates downloading, converting, and if needed concatenating and resampling of GNSS base station data.

There are currently 22 supported networks, providing access to thousands of publicly available base stations worldwide. Waypoint provides a KML file for all supported networks within the *Waypoint Downloads* section of the NovAtel website.

The *Add Closest* tab can be used to search for base station data by providing either a coordinate or a converted GPB file that you wish to process. This function not only reports a list of the nearest stations, but also automatically scans the date, start/end times, path to download the files to and sampling rate of the GPB file.

The download utility can be used not only to quickly retrieve GNSS base station data, but also to download precise ephemeris and clock files, Waypoint TerraStar NRT correction files, additional GNSS broadcast ephemeris data.

Download

List of Stations to Download

This displays a list of the stations that have been selected for download. The list is empty until you add to it using the *Add from List* or *Add Closest* tabs.

Settings

The *Path to send files to* field specifies where to save the downloaded files. The *Date and Time Range* parameters indicate the date and time range (GMT) of the data to be downloaded. If using the *GPB search mode* option on the *Add Closest* tab, all of the parameters under *Settings* are scanned automatically.

Selecting *Leave 'as is'* will preserve the original sampling data rate of the downloaded data. Common sampling rates provided by GNSS networks are 1, 5, 10, 15 and 30 seconds. Some networks, such as CORS, only make high rate available for a limited period of time (such as 30 days) prior to archiving the data at a 30 second sampling rate. Therefore it is good practice to retrieve base station data within days of your survey when possible.

In differential processing, only common epochs can be processed between master and remote. Thus, if you require processed output at the same logging interval as the remote, base station data needs to be re-sampled to the same interval should it be collected at a lower rate.
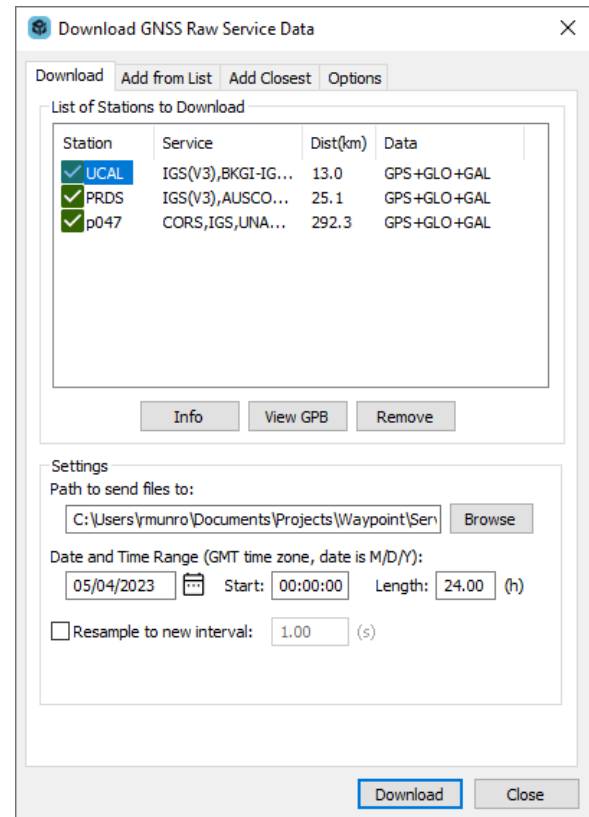
Resampling measurements introduces noise, and the magnitude of the added noise is dependent on the original sampling rate of the data. Waypoint has found that the amount of noise introduced when resampling from an original rate of 5/10/15 seconds is negligible. When resampling from 30 seconds however, 1-2 cm of noise (RMS) can be introduced, although that is typically within the noise of a kinematic survey.

Add From List

List of Stations

This window provides an alphabetical listing of all services. Expand the list to show the individual stations within each service. The *Info* button provides an approximate coordinate, which is used when searching for base station data using the *Add Closest* tab. The *Add* button places the station on the *List of Stations to Download* under the *Download* tab.
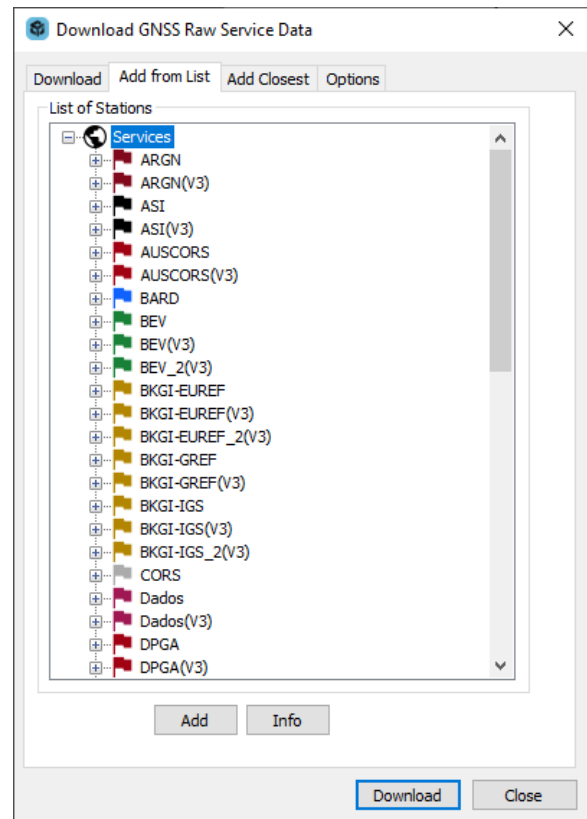
Add Closest

This tab supports two search modes: using a GPB file as input or a user defined position.

If inputting a GPB file, the download utility searches your file at regular intervals and will report the minimum distance to each base station at any point in the trajectory.
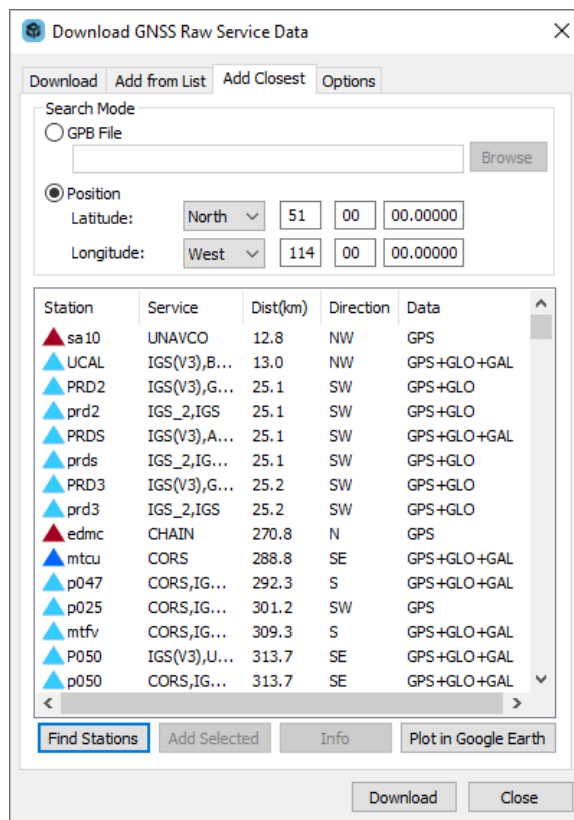
Options

Precise Files

Precise ephemeris and clock data can be downloaded here for GPS-only products, GPS+GLONASS products, or "All GNSS" products. The latter includes precise data for GPS, GLONASS, Galileo, BeiDou and QZSS. The different sources of precise products will vary in their latency.

Precise ephemeris and clock data are required for PPP processing in order to correct for meter level errors. Precise ephemeris data is optional in differential projects as much of the orbital error is canceled, as the line of sight component of satellite orbital error is correlated with baseline length. Differential projects involving baseline lengths in excess of 150+ km are likely to benefit from the inclusion of precise ephemerides. Generally speaking, it is considered best practice to add precise ephemerides to every project as their inclusion will help compensate for any missing broadcast ephemerides and will only benefit processing results.

Additional Options

Any files selected here are downloaded for the day(s) specified on the *Download* tab. You can specify any of
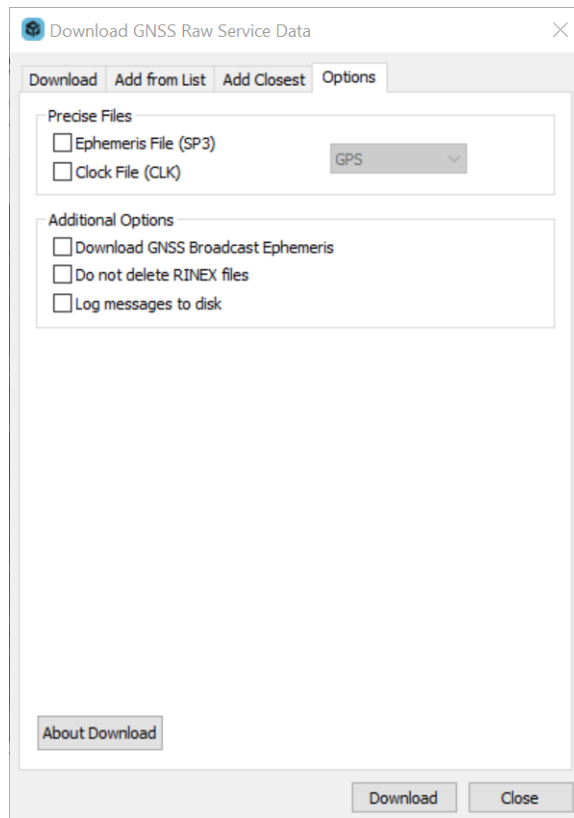
the correction files listed below for download.

Download GNSS Broadcast Ephemeris

Downloads a GPS and GLONASS global RINEX navigation file for the date specified in the Download tab and converts to Waypoint's EPP file format. Can be used to supplement missing ephemeris data in a project.

Do not delete RINEX files

The Download Utility will automatically delete downloaded RINEX files after conversion to GPB. If you wish to keep the original RINEX data, select this option.

Log messages to disk

When enabled, the tool will save all the messages that appear in the messaging window to a log file on disk. The file will be called "download_messages.log" and will be saved to the folder specified by the "Path to send files to" setting on the *Download* tab.

Add Stations and Services

The services currently found within the download utility are supported because they provide public access to data and they are known to us.

If you know of another service which provides public FTP access to GNSS reference data, contact Waypoint support (support.novatel@hexagon.com) as it may be possible to add the service to the software. This has the added benefit of making the service available to all other users as well.

If you prefer to add your own custom service, create a *user.xml* file within your User directory (C:\NovAtel\WayptGPS880\Resources\User). The first line of the *user.xml* file must contain <DN1> and the last line must be </DN1>.

Service and station records must conform to the format described below.

> ⓘ You might find it easier to copy a service and station record from the *manufact.xml* file and paste it into *user.xml* file for modifying.

Adding a service requires knowledge of the FTP address at which the data is stored. The directory structure and file type must be known.

Service records must conform to the format described below. Refer to the manufact.xml file for examples of service and station records.

Station record format

```
<station>
        <name></name>                      Four-character station name as saved on FTP server. See Note 1.
        <download>
                <appxlat></appxlat>    Latitude in decimal degrees (signed).
                <appxlon></appxlon>    Longitude in decimal degrees (signed).
                <appxht></appxht>      Ellipsoidal height, in meters.
                <serv>
                <name></name>          Name of service to which the station belongs. See Note 1 and Note
                                       3.
                </serv>
        </download>
</station>
```

Service record format

`<service>`

`<name></name>`	Name of service, up to a maximum of 8 characters. See Note 1.
`<data></data>`	
`<protocol></protocol>`	Type of file transfer protocol used by the service (FTP, HTTP or HTTPS).
`<encryption></encryption>`	The encryption method used (false or explicit). Applies only to FTP connections.
`<address></address>`	Address of the FTP server.
`<username></username>`	Required to log into nonpublic sites. See Note 1 and Note 4.
`<password></password>`	Required to log into nonpublic sites. See Note 1 and Note 4.
`<ofile></ofile>`	Generic path to the observation file containing daily (24-hour) data. If the daily data is unavailable or not provided, download of hourly data will be attempted if defined. See Note 6.
`<dfile></dfile>`	Generic path to the compressed observation file. See Note 4 and Note 6.
`<nfile></nfile>`	Generic path to the GPS navigation file. See Note 6.
`<gfile></gfile>`	Generic path to the GLONASS navigation file. See Note 4 and Note 6.
`<hofile></hofile>`	Generic path to the hourly observation files. See Note 4 and Note 6.
`<hdfile></hdfile>`	Generic path to the compressed hourly observation files. See Note 4 and Note 6.
`<hnfile></hnfile>`	Generic path to the hourly GPS navigation file. See Note 4 and Note 6.
`<hgfile></hgfile>`	Generic path to the hourly GLONASS navigation file. See Note 4 and Note 6.
`<color></color>`	Color to use for symbols in utility's interface. See Note 4 and Note 5.

`</service>`

Station and Service record notes

1. This field is case-sensitive.

2. Only the Z, GZ, and ZIP formats of compression are supported.

3. The service name must match the *ServID* field of a service record, as defined in the *manufact.xml* file or, if the service is user-created, in your *user.xml* file. If the station is found on more than one service, enter a separate <name> entry for each service.

4. This field is optional and, thus, does not need to be present.

5. The color defined here is used in the interface to identify the stations belonging to this service. The following colors are available: red, green, blue, magenta, cyan, gray, wine, black, gold, darkgray, darkgreen, darkblue, lightcyan, and darkmagenta.

6. This field identifies the format of the directory structure used on the FTP site to organize the data. Any folders in the structure that are common to all data must be hard-coded into this field. The rest, however, must be defined using the following case-sensitive strings:

[JJJ]	*Julian Day*
[YYYY]	*Year*
[XXXX]	*Station ID*

[week]	*GPS week*
[wkrl]	*GPS week* - 1024 - padded with leading zeroes
[wkrn]	*GPS week* -1024 - without padding
[yy]	*Last two digits of the year*
[d]	*Day of the week* (0 – 6)
[MN]	*Month number*
[DM]	*Day of the month*
[H]	*Hour of the day*, in upper case (A-X)
[II]	*Hour of the day*, numeric (00-23)
[mmm]	first three letters of month (Jan-Dec)
[CITY]	any custom string (such as the name of a city or region) contained within an FTP sites folder structure that varies for individual stations

3.11   Window Menu

3.11.1   Tile

This option will tile all windows within the screen.

3.11.2   Close Window

This option will close the active window.

3.11.3   Close All Windows

This option will close all open windows.

3.11.4   List of Windows.

Each additional window opened will be listed here. A check mark will be displayed next to the currently active window.

3.12   Help Menu

3.12.1   Help Topics

Opens an offline HTML version of this manual.

3.12.2   Support Web Portal

Opens the online documentation portal.

3.12.3   Check for update...

Provided an internet connection, this feature checks the Waypoint server to see if any software updates are available. If so, they can be directly downloaded and installed.

3.12.4   Download manufacturer files

Provided an internet connection, use this option to download the latest manufacturer files from Waypoint's FTP site. The files downloaded are listed below.

List of files downloaded when manufacturer files are updated

manufact.dcb
List of the differential code biases, in nanoseconds, between the P1 and C/A code for each satellite. Used by PPP and applied to any receivers that track the C/A code on L1 (as opposed to P1). If this file is out of date it may limit PPP solution convergence.

manufact.xml
List of base stations available for the *Download* utility. This is usually updated monthly.

manufact.dtm
List of datums, ellipsoids and transformations between datums.

manufact.fvt
List of *Favourites* and the groups they are contained in.

manufact.grd
List of manufacturer defined grids.

manufact.utc
List of UTC leap seconds and dates they were or will be introduced.

manufact.atx
Composite absolute antenna calibrations in ANTEX (new IGS) format.

manufact.cim
List of the IMU conversion profiles.

manufact.imu
List of the supported IMU error models.

manufact.pgr
List of the plot groups and the plots included in the groups.

3.12.5 NovAtel Waypoint Products

This option opens the Waypoint Software page in your default web browser. From here, more information on Waypoint Products can be found, including information regarding the latest version, notices of training seminars, links to FAQ/training materials and technical reports.

3.13 About

This window displays information about the software version, build dates and copyright information.

Chapter 4   GrafNet

4.1   GrafNet Overview

GrafNet is a batch static baseline processor and network adjustment package. It is used to establish or check base station coordinates for later use within GrafNav, or survey entire static networks. GrafNet accepts GNSS data only, no terrestrial observations can be imported.

GrafNet is included with both GrafNav and Inertial Explorer, however can also be purchased separately as *GrafNav Static*. This section includes examples of networks that are commonly processed in GrafNet, as well as step-by-step instructions for first time users.

4.1.1   Types of Networks

Closed Loop Network

Surveyors often use this style of network because of increased reliability. Due to the closing of the loops, any baseline determination errors will show up as tie point errors. Such closure values can be seen via *Process | View Traverse Solution*. If just two GNSS receivers are employed, then a method called "leap-frogging" can be used to collect the data. In this procedure, starting from a known point, the lead receiver is placed on the first point to be surveyed. After the first session is complete, the trailing receiver is moved ahead of the lead receiver so that it now becomes the lead. The next baseline is observed and this procedure is repeated until small (4-6) loops are closed.

Figure 2: Closed Loop Network
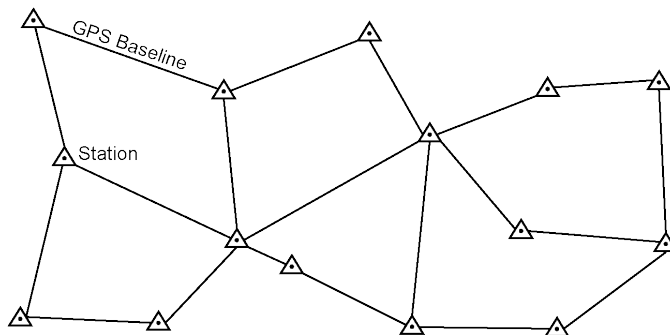
> Antenna height measurement errors will often cancel with this method and should therefore be double-checked. Methods involving more than two receivers become quite complex, and are past the scope of this section.

Radial Network

Also referred to as *Single Base Station*. Applications where productivity is more important, like GIS, do not need the same degree of reliability as the closed loop network. For these situations, use open loop networks. An example of this a network is shown below. For this method, one receiver is left stationary over a reference or control point. One of more remote GPS receivers are moved from point to point being surveyed.

Figure 3: Radial Network
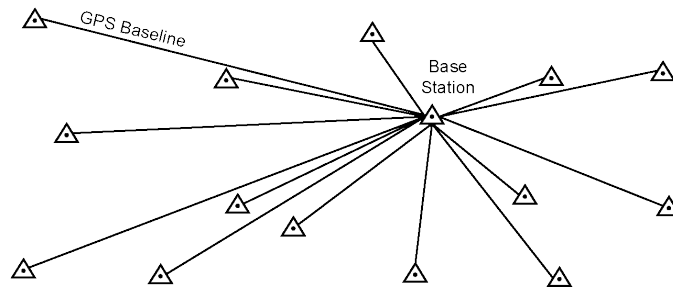
4.1.2 Static Solution Types

GrafNet automatically forms sessions between any GPB files that have a minimum amount of overlapping data. The default value is 180 seconds, but this can be edited from the *Import Options* button when adding observations to a project. There are three modes of static processing, including:

Fixed Solution (ARTK)

In this mode of processing, integer ambiguity resolution is attempted using ARTK.

When choosing this mode, GrafNet will attempt to fix integer ambiguities regardless of the baseline distance separation. This will overwrite the *Automatic* setting, which chooses between fixed and float solution using the baseline distance and the tolerances set within the *ARTK* tab.

The settings within the *Advanced* tab control whether ionospheric processing is engaged when attempting a fixed integer solution and whether the tropospheric error state is engaged.

GrafNet attempts to fix new ambiguities whenever there is a change in satellite geometry, i.e. when a new satellite rises or a satellite drops below the elevation mask. A history of fixes are saved throughout the session and the final result is by default the averaged value.

Float Solution

This method does not attempt to resolve integer ambiguities. Float solution accuracy is largely dependent on the length of the occupation, as float ambiguities improve with time as they converge towards integer values.

Using this setting will process a float solution for the baseline(s) and override the *Automatic* mode which chooses between fixed and float modes using the baseline distance and tolerances set within the *ARTK* tab.

The settings within the *Advanced* tab control whether ionospheric processing and the tropospheric error state are engaged when processing a float solution.

Automatic

Automatic mode chooses between fixed and float modes using the baseline distance and the tolerances set within the *ARTK* tab as criteria.

The following table contains a list of common solution types in GrafNet.

Table 12: Common Solution Types

Solution Type	Fixed Integer	Ionospheric Correction	Tropospheric Error State	Description
L1-Float	N	N	N	Single frequency float solution without ionospheric correction or tropospheric error state

Solution Type	Fixed Integer	Ionospheric Correction	Tropospheric Error State	Description
L1-ARTK	Y	N	N	Single frequency fixed solution without ionospheric correction or tropospheric error state
L1L2-Float	N	N	N	Dual frequency float solution without ionospheric correction or tropospheric error state
L1L2-Float-Iono	N	Y	N	Dual frequency float solution with ionospheric correction and without tropospheric error state
L1L2 Float-Iono-Tropo	N	Y	Y	Dual frequency float solution with ionospheric correction and tropospheric error state
L1L2-ARTK	Y	N	N	Dual frequency fixed solution without ionospheric correction or tropospheric error state
L1L2-ARTK-Iono	Y	Y	N	Dual frequency fixed solution with ionospheric correction and without tropospheric error state
L1L2-ARTK-Iono-Tropo	Y	Y	Y	Dual frequency fixed solution with ionospheric correction and tropospheric error state

4.1.3 Computing Coordinates

Once the processing is complete, there are two methods to produce coordinates for each station.

Traverse Solution

This solution automatically computes during processing. It starts from known stations and transfers positions to neighboring stations one baseline at a time. A tie or closure will be computed where it is possible to derive a station coordinate from two or more directions as indicated by the vector arrows which show the direction of coordinate transfer.

Network Adjustment

This method includes all processed vectors and estimated accuracies into a single weighted least-squares adjustment. Errors are distributed using least squares throughout the network to produce more accurate station coordinates than the transverse solution. The network adjustment may flag poor fitting baselines within the *Output Vector Residuals* section of the network report.

4.2 Start a Project with GrafNet

4.2.1 Install Software

GrafNet is automatically installed when installing either GrafNav or Inertial Explorer. If you have not previously installed the software, see *How to install Waypoint software* on page 21 for installation instructions.

4.2.2 Convert Data

GrafNet will only import GPB files. As such, prior to importing data to a GrafNet project the data must first be converted. See *GNSS Data Converter Overview* on page 172 for information about how to convert raw GNSS

data to GPB format.

4.2.3   Create a Project

Follow the steps below to create a project.

1. Convert all raw data to Waypoint format prior to creating a GrafNet project. See *GNSS Data Converter Overview* on page 172 for more information.

2. Open *GrafNet* using the Start menu or the desktop short cut.

3. Select *File | New Project*.

4. Browse to where you would like to create the project.

5. Give the project a name and click *Save*.

> (i)   Entering the name of a project that already exists overwrites the file contents.

4.2.4   Add Observation Files to the Project

Follow the steps below to add observation files.

1. When creating a new project, the *Add Observation* window launches automatically after giving your project a name.

2. Click *Get Folder* and select the directory containing the converted data (GPB files).

3. Select the files that you want added or choose *Select All*. Select *Add* after all of the desired files have been added.

4. Verify the station name, antenna height and antenna model for each station loaded.

5. Click the *OK* button for each station loaded.

6. When finished loading all stations, select *Close* on the *Add Observations* window. Unprocessed vectors will then be displayed to the GrafNet map window.

> (i)   If data has been collected over the same point more than once, the station ID should be the same for each observation. Otherwise, two separate stations will be formed and solved for.

4.2.5   Add Control and Check Points

A Ground Control Point (GCP) is a base station with known coordinates. GrafNet computes positions of unknown points by transferring positions throughout the network using the processed vectors from control points.

Check points are points with known coordinates, but their positions will not be constrained in the network. Rather, they will be used only to check the difference between the known coordinate and the processed position for that point. Adding a minimal amount of control to your project (one 3D GCP) and then adding all other control points as check points is a good way to check the agreement between control points in your network prior to processing a fully constrained solution.

Follow the steps below to add a ground control point.

1. Select *File | Add / Remove Control Point*.

   Alternatively, you can right click on the station you want to add as a GCP and choose *Add as Control Point*. If you use this latter approach, skip directly to step 4.

2. Click the *Add* button.

3. Select the ID corresponding to the control point to be added.

   If the GPB file was converted from RINEX and coordinates were scanned from the RINEX header, these will be automatically loaded.

4. Enter or verify the coordinates and datum for that station.

5. Click the *OK* button.

   Repeat similar steps to add check points.

4.2.6   Set the Processing Options

After adding at least one GCP to your project, you will be able to access GrafNet's *Process Session* menu under the *Process* menu.

If you are processing a new project, it is recommended to use the GrafNet default options. GrafNet automatically chooses the type of solution to process based on the type of data available (single or dual frequency) and the baseline length.

If you wish to override any of the default processing settings, you can do so by editing the options available under the Process Session dialog prior to processing.

1. Select the desired static processing mode. These modes are described in *Static Solution Types* on page 136.

4.2.7   Process All Sessions

The *Process* tab of the GrafNet processing options controls which baselines will be processed. When first accessing a new project, the default selection should be *All unsuccessful (status less than good)* which will result in all of the baselines in the project being processed.

1. Ensure *All unprocessed (status less than good)* is selected under as the *Sessions to Process* on the *Process* tab.

2. Click the *Process* button.

3. Upon processing, baselines will either be color coded green (good) or red (failed). If baselines appear red, see *Fix Bad Baselines* on the next page.

4.2.8   Verify That All Baselines Have Passed

Passed baselines are plotted in green, failed baselines in red, purple or blue. Duplicate baselines appear yellow.

4.2.9   View Traverse Report

Access the traverse report through *Traverse | View Traverse Solution*. Loop, check and duplicate ties will be reported at the bottom of the report, which is valuable information for QC.

4.2.10   Run Network Adjustment

Follow the steps below to run a network adjustment. After these steps are completed, the *Network Adjustment Results* opens, while error ellipses are plotted for each station on the *Map Window*.

1. Select *Process | Network Adjustment*.

2. Click the *Process* button.

4.2.11   Export Station Coordinates

Follow the steps below to export station coordinates.

1. Select *Output | Export Wizard*.

2. Enter an output file name.

3. Select the source for the coordinates (usually *Network*).

4. Select a profile containing the desired output variables.

4.2.12   Fix Bad Baselines

The following sections contain ideas to try when attempting to fix bad (red) baselines in GrafNet.

Fixed Static Solutions

If a fixed integer solution is not achieved, consider lowering the ARTK quality acceptance criteria to its lowest setting (Q0) and reprocessing. When doing so, it is important to check any loop, check and duplicate tie points in the traverse report to ensure the quality of the solution.

If a fixed integer solution is still not achieved, check the baseline distance and plot the number of satellites, DOP and estimated carrier RMS in order to check if conditions are not favorable to integer ambiguity determination.

Change the Processing Direction

Switch from Forward to Reverse processing. The reverse solution might pick a different base satellite and have a different solution that passes.

Change the Elevation Mask

GrafNet by default uses a 15° elevation mask. This is because tropospheric, ionospheric and multipath errors increase significantly on low elevation satellites. Lowering the mask to 10° allows more satellites into the solution, strengthening the geometry. The improved geometry may more than compensate for increased measurement errors.

Change the Processing Time Range

The start / end times can be modified from within the *General* tab. Sometimes a data set will benefit if a problematic section is removed, such as an extended period where very few satellites are available (plot the Number of Satellites to check this).

Satellite Omission

A bad satellite has many bad data warnings in the message log file (FML/RML). Omit this satellite with the *Advanced* tab options.

4.3   File Menu

4.3.1   New Project

Use this option to create a new GrafNet project, which carries a GNT extension.

4.3.2 Open Project

To open an existing project, follow the steps below.

1. Select *Open Project* from the *File* menu.

2. Choose the name of the project from the dialog box that appears prompting you to select the name of an existing project (GNT file).

3. Click the *Open* button.

4.3.3 Save Project

This option saves the GrafNet project file (.gnt) to disk, including all observations added to the project.

4.3.4 Save As

Use the *Save As* command under the *File* menu to create a new project that has identical processing options as the current project. This allows you to change the options in the new project and process the data without losing the solution computed by the original configuration.

4.3.5 Add / Remove Observations

This feature adds observation files to GrafNet projects. These files must be converted to GPB files using *File | Convert | Raw GNSS to GPB*.

If the GPB file was converted from RINEX, the station name, antenna height and antenna profile may be loaded automatically when adding stations. Verify this information is imported correctly for each loaded station.

Import Options

Clicking the *Import Options* button provides access to the following options:

Prompt for station name and antenna height
This option is on automatically as it is good practice to ensure the station name, antenna height and antenna model are correctly loaded into the project for each station. If however you are confident the data will be loaded correctly automatically and you are loading a large number of observations, consider disabling this option.

Break up occupations if gap is greater than: 180 (s)
If a GPB file contains a data gap larger than this adjustable threshold, GrafNet will treat the data before and after the gap as separate sessions. The default value is 180 seconds. If more than one session is detected in your data and you are confident the station did not move, deselect this option when importing data.

Minimum observation time per session:
GrafNet will not form sessions between stations that contain less than this adjustable threshold. The default value is 180 seconds. This is a good way of filtering out short and unintentional baselines from being included in your project.
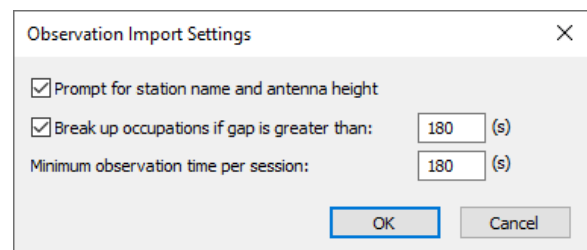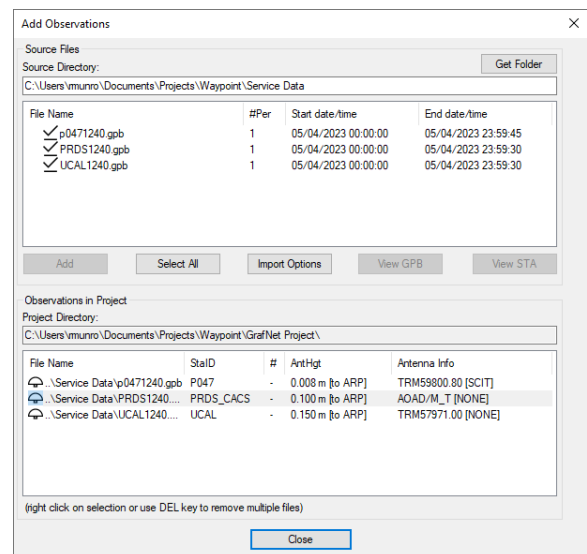
4.3.6   Add / Remove Control Points

Add at least one 3D or horizontal ground control point before processing. Sessions will not be processed unless they are connected to a control point. The three types of control points include the following:

- 3D: constrained horizontally and vertically
- 2D: constrained horizontally
- 1D: constrained vertically

After selecting *Add / Remove Control Points* from the *File* menu, click *Add* to enter a new control point or *Edit* to adjust the station, position or Datum of a control point. Control and check points can also be added by right clicking on the stations in the GrafNet map window. When right clicking on a station, *Add as Check Point* and *Add as Control Point* are available menu items. The station ID should match that of the corresponding station.

Standard deviations can be entered at this stage. The default values are 5 mm for horizontal and 5 mm for vertical. Standard deviations are only taken into account in the network adjustment. They are useful for combining high and low accuracy control points and will control the extent to which the network adjustment adjusts control point positions.
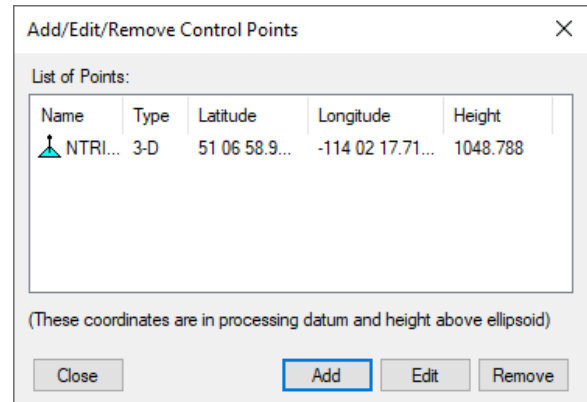
4.3.7   Add / Remove Check Points

Check points are useful for gauging how well the network fits the existing control fabric. They are added in the same manner as control points, except that standard deviations are not applicable.

4.3.8   Add Precise Files

Use this feature to add precise ephemeris and clock files to the project. Precise ephemeris files will reduce residual satellite orbital error on long baselines. See *Add Precise/Alternate Files* on page 55 for more information.
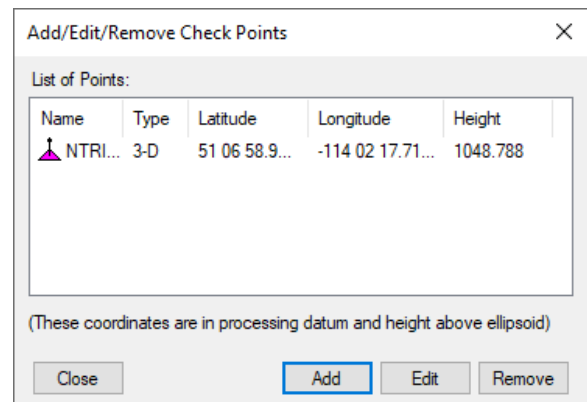
4.3.9   Import Project Files

This feature imports stations and baselines from another GrafNet project into the current project.

4.3.10   View

ASCII File

See *ASCII File(s)* on page 71 for information regarding this feature.

Raw GNSS Data

See *Raw GNSS Data* on page 71 for information regarding this feature.

4.3.11   Convert

Raw GNSS to GPB

Users have to convert their raw data files to GPB format prior to importing into GrafNet. More information on this utility is available in *Convert Raw GNSS data to GPB* on page 172.

4.3.12 Concatenate, Slice and Resample

See *Concatenate, Slice and Resample Files* on page 171.

4.3.13 Recent projects

Displays recent projects.

4.3.14 Exit

Exits the program.

4.4 Process Menu

4.4.1 Processing Sessions

This option brings up the *Process Sessions* window, where all processing options are accessed.

Process Options

Sessions to Process

Allows you to decide which session to process. The options are listed below.

All unprocessed
Processes all sessions listed as either *Unprocessed* or *Approximate*. These sessions are blue or purple in the *Map Window*.

All unsuccessful
Processes all sessions that do not have a *Good* status. This includes all sessions that are not green in the *Map Window*. Processing will start nearest to the control points and move outward.

Only those sessions shown in Data Manager
Process only the sessions that are presently listed in the *Data Manager* window.

Reprocess entire project
Reprocesses all solutions, regardless of status.
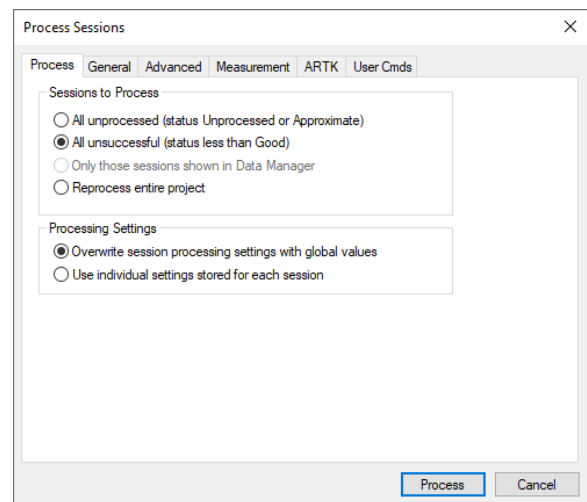
Processing Settings

Determines which processing settings to use for each baseline. The options are listed below.

Overwrite session processing settings with global values
Applies the options set under *Options | Global Settings* to all baselines being processed. Any individual baselines whose settings were changed will have their settings overwritten.

Use individual settings stored for each session
Uses the options as individually set for each baseline for processing.

General Options

Process Direction

The direction can be set to *Forward*, *Reverse* or *Both directions*. The forward and reverse solution should provide similar solutions for a static session but in some circumstances, a reverse solution passes when a forward fails, or solutions may differ because of different base satellite selections.

Static Solution Type

See *Static Solution Types* on page 136 for information.

Frequency

Defines the type of data used for processing. The following settings are available:

> **Single frequency**
> Overrides automatic selection and applies single frequency (L1 only) processing.
>
> **Dual frequency**
> Overrides automatic selection and applies dual frequency processing. L1 / L2 data must be present in all observation files.
>
> **Automatic**
> Chooses between single and dual frequency processing depending on the common data available between the base and remote.

Constellation Usage

GrafNet supports GPS, GLONASS, BeiDou, Galileo and QZSS. By default, all common data will be processed, however individual constellations (other than GPS) can be disabled here.

Elevation Mask

Satellites below this mask angle will be ignored. The default value is 15°. Lowering this value allows more satellites to be used, possibly improving a solution with poor geometry.

Time Range

This option is only available when processing sessions individually.

Interval

Allows you to choose the processing interval. 30 seconds is the default processing interval as processing high rate data does not typically improve static processing results.

Advanced Options

Satellite Omissions

See *Satellite / Baseline Omissions* in the *General (Differential Settings)* on page 76 for more information.

Ionospheric Options

See *Ionospheric Processing (Differential processing only)* on page 82 for a description of the Ionospheric options.

Forward/Reverse Process Direction Handling

Use solution last processed
Does not combine forward and reverse solutions if available, but rather uses the last solution processed in the traverse and network solutions. This setting is useful when reprocessing problematic baselines.

Combine FWD/REV solutions
If both forward and reverse solutions are available they are combined statistically. This is the software default.
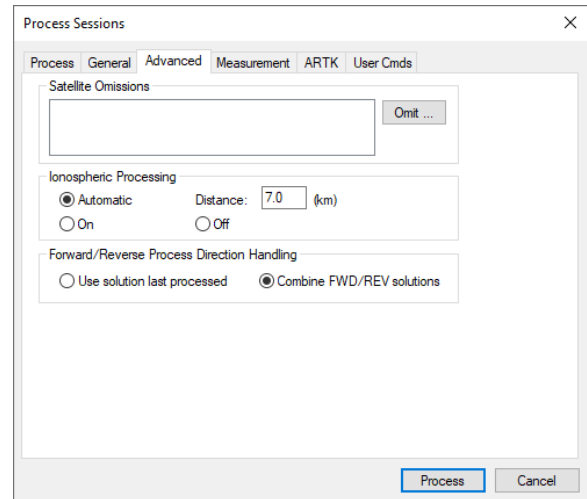
Measurement Options

See *Measurement* on page 81 for information regarding the settings on this tab.
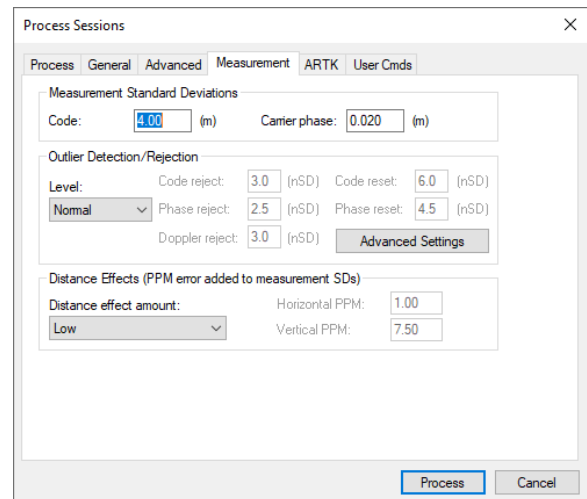
ARTK Options

Quality Acceptance Criteria
The criteria used in statistical testing in order to accept or reject an ARTK fix. Consider increasing this value if the solution type of vectors in your network indicate fixed solutions, and high loop, check, or duplicate ties are reported in the traverse report.

The higher this threshold is set, the less likely it is that incorrect integer ambiguities will be accepted. Conversely, the higher this is set, the less likely any fixed integer solution will be achieved.

Maximum Distance for Single Frequency
Controls the maximum distance at which a fixed integer solution will be attempted using ARTK for single frequency data.

Maximum Distance for Dual Frequency
Controls the maximum distance at which a fixed integer solution will be attempted using ARTK for dual frequency data.

Solution Type
Whenever there is a change in satellite geometry (i.e. a new satellite rises or one drops from view), GrafNet attempts to recompute fixed integer ambiguities. A history of fixed integer solutions throughout the session is saved and the solution GrafNet chooses is controlled by this option. The default is to average all available ARTK fixes but choosing the solution with lowest (best) variance, lowest (best) RMS or highest (best) reliability may help when troubleshooting a problematic baseline. In order to evaluate the effectiveness of each option, check the magnitude of the loop and check and duplicate ties in the traverse report.

Minimum Reliability
ARTK will not return a successful solution unless the reliability of the ARTK fix meets this threshold. This option is off by default.

Maximum RMS
ARTK will not return a successful solution unless the RMS of the ARTK fix meets this threshold. This option is off by default.
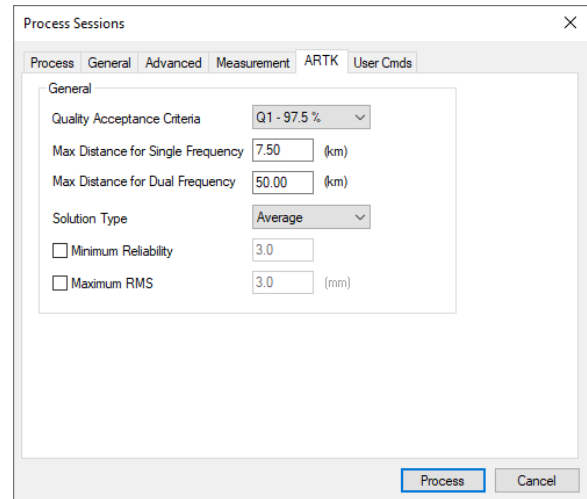
User Cmds

This changes any command that is passed to GrafNet. It can be used to change commands that are set by the other option tabs or set commands that are not handled by the other option tabs.

When a configuration file is loaded, all commands that are not handled by the other option tabs appear here. This includes commands that are not supported in the version of GrafNet being used. These commands can easily be deleted here.

4.4.2   Rescan Solution Files

This option rescans the FSS (forward static solution) and RSS (reverse static solution) files. This option will only have an effect if baselines have been processed outside of the GrafNet interface and GrafNet is not recognizing the updated processing results. Normally, this happens automatically but this is controlled through the GrafNav/GrafNet interface settings found in the *Advanced* tab of the GrafNet processing options.

4.4.3   Ignore Trivial Sessions

GrafNet defines trivial baselines as those that are unnecessary as a result of multiple receivers simultaneously running. The problem with this is that the baseline solutions computed by GrafNet are correlated, and so they are dependent. Removing trivial baselines reduces these dependencies, while still maintaining a closed loop. It also creates a network where the standard deviations reflect the actual errors more accurately.

Consider the network in *Figure 4: Trivial Baselines* below. The six stations are surveyed with four receivers during two one-hour sessions. During the first session, stations A, B, C, and D are observed. During the second session, the points C, D, E, and F are observed.

Figure 4: Trivial Baselines
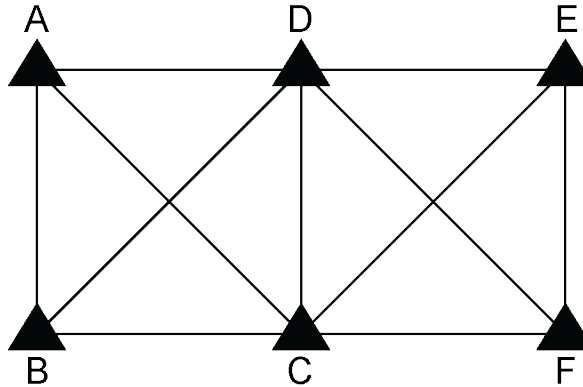
This network can be divided in two sub-networks, formed by the first and second time periods. Before the trivial baseline removal, every baseline in these two sub-networks is dependent on the other baselines. These dependencies cause the loop ties to be low.

With four receivers or more collecting data at the same time, a sub-network is very over-determined. Using three GPS receivers, the network is still over-determined, but all baselines need to be included to form a closed loop. GrafNet removes these dependent or trivial baselines by creating a single loop that connects all of the points in the sub-network. *Figure 5: Network with Trivial Baselines Removed* below illustrates that it is easy to remove these baselines.

Figure 5: Network with Trivial Baselines Removed
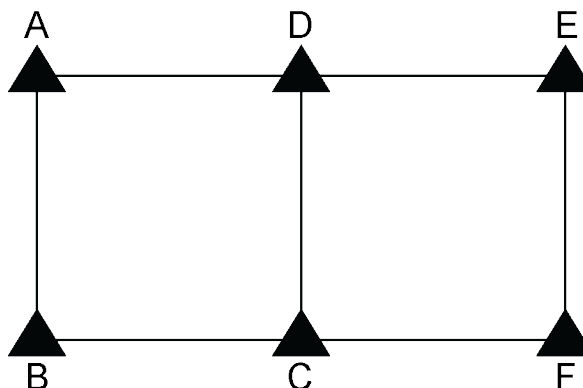
With four receivers, there are two dependent baselines in each sub-network. GrafNet removes these trivial baselines for each sub-network. *Figure 6: Removal of Trivial Baselines* on the next page shows two possibilities of what GrafNet might do with the first sub-network.

Figure 6: Removal of Trivial Baselines
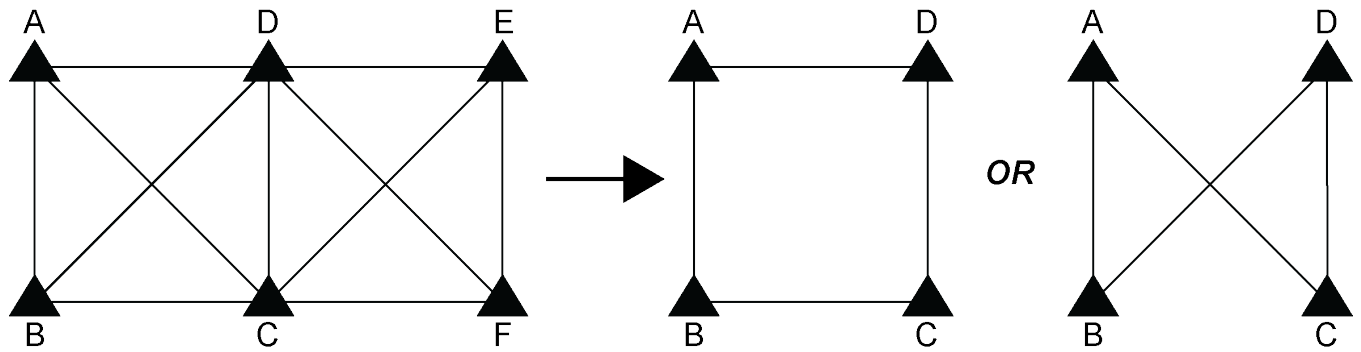
GrafNet removes the trivial baseline by setting their session status to *Ignore*. It is possible to unignore any session by simply changing its status back to *Unprocessed*. GrafNet tries to keep the sessions that are of best quality. The following criteria is considered:

- The amount of time the baseline was surveyed.

- The frequencies used in the surveying of the session.

- The length of the baseline.

- The number of connecting baselines to the two end-points.

As shown in the figure *Figure 5: Network with Trivial Baselines Removed* on the previous page, GrafNet automatically excluded AC, BD, CE, and DF. It then forms a single loop for each of the time periods. DC is a baseline with a duplicate session.

4.4.4 Unignore All Sessions

This feature changes the status of all ignored sessions from *Ignore* to the status they had previously.

4.4.5 Compute Loop Ties

In some cases, the Traverse or Network residuals show a poor fit. The first step is to ensure that the network is minimally constrained, which means that there should only be one 3-D control point, or one horizontal and one vertical control point. Convert any additional control points to check points. See *Add / Remove Check Points* on page 142 or *Show Data Manager* on page 159 for help.

For a constrained network, the poor fit indicated by large residuals can be caused by the following two issues:

- Incorrect antenna heights used for multiple occupations of a point

- Baseline solution is incorrect (by far the most common cause)

In some cases, it is obvious from the traverse output which baseline is the culprit, but often further investigation is required. The *Compute Loop Tie* feature makes such examinations much easier. By adding the vectors of a loop within the network, discrepancy values are formed in the east, north and height directions. For a loop without problems, these values should be near zero. If not, then one of the baselines forming the loop has an error. Loops can be formed in the following two ways:
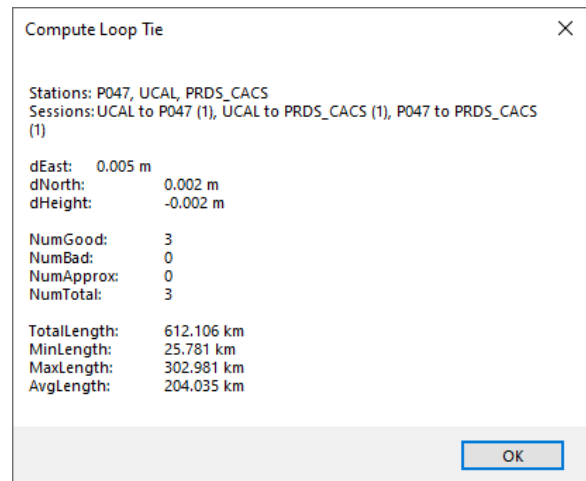
- Selecting stations

- Selecting baselines forming loops

Make the selections on the map or select the stations or sessions in the *Data Manager* window. After selecting the first station or session, hold down the *Ctrl* key while selecting the remaining ones. Selection must be continuous, but it does not matter if the loop is formed in the clockwise or counter-clockwise direction. Once a complete loop is formed, select *Process | Compute Loop Tie* or right-click on one of the selections in the *Data Manager* window and select *Compute Loop Tie*. A window containing various statistics for the closed loop is displayed.

4.4.6 Network Adjustment

GrafNet contains a least-squares network adjustment that can be accessed through *Process | Network Adjustment*. External network adjustment programs, such as StarNet, also support GrafNet's output format.

Network adjustments are a means to more accurately compute each station's coordinates given the solution vectors computed for each session / baseline. Such an adjustment uses the X, Y and Z vector components and also utilizes the 3 x 3 covariance matrix which is the standard deviation values + coordinate-to-coordinate correlation. Using least squares, the errors are distributed based on a session's estimated accuracy. More weight is placed on sessions with lower standard deviations.

Advantages

In the traverse solution, each station's coordinates are determined using one session from one previous station. For networks with redundant measurements, which is usually the case, this will lead to sub-optimal determination of a station's coordinates. The network adjustment does a much better job of distributing errors. This makes it less sensitive to errors as long as a session's estimated accuracy is representative of actual errors. Thus, the network adjustment always produces the best station coordinates.

Another advantage of the network adjustment over the traverse solution is that it computes a standard deviation for each station coordinate, which is not possible in a traverse solution.

Before running the network adjustment, all baselines must have already been processed. Only good (green) baselines will be used, unless otherwise specified with the *Utilize sessions labeled 'BAD' in network adjustment* option.

Settings

Scale Factor
Error ellipses should appear on the stations in the *Map Window*. These ellipses are scaled by this option.

Confidence Level
The level of confidence (in percent) of the error ellipse can also be adjusted. This uses a statistical 2-D normal distribution. Changing this value does not alter the final coordinates, but it will scale the final standard deviations and covariance values. For example, 95% results in a standard deviation scale factor of 2.44.

Output Options

Controls what is output from the network solution.

Show input stations and vectors
Outputs all the control and check points and their vectors. The coordinates are output in geographic form.

Show orthometric height for output coordinates
Requires that you provide a geoid file, which can be selected with the *Browse Geoid* button.

Other output options include outputting the estimated standard deviations.

To process the network adjustment, click the *Process* button. This step must be performed each time a project is re-loaded.

Show output coordinates
Output coordinates may be shown in *Geographic* (latitutde/longitude/ellipsoidal height), *Grid* and/or *ECEF* coordinates.

View output file on completion
Lets you view the ASCII solution file once the adjustment has been made.

Using Multiple Control Points

When multiple control points are present, it is suggested to initially use only one. This prevents errors in the existing control from causing otherwise correct session vectors not to fit. Therefore, large tie errors in the traverse solution or large residuals in the network adjustment are attributed to GNSS processing and not poorly fitting base station coordinates.

The variance factor is only truly valid as a scale factor for a minimally constrained adjustment. See *Interpreting the network adjustment report* on the next page for information about interpreting the output. Once satisfied with the quality of the GNSS data and the fit of the session vectors, you can add additional control points with *File | Add / remove Control Points* or by right-clicking on a station in the *Map Window* and selecting *Add as Control Point*.

Since the network adjustment is a least-squares adjustment, it will move control point coordinates to make the network fit better. This is an undesirable effect for many applications. To avoid it, give control points very low standard deviations. The default value is 5 mm, which might have to be lowered if the network fit is poor. Lowering the standard deviation to 0.0001 m forces the control point to "stay put". A standard deviation of zero is not allowed. Change the standard deviation for control points via *File | Add and Remove Control Points*. Select the desired control point and click *Edit*.

How to Process with the Network Adjustment

1. After successfully processing all of the baselines within GrafNet, access the network adjustment via *Process | Network Adjustment*.

   > ⓘ The network adjustment only accepts session data flagged as *Good*. Other baselines will be ignored unless otherwise specified with the *Utilize sessions labeled 'BAD' in network adjustment* option.

   For the initial run of the network adjustment, the scale factor should be set to 1.0. This will not scale the final standard deviations to match observed session vector residuals. See *Variance Factor and Input Scale Factor* on page 152 for more information.

2. Click the *Process* button to compute a network adjustment solution. Any errors encountered are displayed.

3. If there are any "hanging stations", which are stations that are not attached to the network or are attached by a *Bad* baseline, the adjustment will fail. It is possible to change the status of the baseline to *Good* from the *Sessions* window in *Data Manager*.

4. A .net file is created, which can be viewed via *Process | View Network Adjustment Results*.

> (i) The network adjustment must be re-run if you have reprocessed sessions or changed the station configuration.

Interpreting the network adjustment report

The network adjustment output is an ASCII file that can be viewed and printed from GrafNet.

Input Stations

This is a list of the control (GCP) and check points in the project. Their associated geographic coordinates and standard deviations are also shown.

Input Vectors

This is the ECEF vector components for each session that has a *Good* status. The lower triangular of the ECEF covariance matrix is shown next to the vector components. The value in brackets is the standard deviation of the ECEF X, Y or Z axis in meters. The covariance values are not scaled by the Scale Factor entered at the start.

Output Vector Residuals

This indicates how well the session vectors fit in the network. The residual values are shown in local level, where RE is the east axis residual, RN is the north axis residual and RH is the Z axis residual. These values are expressed in meters and should ideally be a few centimeters or less. Larger values may be acceptable for larger networks.

In addition to the residual values, a parts-per-million (PPM) value is shown. This indicates the size of the residuals as a function of distance. 1 PPM corresponds to a 1 cm error at a distance of 10 km. The baseline length is also shown in kilometers. Baselines less than 1 km can have large PPM values. This is because other errors such as antenna centering become an influencing issue. This might not indicate an erroneous session solution. The last value is the combined (east, north and up) standard deviation (STD).

Check Point Residuals

If check points have been added, this section shows how well the known coordinates compare to those computed by the network adjustment.

Control Point Residuals

This section shows the adjustment made to control point residuals. When just one control point is used, then the adjustment will always be zero. With two or more points, the adjustment depends on the input control point standard deviation and the session vector standard deviations.

Output Station Coordinates

This shows the computed coordinates for each of the stations both in geographic and ECEF coordinate systems. The output datum is indicated by the *Datum* parameter at the top of this file.

Output Variance / Covariance

This section shows the local level (SE, SN and SZ) standard deviations along with ECEF covariance values. The standard deviation values are scaled by both the input scale factor and the statistical (confidence) scale

factor. The covariance values are only scaled by the input scale factor. If error ellipse parameters are desired, then the *Write Coordinates* feature should be used.

Variance factor

See *Variance Factor and Input Scale Factor* below for information.

Using Horizontal and Vertical Control Points

GrafNet supports horizontal and vertical control points in addition to full 3-D control. To utilize either option, you must have available 1-10 m accurate coordinates for the unknown axes (that is, Z for horizontal control and latitude and longitude for vertical control). These coordinates can be obtained from the single point solution or from an initial network adjustment run using just one 3-D control point. The latter method is normally used.

Variance Factor and Input Scale Factor

The variance factor is at the bottom of the network adjustment report. It is the ratio between the observed residual errors and the estimated session (baseline) accuracies. Ideally, the variance factor should be 1.0. This indicates that the estimated errors correspond well to observed errors. A variance factor less than 1.0 indicates that the estimated errors are larger than the observed errors (that is, session standard deviations are pessimistic). Most often, a value greater than 1.0 denotes that observed errors are larger than estimated accuracies (that is, session standard deviations are optimistic) unless the GPS data is very clean. Thus, low variance factors are normally desired. Very large variance factors of 100+ normally indicate abnormally large session errors (that is, a very poor network fit), and you should try and investigate the source of the problem before using the coordinates produced.

The variance factor can also be used to scale the station standard deviations to more realistic values. The network adjustment is initially run with a unity scale factor. The resulting variance factor can then be inserted in the scale factor field from the first screen. After running the network adjustment with this new scale factor, you will notice larger or smaller standard deviations and that the new variance factor should now be ~1.0. This procedure will only work for a minimally constrained adjustment (that is, one 3-D control point, or one 2-D and one 1-D control point).
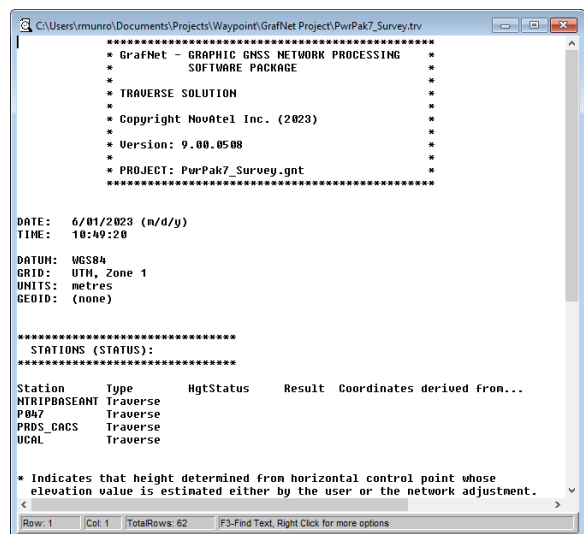
4.4.7   View Traverse Solution

GrafNet computes a traverse solution automatically after processing each session. The traverse report is written to a TRV file and opened automatically in GrafNet's internal viewer.

Traverse Solution

Prior to generating the network adjustment report, it is recommended that you view the traverse report. The traverse report contains useful information, particularly a report on any loop, check and duplicate ties in the project.

For stations that have more than two baselines connecting, a loop tie is computed. This means that there is more than one possible transfer of coordinates to this point. The first transfer is used for coordinate generation. Subsequent transfers are used to compute loop ties. The loop ties are good for locating erroneous baselines but they are an accumulated error of many baselines to that point. This means that the last baseline in that traverse leg may not be the erroneous one. These ties also give a good indication of the accuracy of the network, but the magnitude of the errors will be larger than the

network adjustment residuals. The traverse method accumulates errors (closures) while the network adjustment spreads these errors across the whole network.

4.4.8   View Processing Report

This option displays the RPT file containing information about the stations, sessions, baselines and observations. It also gives a summary for each session processed.

4.4.9   View All Sessions

This option will display all sessions in the Data Manager.

4.4.10   View All Observations

This option will display all observations in the Data Manager.

4.4.11   View All Stations

This option will display all stations in the Data Manager.

4.5   Options Menu

The following options are available on the *Options* menu.

4.5.1   Global Settings

This feature accesses the global processing options. The options set here are applied to all baselines in the project, overriding any settings that may have been customized for individual baselines. The processing settings for individual sessions can be customized by right-clicking on the session in the *Data Manager* and selecting *Options*.

4.5.2   Sessions Settings (Shown in Data Manager)

This feature allows you to set the processing options for only the sessions currently appearing in the *Data Manager*. In order to use this feature, the *Sessions* window of the *Data Manager* must be open.

4.5.3   Grid Options

See *Grid/Map Projection* on page 123 for information regarding this feature.

4.5.4   Geoid Options

This feature allows specification of the project geoid. The geoid selected is used as a reference when outputting orthometric heights in the Traverse Solution and network adjustment.
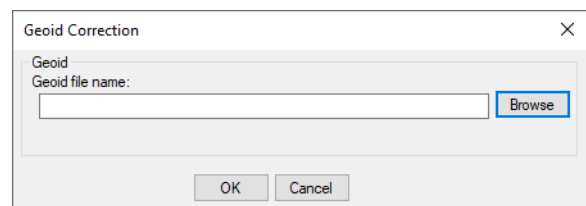
4.5.5 Preferences

GrafNet Display

See *Preferences* on page 60 for information regarding any options not described here.

> ##### Zoom Display Settings
> The *Ellipse scale* field changes the size of the error ellipses. Projects covering large areas might have large ellipses and decreasing the values for all three zoom scales (0, 1, and 2) will make the ellipses smaller.
>
> ##### Error Ellipse Display
> Controls whether session and station ellipses are plotted. Station ellipses are only generated after a network adjustment. The crosses on the ellipse option shows the axes of the error ellipses.
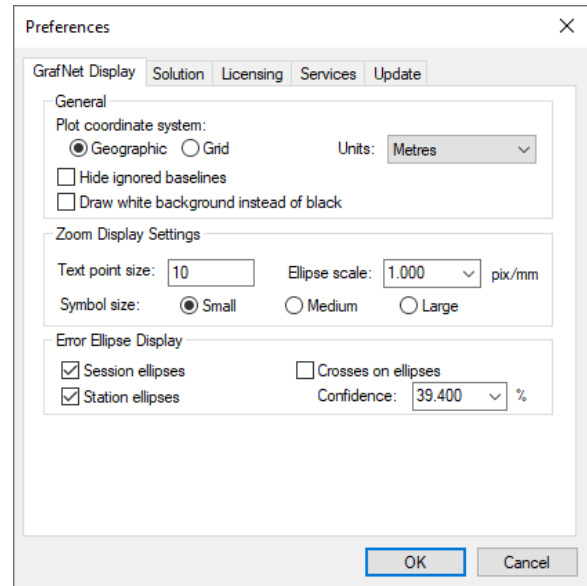
Solution

Allows the user to choose their default datum and simultaneous forward/reverse processing.

4.6 Output Menu

4.6.1 Export Wizard

The Export Wizard facilitates customized ASCII exporting of processed results. Manufacturer profiles are included with the installation, however they can be edited and new profiles can be created.

When creating or editing an export profile, you can choose from over 150 source variables. Units, precision, column width, field separators, and header/footer information can all be customized.

You can choose to export all processed epochs, interpolated results for features/stations (such as camera marks) or static sessions. The Waypoint application will try to auto-detect which *Source* to use given the data in your project. For example, if more than 80% of the remote file is static, the *Source* will default to *Static Sessions*. If more than a handful of features are loaded into the project, the *Source* will default to *Features/Stations* as this is presumably the data of interest.

How to create a new Export Wizard profile

1. Click the *New* button and type a unique name for the profile.

   Alternatively, it may be quicker to modify a copy of an existing profile that contains most of the variables required.

2. In the *Define Profile* window, add the desired variables from the *Source Variables* list. All source variables are organized under various headings from a pull down list.

   After selecting a variable, click *Add* to add the variable to the bottom of the list or *Insert* to add the variable above the highlighted variable in the list. See the table in *Output Variables* on page 233 for a list of variables available for output.

3. After you are finished adding all the necessary components of the profile, click the *OK* button to save the profile.

Tips for creating an export profile

- To create a profile that does not have spaces between variable entries and the record is based on column width, follow these steps:

  1. Go to the *Define Profile* window.
  2. Click the *Field Separator* button.
  3. Select *None* under *Separation Character* to remove any field separators in the file.

  > (i) The same procedure can be used to have the output be space or comma delimited.

- To change the file by adding a header/footer of a specific format, the *Header/Footer* button in the *Define Profile* window allows you to add headers/footers from a predefined text file. If specific characters are needed to designate the start and end of a text file, strings of characters can also be added to the beginning and end of the file.

- For formats that require no decimal points to be shown in the file, like SEGP1 and Blue Book, the decimal points can be removed by going into the chosen variable, clicking the *Format* button in the *Define Profile* window, and enabling the *Do not print decimal point* option.

- If you need a text string label to designate the type of record being printed/read, for example, $--GLL, *81*, open up the *Miscellaneous* variable category and add the *User Text String* variable. Change the format of the string by entering the text needed for the label and select the *Fixed Width* option if the format is dependent on column width.

- Review the *Header/Footer* button. You can put in your own header file and display datum/projections information, column descriptions and titles. A special character can also be inserted at the start of each header line making it easier for other software to skip past the header. At the bottom of the file, you can add errors/warnings of any problems that were encountered and processing summary information.

> The table in *Output Variables* on page 233 describes the many variables that you can include in your output profiles. Not all variables are available for use with each source.

How to use the Export Wizard

1. By default, the export file name is the same name and directory as the project file (.proj), except with a .txt extension. The file name and directory of the export file can be changed using the *Browse* button.

2. Ensure the *Source* has been set correctly according to what you would like to export.

   Choosing *Epochs* produces an output record for each common measurement epoch for the entire trajectory.
   Choosing *Features/Sessions* exports results, linearly interpolated between the nearest two epochs, for any camera marks, features or stations loaded.

   Static Sessions is accessible provided static sessions have been collected. Choosing this option exports the final post-processed (best converged) solution for each static session.

3. Choose an export profile and select *Next* to start the Wizard. Depending on the variables in the profile, the Wizard will prompt you for any needed information. For example, if the chosen export wizard profile contains orthometric heights, you will be prompted to locate a Waypoint geoid file (.wpg).

4. Click *Finish* on the last page of the Wizard. If *View ASCII output file on completion* was selected on the last page of the Wizard, the text file will open within the internal ASCII viewer.

Creating an Output File

The following is an example of the Export Wizard dialogs that appear when exporting *Epochs* using the *Geographic* profile.

Note that when exporting *Features* or *Static Sessions*, or when choosing a different export profile, you may see different dialogs. This is because the Wizard only prompts you for the required information according to your selections.

Select Output Coordinate Datum

The first page of the Wizard provides an opportunity to apply a datum transformation during export. This is required if the datum you wish to export to is not the same as the processing datum.

Filter Output/Estimated Accuracy Scaling

Results can be filtered using either the quality numbers or combined (3D) standard deviation. An example of when it is useful to filter by quality number is when only fixed integer solutions are to be exported. In that case, apply a value of 1 for the quality number filter.

This dialog also provides an opportunity to scale the standard deviations output to a higher confidence interval. By default 1-sigma values are output. However due to the conservative measurement weighting applied to code, carrier, and Doppler measurements, they are not by nature overly optimistic.

Export Definition Complete

The last page of the Wizard provides a summary of the file name and path where the file will be written and the *Source* to be exported. The export variables within the profile are also summarized. Optionally, the output file can be viewed after export by selecting *View ASCII output file on completion*.
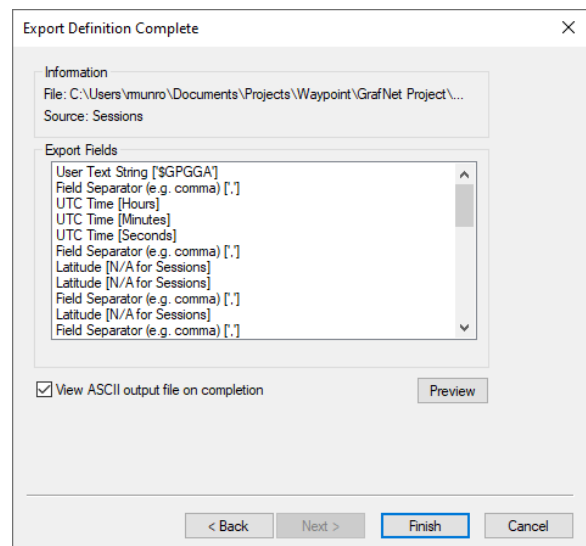
4.6.2   Output to Google Earth

See *Export to Google Earth* on page 119 for information regarding this feature.

4.6.3   Export to DXF

Only the options specific to GrafNet are discussed here. For descriptions of the other options, see *Export to DXF* on page 120.

Station Error Ellipses

Displays the error ellipses around each station and is only available if a network adjustment has been completed.

Baseline Error Ellipses

Only the baselines that were processed.

Error ellipse scale factor

The ellipse scale factor scales the ellipses so they will be visible if you do not see them in the DXF file.

4.6.4   Export to STAR*NET

This feature creates an EXP file which is accepted as input to MicroSurvey's STAR*NET network adjustment software.

4.6.5   Build HTML Report

Creates an HTML file containing a bitmap version of any plot that is currently open, including the Map Window. These HTML and BMP files are saved to the HTML folder contained within the project folder. The HTML file also contains information regarding the processing run(s) used to generate the plots.

4.6.6   Show Map Window

Map Window

If you have unintentionally closed the GrafNet Map window, it can be re-opened using this option.

Mouse Usage in Map Window

Either double-clicking or right-clicking on a station, gives you access to several options, which are described in *Show Data Manager* on the next page.

> (i) Clicking on a station displays the station in the Stations window of the Data Manager, while clicking on a baseline will display that baseline and any duplicates in the Sessions window.
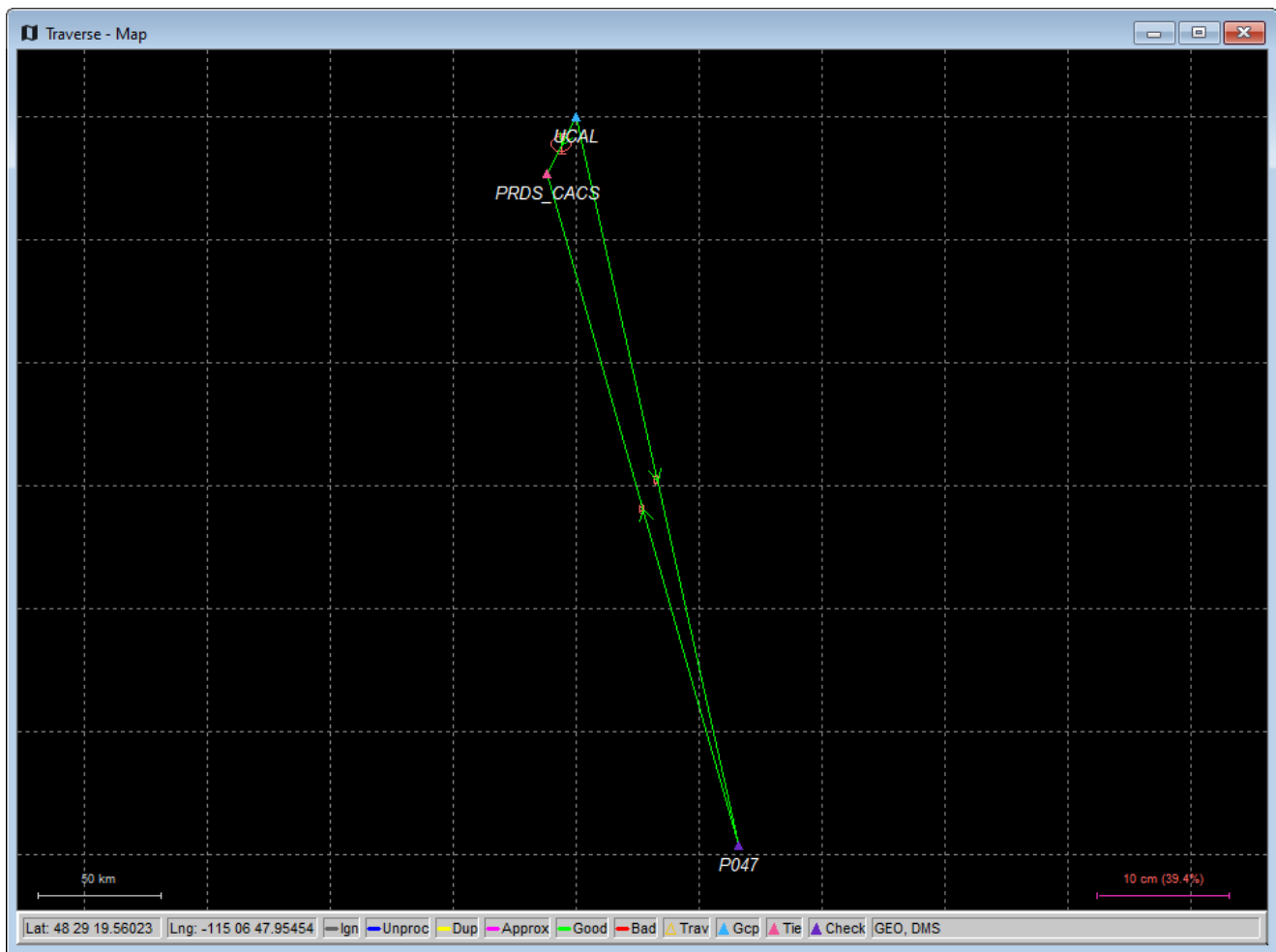
4.6.7   Show Data Manager

Data Manager

This interactive window allows for easy display and organization of all project data.

Observations Window

The *Observations* window displays information regarding all the observation files (GPB) that are included in the project.

Columns in the Observations Window

Name
Name of the station (entered or scanned during data import).

AntHgt
Antenna height for the period at which the observations were made.

AntType
Name of absolute antenna model applied.

File
File, path and name of the GPB observation file.

#
If multiple observation periods are contained within one GPB file, this column indicates which of those observation periods is being referred to. Observation periods are numbered sequentially in the order they appear in the GPB file.

Length
Length of the observation period in HH:MM:SS.

Start Date
Date when the observation period started in MM/DD/YYYY.

Start Time
Time of day at which the observation period started in HH:MM:SS.

Receiver
Name of receiver as decoded to the GPB file.

Freq
Indicates whether data is single or dual frequency.

Int(s)
Interval, in seconds, at which the data was logged.

Right-click Options for Observations in Project Window

The following options are available by right-clicking on an observation:

View
Displays the *Information* window for the observation file.

Edit
Opens the *Add / Edit Observation* window, in which the station name and antenna information can be corrected.

Delete Observation
Removes the observation period from the project.

View GPB File
Opens the observation file in *GPB Viewer*.

View STA File
Opens the station file for the associated GPB file.

View Ephemeris File
Opens the ephemeris file (EPP) for the associated GPB file.

Plot Coverage
Opens the *File Data Coverage* plot for all observations in the project. See *Common Plots* on page 109 for information regarding this plot.

Plot L1 Satellite Lock
Launches the *L1 Satellite Lock / Elevation* plot. See *Common Plots* on page 109.

Plot L2 Satellite Lock
Launches the *L2 Satellite Lock / Elevation* plot. See *Common Plots* on page 109.

Show Sessions using Observation
Displays all sessions involving the observation period in the *Sessions* window.

Expanding the *Observations* branch in the *Data Objects* window on the left-hand side of the *Data Manager* allows the observations to be displayed individually in the *Observations* window. Expanding each observation in the *Data Objects* window displays the station that was observed.

Stations Window

The *Stations* window displays information regarding all the points observed in the network.

Columns in the Stations window

Name
Name of station.

Type
See *Table 13: Station Color Legend* on the next page for information on station types.

Latitude
Latitude of the station.

Longitude
Longitude of the station.

EllHgt
Ellipsoidal height of the station.

Source
Indicates whether the station coordinates are from the traverse solution or the network adjustment.

#Files
Number of observations periods for that station.

TotalLen
Total observation time made at that station.

A(mm)
Semi-major axis of error ellipse at that station, as defined from the network adjustment.

B(mm)
Semi-minor axis of error ellipse at that station, as defined from the network adjustment.

DH(mm)
Estimated height standard deviation.

Right-click Options in the Stations Window

The following options are available by right-clicking on a station:

View Solution
Displays the solution from traverse computation and network adjustment, if valid.

Add as Control Point
Allows you to define the station as a control point.

Add as Check Point
Allows you to define the station as a check point.

Edit Control / Check Point
Allows for editing of the input coordinates of stations already defined as check or control points.

Toggle between Control / Check Point
Switches status between control point and check point.

Add to Favourites
Adds the station to the *Favourites* list, using the computed coordinates.

Remove Processing Files
Removes all observation files logged at that station from the project.

Show Observations
Displays all observation periods for that station in the *Observations* window.

Show Connecting Sessions
Displays all sessions involving that station in the *Sessions* window.

Expanding the *Stations* branch in the *Data Objects* window on the left-hand side of the *Data Manager* allows for the stations to be displayed individually in the *Stations* window. Further expanding each station in the *Data Objects* window displays all observation files in which the station was observed.

Table 13: Station Color Legend

Color	Description
Cyan	**Control point** – A reference station with known coordinates
Dark Purple	**Check point** – Station has known coordinates available, but they will only be used as a check. Comparisons are found in the TRV file. The network adjustment output file (NET) also shows check point residuals.
Light Purple	**Tie point** – Two or more sessions are connected as remotes to this station via the traverse solution. The TRV file will show traverse ties.
Yellow	**Traverse point** – No tie information can be computed as there is only one avenue for establishing coordinates for this station.

Sessions Window

The *Sessions* window displays information regarding all the sessions in the network.

Columns in the Sessions Window

Name
Name of the session, which serves to indicate the direction of coordinate transfer.

SD
Standard deviation, in mm, of the baseline as calculated by the Kalman filter.

Reliability
Reliability of the fixed static solution, if available.

RMS
RMS of the fixed static solution. Applies only to fixed baselines.

SolType
Indicates solution type. See *Static Solution Types* on page 136 for a full description.

Time
Length of session, in *hh:mm* format.

Dist
Baseline distance, in km.

Status

Solution status. See *Static Solution Types* on page 136 for descriptions.

From

Indicates the *FromStation*.

To

Indicates the *ToStation*.

#

If multiple sessions exist for the same baseline, indicates which session is being referred to.

Right-click Options in the Sessions Window

The following options are available by right-clicking on a session:

View Results

Displays the results of forward or reverse processing, or the combined solution.

View Information

Displays the *Information* box for the session.

View File

Opens the message log, static summary, trajectory output or configuration files.

Plot

Launches the plots discussed in *Common Plots* on page 109.

Options

Allows access to the processing settings so that they can be set individually for this session. See *Process Menu* on page 73 for additional information.

Override Status

Manually sets the status of the session. See *Static Solution Types* on page 136 for information. Ignore redundant or troublesome sessions. You can assign a *Good* status to a failed baseline if the solution is, in fact, correct. Only do this on closed loop networks.

Process

Processes the session independently of all others.

Delete

Deletes all of the processing files related to that session, or deletes either the forward or reverse solution.

Compute Azimuth / Distance

Displays the *Distance and Azimuth* box for the session.

Show To / From Stations

Displays both stations in the *Stations* window. See *Stations Window* on page 161 for information.

Show To / From Observations

Displays both station *Observations* windows. See *Observations Window* on page 159 for information.

Expand the *Sessions* branch in *Data Objects* of the *Data Manager* to display individual sessions in the *Sessions* window.

Control / Check Points Window

The *Control / Check Points* window displays information regarding all the stations assigned known coordinates in the network.

Columns in the Control / Check Points Window

Name
Name of the station.

Type
Type of control or check point, which can be 3D, horizontal or vertical.

Latitude
Known latitude of the station.

Longitude
Known longitude of the station.

EllHgt
Known ellipsoidal height of the station.

HzSD
Standard deviation of the known horizontal coordinates. Applies only to 3D and horizontal control points.

VtSD
Standard deviation of the known vertical coordinate. Applies only to 3D and vertical control points.

dE
Easting residual between input coordinate and traverse solution at check point.

dN
Northing residual between input coordinate and traverse solution at check point

dH
Height residual between input coordinate and traverse solution at check point

Right-click Options in the Control / Check Points Window

The following options are available by right-clicking on a control or check point:

View Info
Displays the *Information* box for the point.

Edit
Allows for editing of known coordinates via the *Add / Edit Control Point* window.

Toggle between Control / Check
Switches status between control point and check point.

Show Station
Displays the station in the *Stations* window. See *Stations Window* on page 161 for information.

Expanding the Control or Check Points branches in the *Data Objects* window on the left-hand side of the *Data Manager* allows for the points to be displayed individually in the *Control / Check Points* window.

4.6.8   Baselines Window

The *Baselines Window* displays information regarding all the sessions in the network. See *Columns in the Sessions Window* on page 162 for a description of the columns displayed and the options available by right-clicking on a session.

Expanding the *Baselines* branch in the *Data Objects* window on the left-hand side of the *Data Manager* allows for the sessions to be displayed individually according to the baseline they are expanded from. Expanding

each baseline in the *Data Objects* window allows for the display of any individual session in the *Sessions* window.

Table 14: Baseline Color Legend

Color	Description
Blue	**Unprocessed** – Normally represents an unprocessed baseline. In some cases when processing quits prematurely, the color may remain blue. The return error message can be viewed by right-clicking the baseline in the *Sessions* window of the *Data Manager* and selecting *View Information*.
Grey	**Ignored** – Indicates a session that is to be ignored.
Yellow	**Duplicate** – Indicates a duplicate baseline, meaning that it has more than one session. Such baselines are plotted with two colors, with one being yellow. The second color represents the best solution among all the sessions for the duplicate baseline.
Red	**Bad / Failed** – Represents a baseline where processing failed one or more tests and is thus deemed to be bad. Right-click the baseline in the *Sessions* window of the *Data Manager* and select *View Information* to determine the problem. If you are confident that the solution is okay, the status can be changed from the Sessions window as well. You can control when float solutions pass via the *Solution* tab under *Options	Preferences*.
Green	**Success** – Indicates a session that has passed all tests.

4.7   Tools Menu

See *Tools Menu* on page 121 for information regarding the features available through this menu.

4.8   Help Menu

4.8.1   Help Topics

Opens an offline HTML version of this manual.

4.8.2   Support Web Portal

Opens the online documentation portal.

4.8.3   Check for update...

Provided an internet connection, this feature checks the Waypoint server to see if any software updates are available. If so, they can be directly downloaded and installed.

4.8.4   Download manufacturer files

Provided an internet connection, use this option to download the latest manufacturer files from Waypoint's FTP site. The files downloaded are listed below.

List of files downloaded when manufacturer files are updated

manufact.dcb
List of the differential code biases, in nanoseconds, between the P1 and C/A code for each satellite. Used by PPP and applied to any receivers that track the C/A code on L1 (as opposed to P1). If this file is out of date it may limit PPP solution convergence.

manufact.xml
List of base stations available for the *Download* utility. This is usually updated monthly.

manufact.dtm
List of datums, ellipsoids and transformations between datums.

manufact.fvt
List of *Favourites* and the groups they are contained in.

manufact.grd
List of manufacturer defined grids.

manufact.utc
List of UTC leap seconds and dates they were or will be introduced.

manufact.atx
Composite absolute antenna calibrations in ANTEX (new IGS) format.

manufact.cim
List of the IMU conversion profiles.

manufact.imu
List of the supported IMU error models.

manufact.pgr
List of the plot groups and the plots included in the groups.

4.8.5 NovAtel Waypoint Products

This option opens the Waypoint Software page in your default web browser. From here, more information on Waypoint Products can be found, including information regarding the latest version, notices of training seminars, links to FAQ/training materials and technical reports.

4.9 About

This window displays information about the software version, build dates and copyright information.

This section describes the following utilities that are included with Waypoint's software:

- *GPB Viewer Overview* below
- *Concatenate, Slice and Resample Files* on page 171
- *GNSS Data Converter Overview* on page 172
- *Raw IMU Data Converter* on page 195

This section goes through each menu of their interfaces. Step-by-step instructions for first time users are also included.

5.1 GPB Viewer Overview

GPB files are in a binary format and cannot be viewed with a normal text editor. *GPBViewer* allows you to both view and edit your raw GNSS data.

5.1.1 File Menu

The following options are available on the *File* menu.

Open

Any GPB file can be opened with this feature.

Close

This feature closes the GPB file without exiting from *GPBViewer*.

Save As

If you are making modifications to a GPB file (such as the static/kinematic flag), this feature can be used to create a copy of your file prior to making any changes. An associated ephemeris file (.epp) will automatically be written when using the *Save As* feature.

Export to Waypoint Trajectory

This feature saves data from the binary GPB file into a Waypoint trajectory file.

Load Alternate Ephemeris File

The GPB viewer uses ephemeris data to calculate and display satellite elevations at each epoch. If no ephemeris data was decoded, an alternate ephemeris file can be loaded here. Ephemeris data is required when performing certain editing functions within the GPB viewer.

The *Download Service Data* utility can be used to download and convert GNSS broadcast ephemeris data. See *Download Service Data* on page 128 for more information.

Exit

Exits the program.
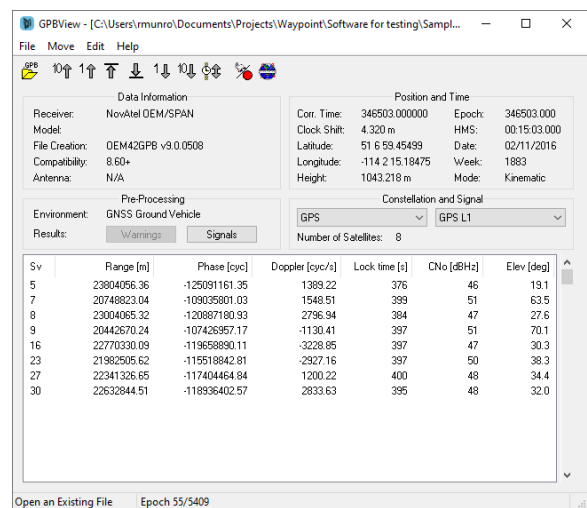
5.1.2   Move Menu

Forward n and Backward n

Scrolls through *n* epochs in the direction indicated.

Start of file and End of file

Moves to the first and last epoch in the file.

> ⓘ It is easier to scroll through the GPB file using the shortcut keys, specified under the *Move* menu beside each option.

Search

Moves to a specific location in the file. You can specify an epoch number or a time, in either GPS seconds of the week or GMT format.

5.1.3   Edit Menu

Several options under this menu make permanent changes to the GPB file. Prior to doing so, you may wish to create a copy of the original file using the *Save As* option under the *File* menu.

Switch Static/Kinematic...

The processing mode (static or kinematic) is determined by the static/kinematic flag decoded to the GPB file. This flag is normally set during decoding, however it can be altered after decoding using this option.

> ⓘ The static/kinematic flag is found in the Position Information section of the GPB Viewer.

Process Mode

Specifies whether the mode is to be set to *Static* or *Kinematic*.

Epochs to Convert

Determines which epochs will be switched.

All Epochs

Switches all epochs from the start of the file onwards or from the current location onwards, depending which starting point is specified under *Start Location* options.

Number of Epochs

Converts the specified number of epochs, subject to the chosen starting point. You can also convert a specific time range that is based on GPS seconds of the week.

Specified Time Range

Converts the specified time range based on GPS seconds of the week.

Time Ranges from File

Inputting start and stop times to a text file is an efficient method of converting multiple ranges of epochs.

When converting from static to kinematic, use the following format: Start(SOW) Start(week) End(SOW) End(week).

When converting from kinematic to static, use: ID Start(SOW) Start(week) End(SOW) End (week) Description.

In both cases, do not write a header to the file.

Start Location

Use in conjunction with *All epochs* and *Specified Epochs*, under *Epochs to Convert*. Determines the starting point of the conversion.

Week Number

Week numbers are extracted during conversion of raw GNSS data. In the rare event that a receiver does not output a week number or outputs an incorrect week number, it may not be possible to post-process the data. This issue should be addressed with the GNSS receiver manufacturer, but it can also be fixed here.

Recalculate Position and Time

If position records are requested when logging data, the Raw GNSS Converter writes them to the GPB file. If no position records are logged, the pre-processing functions will compute a single point C/A only solution during data conversion. This is done in order to plot the unprocessed trajectory to the Map window and, more importantly, is also used to determine whether ionospheric processing should be engaged as the average baseline distance is checked prior to processing.

GNSS ephemeris data is required should the pre-processing functions attempt to recalculate missing position records. If neither position records nor ephemeris data were requested when logging data, no position records are written to the GPB file. If this is the case, recalculating position and clock data for a file can be done using this option. You may be required to load
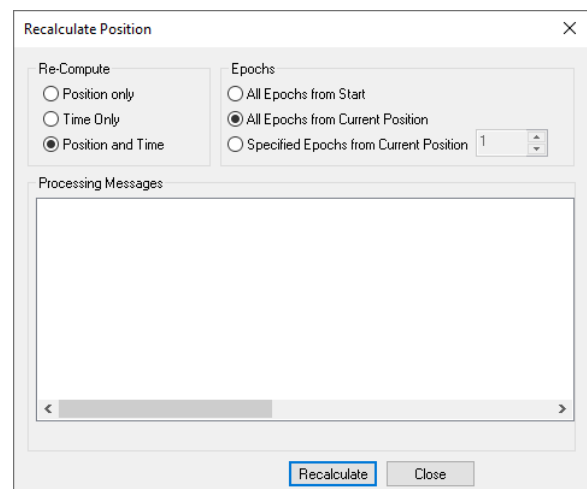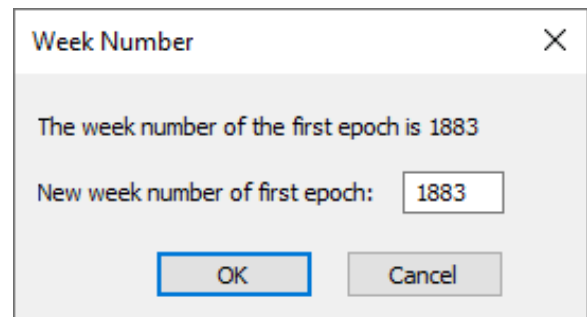
alternate ephemeris data (*File | Load Alternate Ephemeris*), should this be the reason no position data is present in your original file. See *File Menu* on page 167 for more information.

Disable Satellite(s)

Disabling satellites is normally done within the *Satellite/Baseline Omissions* section of the processing options. See *Satellite/Baseline Omissions* on page 77 for more information. This is the recommended method of ignoring satellite data, however in rare cases a bad satellite may be causing other problems in the data such as a grossly erroneously computed clockshift value. In this case, it may be necessary to disable the satellite in the GPBViewer and then recompute the clockshift.

Disabling a satellite through the GPB viewer cannot be undone, unless a copy of the original GPB file was saved using *File | Save As*, or by re-decoding the raw GNSS data.
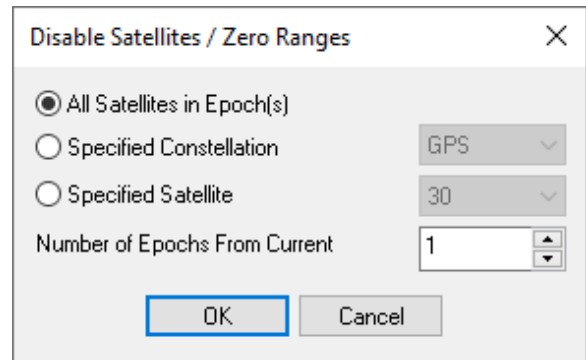
Recalculate Doppler

Missing or erroneous Doppler measurements are normally fixed automatically by the converter's pre-processing functions. Therefore recalculating Doppler from the GPB Viewer is not a commonly needed function. Prior to version 8.40, when pre-processing functions were introduced, this feature was more commonly needed.
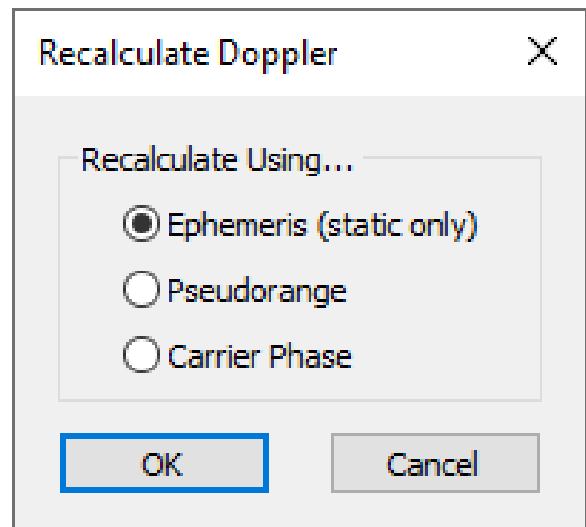
Edit GPS L2C Phase Correction

L2C measurements are affected by an offset relative to L2 P/Y signals. This offset is dependent not only upon the manufacturer of your GNSS receiver, but also the firmware version used. The raw GNSS converter applies a default L2C offset for each supported data type, however this may need to be adjusted for your specific receiver.

The correct L2C offset is needed in order to correctly resolve integer carrier phase ambiguities. If the incorrect L2C offset is applied, integer ambiguity resolution will fail even in ideal conditions. That is, even with a short distance between base and remote antenna, low multipath and unobstructed tracking of all available GNSS satellites, correct ambiguity resolution becomes impossible.

The RINEX converter applies a default L2C offset of 0 cycles, as it is common for receiver manufacturers to remove the L2C offset during conversion to RINEX. If this is the case, measurements will be decoded as L2C
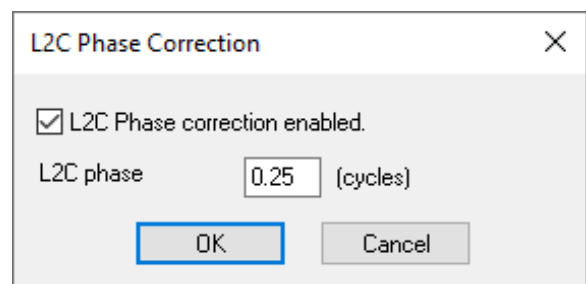
(due to a flag set within the raw GNSS data), however the correction needs to be zeroed as it has already been removed by third party software.

If converting RINEX data that is known to contain a non-zero L2C offset, or any receiver which requires a different L2C offset than is applied by default, the correct value can be entered either during conversion (see the receivers global conversion options) or after conversion using this feature. There are four possible L2C offset values regardless of receiver manufacturer or firmware version: -0.25, 0.25, 0.5 or 0.

5.2   Concatenate, Slice and Resample Files

This utility is available from *File | GPB Utilities*. This utility can be used to:

- Combine multiple GPB files from the same receiver into one. This could be used to combine multiple hourly observations into a larger file prior to processing.

- Resample static data to a higher interval (1 Hz to 10 Hz), or reduce the sampling rate of any file (static or kinematic) to a lower rate (10 Hz to 1 Hz).

- Produce multiple time sliced output files from one larger file (e.g. produce 24 individual hourly files from a single 24 hour file).

5.2.1   Input Files

Use the *Add* button to locate the input GPB file(s). To concatenate several files, add them all at once as they will be automatically sorted chronologically.

5.2.2   Output File(s)

Determines how the creation and naming of new files is handled. For concatenating files, use the *Combine all Input Files into one file* option and provide a name for the output GPB file. For resampling or splicing multiple files, use the *Process Input Files individually* option. The name of the created output files depend on the name of their respective input file and the suffix that is specified. To break up a file into multiple files of n minutes, enable the *Break up input files into time sliced output files* option.
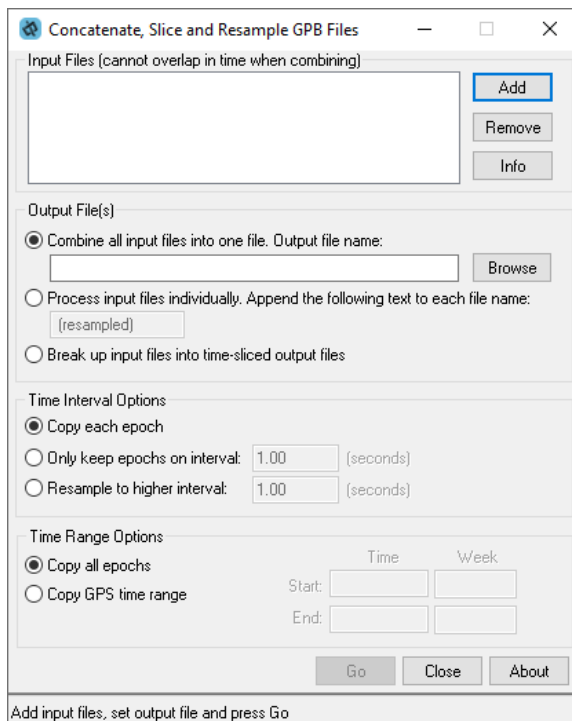
5.2.3   Time Interval Options

Copy each epoch
Select this if the data rate of the output file is to match that of the input file.

Only keep epochs on interval
Use this when a file is resampled to a lower data rate. The interval specified determines which epochs are copied into the output file.

Resample to higher interval
Use this when a file is resampled to a higher data rate.

> (i) Resampling can only be performed on static data.

5.2.4 Time Range Options

Determines the range of time that is to be used for the creation of the new file. *Copy all epochs* is generally for resampling purposes. Splicing a file requires the selection of either *Copy Time Range* or *Copy Epoch Numbers*.

5.3 GNSS Data Converter Overview

This utility converts raw GNSS data into GPB format. Supported receiver formats are documented in *Supported Data Formats* on the next page.

5.3.1 Convert Raw GNSS data to GPB

Receiver Type/Format

Choosing a receiver type prior to conversion applies a file filter commonly associated with data from the receiver type. You may add or modify the default filters for any receiver type.

After browsing to the folder containing GNSS data to be converted, it is recommended to leave the receiver type as *Unknown/AutoDetect* and use either the *Auto Add All* or *Auto Add Recursively* functions, which are described below.
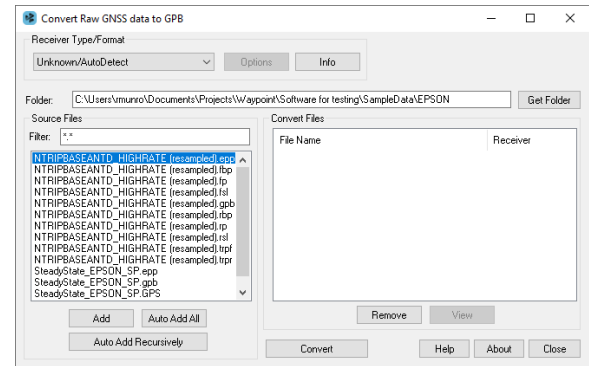
> ##### *Options*
> To view decoding options for individual receiver types, choose the receiver type from the pull down menu and then select *Options*. Any changes made to the decoding options are remembered and applied in the future.
>
> You may wish to access the global options of a particular receiver in order to change the static/kinematic decoding preference or the default L2C offset.
>
> ##### *Info*
> Provides information on the version and status of the DLL file used for the conversion.

Get Folder

Use the *Get Folder* button to browse to a folder containing raw GNSS data.

Source Files

Lists the files in the folder with extensions matching those specified in the *Filter* field.

> ##### *Add*
> When selecting *Add* on a *Source File* with the *Receiver Type/Format* as *Unknown/Auto Detect*, the raw GNSS data file is scanned and auto-detection of the receiver type is attempted. If auto-detection is successful, it will be added for conversion within the *Convert Files* section. If auto-detection is unsuccessful, it may be necessary to first choose the Receiver Type/Format and then select *Add* on the Source File in order to attempt to convert it.
>
> ##### *Auto Add All*
> Auto-detects all the files in the *Source Files* list for conversion.
>
> ##### *Auto Add Recursively*
> Auto-detects all files in the immediate folder and its subfolders. The maximum number of files that can be added is 256.

Convert Files

This lists all the files to be converted. Prior to conversion, all files will be assigned a gray/white icon. Once the files have been converted, the icon changes to either a green check mark if conversion succeeds or a red X if conversion fails. Options available here including the following:

Remove
Removes the selected file from the *Convert Files* window.

View
Opens the converted GPB file within the GPB Viewer.

5.3.2   Pre-processing Checks

After conversion to GPB, pre-processing checks are performed in order to help ensure the file is ready for post-processing. Functions performed by the pre-processing checks include:

- Ensuring positions are present in the GPB file. If no position records have been requested during data logging, pre-processing computes a code only single point solution. This computed position is then written to the GPB file. This position is used to display the unprocessed trajectory and determine whether ionospheric processing will be automatically engaged. The latter option depends on the scanned baseline distance prior to processing.

- Ensuring an accurate clock shift has been decoded to the GPB file. This is needed in order to correctly process and export results relative to GPS time. If this value is incorrect by a large amount it can result in gross processing errors.

- Automatic rejection of impossibly large or small pseudorange observations, which can occur due to unusual receiver signal tracking issues. Also automatically rejected are any duplicate PRN numbers (which will cause a processing failure), duplicate epochs and other unusual raw data problems.

- Computing missing Doppler measurements. A common issue with some RINEX data is that Doppler measurements are provided as 0 for the entire file. As the Doppler is used for cycle slip detection, this would result in large processing errors if it is uncorrected. Pre-processing checks ensure any missing Doppler measurements are recomputed from the C/A code.

- Static/Kinematic detection. The pre-processing checks attempt to set the static/kinematic flag appropriately. For surveys with significant position changes from epoch to epoch (such as would be the case for a kinematic survey) data is converted as *kinematic*. Conversely, if no significant movement is detected from epoch to epoch, portions of the data may be converted as *static*. The ability of the pre-processing check to reliably detect static data largely depends on the noise level of the unprocessed (or computed) position data.

- Processing environment detection. The unprocessed position records are scanned in order to determine if the dynamics are characteristic of aerial, ground vehicle or marine surveys. The detected environment is written to the header of the GPB file, which an appropriate processing profile (*GNSS Airborne*, *GNSS Ground Vehicle*, or *GNSS Marine*) to automatically load the first time the processing dialog is accessed for a project.

5.3.3   Supported Data Formats

This section discusses the data formats that are currently supported by the *Raw GNSS Data to GPB* converter. This information includes the conversion options and supported records.

Ashtech B-File

The following describes the options available for this converter:

Ashtech Receiver Type

Selects the receiver used to collect the data. If auto-detect is unsuccessful, then select the receiver manually.

General Options

Perform pre-processing checks
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on the previous page for more information.

Detect static/kinematic from site name
Looks in B-file for data tagged as static or kinematic, using *????* site ID.

Verbose messaging mode
Displays additional warning messages.

Extract stations information from Ashtech 'D-File'
Various Thales hand-held controllers output a D-file containing features and antenna height information. Enable this checkbox to utilize this information.

Ignore SBAS Satellites
Newer versions of Ashtech firmware have resulted in the logging of raw data from SBAS satellites, which are not supported by the software. As such, this option should be left enabled to ensure the data is not written to the GPB file.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

UTC Options

Use the following UTC time
Changes the GPS to UTC time offset from the current nominal value to a user-defined value. Normally used for GLONASS processing if no UTC is contained in the data.

Correct GPS time in D-FILE for UTC offset
D-files can have GPS or UTC time. This option changes time from UTC to GPS.

Dfile Options

Chain Repeated Station Marks into 1 Static Session
Combines sessions that are repeated in the Seismark software into one session.

Do NOT Chain Marks that are more than n seconds apart
This value controls the time tolerance used in the previous setting. If two static periods are marked less than the amount apart, they will be combined.

Table 15: Files Supported for Ashtech B-File

File	Type	Comment
B*ssss*A*yy.jjj*	Measurements	Required.
E*ssss*A*yy.jjj*	Ephemeris	Required.
S*ssss*A*yy.jjj*	Static Station Information	Written to STA file.
D*ssss*A*yy.jjj*	Kinematic Station Information	Written to STA file.
PHOTO.DAT	Event Mark	Read in directly by software.

Thales files follow a strict naming convention. In the table above, *ssss* is the site name, *yy* is the last two digits of the year, and *jjj* is the day of the year.

Antenna heights may need to be edited within the feature editor if not kept constant, as the Thales format only allows for one value.

You might need to select the receiver type manually.

Ashtech Real-Time

This decoder converts Thales Real-Time (DG16, G12, or Super C/A) data. The real-time data forms when data is logged externally from the receiver using a custom data logger.

The following describes the options available for this converter:

General Options

> ***Perform pre-processing checks***
> If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 173 for more information.
>
> ***Decode MACM messages and ignore others***
> If both MBN/MCA and MACM records exist, only the MACM will be decoded.
>
> ***Decode old-style MBN locktime***
> Some older units (for example, Sensor II) output locktimes with a different resolution. Enable this option to output the locktime value.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

Parthus MACM Settings

These settings are for logging MACM records:

> ***Decode Parthus style MACM record***
> Parthus units (NS100, GSU-1, and GSU-2) utilize the MACM record. However, due to timing differences, its implementation is not compatible. Therefore, enable this option.
>
> ***Data interval adjustment***
> The GSU-1 benefits greatly by having the correct data interval entered, while the GSU-2 is best processed using the raw time and having the base interpolated onto these times. See *Concatenate, Slice and Resample Files* on page 171 for help.

UTC Offset for GLONASS decoding

The following option is available for those users logging GLONASS measurements:

> ***Use the following UTC offset for decoding***
> Allows you to define your own UTC offset rather than using the nominal or detected value. Important for GLONASS processing.

Alternate Ephemeris

> ***Use alternate ephemeris***
> Enable this option if ephemeris data is missing (for example, Parthus, GSU-2) to specify an outside EPP file.

Table 16: Records Supported for Ashtech Real-Time

Record	Type	Comment
MBN	Measurements	One of these records is required; The MBN or MACM records are recommended for G12 receivers. The MACM record is designed for high-speed data output that is, 10 Hz or 20 Hz, under limited bandwidth conditions. The ITA record is for G8 receivers, while the MPC is for dual frequency receivers, such as those in the Z-series. The MCL record is an L2 codeless record.
MCA	Measurements	
MPC	Measurements	
MCL	Measurements	
MACM	Measurements	
ITA	Measurements (C/A Code Only)	
CT1	Measurements (C/A Code Only)	
CT2	Measurements (C/A Code and L1 Phase)	
CT3	Measurements (C/A Code, L1 Phase and C/A Code)	
SNV	Ephemeris	Required.
SNG	Ephemeris (GLONASS)	Required for GLONASS users.
PBN	Position	Marks the end of the record. Recommended for GrafNet users.

Javad and Topcon

The following describes the options available for this converter:

Perform pre-processing checks
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 173 for more information.

Use locktime records for cycle slip detection
Locktimes from the Javad receiver are used instead of those computed by the decoder. Enable this if Javad locktimes are problematic.

Use SAVE marker to store sites to .sta file
Markers are saved to an STA file.

Verbose messaging mode
Alerts you of warnings and errors that have occurred.

L2C phase correction
If your receiver logs L2C measurements, then the phase offset must be entered. If you are unsure, you can disable its usage.

Static/Kinematic Mode
This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.
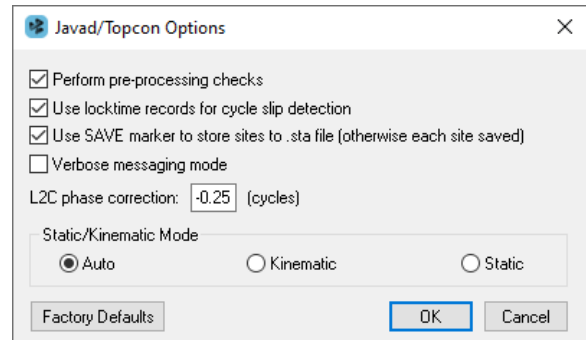
Table 17: Records Supported for Javad and Topcon

Record	Type	Comment
RC, rc	C/A Code Measurement Block	One of these is required, RC suggested
1R, R1, 1r, r1	L1 P-Code Measurement Block	
3R, R3, 3r, r3	L2 C/A Code Measurement Block	
2R, R2, 2r, r2	L2 P-Code Measurement Block	2R suggested
5R, R5, 5r, r5	L5 Code Measurement Block	
PC, CP, pc, cp	L1 Phase Measurement Block	CP suggested
1P, P1, 1p, p1	L1P Phase Measurement Block	
P2, 2P, p2, 2p	L2 Phase Measurement Block	2P suggested
3P, P3, 3p, p3	L2C Phase Measurement Block	
5P, P5, 5p, p5	L5 Phase Measurement Block	
DC, 1d, 2d, 3d, 4d, 5d, D1, D2, D3, D5	Doppler Measurements	DC Recommended

Record	Type	Comment
CE, EC, 1E, E1, 2E, E2, 3E, E3, 5E, E5	SNR (C/N0)	
FC, F1, F2, F3, F5	Signal Lock Flag	
GE	GPS Ephemeris	Required
NE	GLONASS Ephemeris	Required for GLONASS users
NN	GLONASS satellite system list	Required for GLONASS users
EN	Galileo Ephemeris	Required for Galileo users
TO	Clock Offset	
TC	Locktime	
PO, PV, VE	Position	PV Recommended
SI	PRN List	Required
RD	Receiver Date	Required
~~	Receiver Time	Required
==, XA, XB	Event	
UO	GPS UTC offset	
DO	Clock drift	
SX	Extended Satellite Index	
IO	GPS Ionospheric Parameters	
||	Epoch End	
rE	Reference Epoch	

Leica System 500

This decoder handles data from the System 500 or SR530 receivers.

The following describes the options available for this converter:

Perform pre-processing checks
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 173 for more information.

Combine multiple (.o00,.o01…) files into single GPB file
Leica SR530 receivers write all data into separate files from one session with different extensions. Enabling this option will combine files from one session into one GPB file

Verbose message information output
Alerts you of additional warnings and errors that have occurred.

Insert kinematic markers after gaps and stations
Ensures that static sessions are properly created.
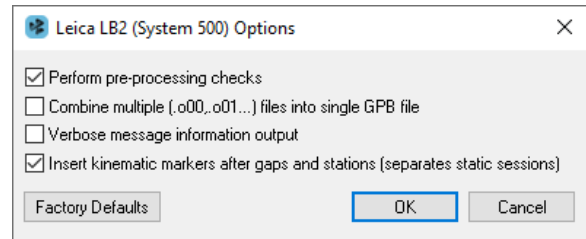
Table 18: Records Supported for Leica 500

Record	Type	Comment
19	Measurements (compressed)	One of these records is required;
20	Measurements (expanded)	record #20 is needed if Doppler data is of interest.
15	Ephemeris	Required.
10	Position	Recommended for GrafNet users.
13	Station/Event Mark	Written to STA file.
9	Antenna Height	Written to STA file.
108	Antenna Type	Written to STA file.

Leica System 1200

The following describes the options available for this converter:

> ### *Perform pre-processing checks*
> If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 173 for more information.
>
> ### *Combine multiple observation files*
> Leica receivers write data into separate files from one session with different extensions. This option combines files from one session into one GPB file

Break multiple observations into separate GPB files (requires 5 minute data gap)
If you have logged data from multiple sessions and/or days, enable this option to create a separate GPB file for each.

Verbose message mode
Alerts you of additional warnings and errors that have occurred.

Static/Kinematic Mode
This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.
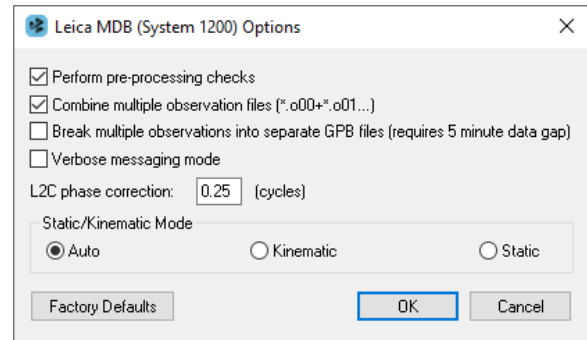
Table 19: Records Supported for Leica 1200

Record	Type	Comment
119	Measurements	One of these records is required, but #120 is recommended
120	Measurements	
115	Ephemeris	Required.
110	Position	Recommended for GrafNet users.
109	Antenna Height	Written to STA file.
113	Event Mark	Written to STA file.

NavCom NCT

The following describes the options available for this converter:

Perform pre-processing checks
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 173 for more information.

Verbose messaging mode
Allows you to see additional warning messages.

Static/Kinematic Mode
This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.
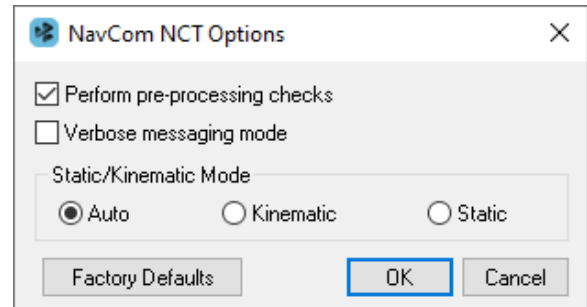
Table 20: Records Supported for NavCom NCT

Record	Type	Comment
0xB0	Measurements	Required.
0x81	Ephemeris	Required.
0xB1	Position	Recommended for GrafNet users.
0xB4	Event Marker	Written to STA file.

NavCom Sapphire

The following describes the options available for this converter:

Perform pre-processing checks
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 173 for more information.

Verbose messaging
Alerts you of additional warnings and errors that have occurred.

Static/Kinematic Mode
This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.
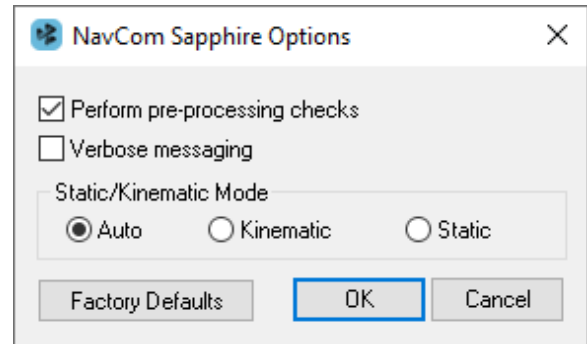
Table 21: Records Supported for NavCom Sapphire

Record	Type	Comment
MEAS1B	Measurements	Required.
EPHEM1B	Ephemeris	Required.
ALM1B	Almanacs	Required for GLONASS users.
PVT1B	Position	Recommended for GrafNet users.

BAE Systems / NovAtel CMC

This decoder handles data from the NovAtel CMC AllStar and SuperStar receivers.

The following describes the options available for this converter:

Perform pre-processing checks
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 173 for more information.

Verbose messaging mode
Displays additional warning messages.

Static/Kinematic Mode
This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.
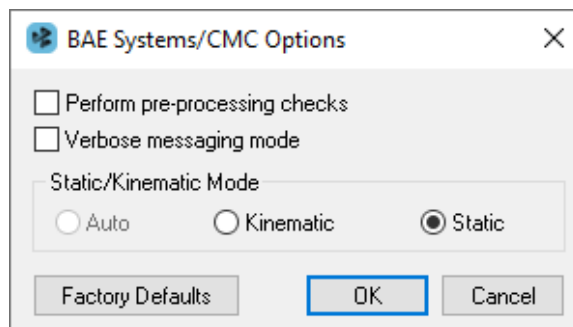
Table 22: Records Supported for BAE Systems / NovAtel CMC

Record	Type	Comment
ID #23	Measurements	One of these records is required, but ID #23 is strongly recommended over the others.
ID #13	Measurements (old style)	
ID #14	Measurements (old style)	
ID #15	Measurements (old style)	
ID #16	Measurements (old style)	
ID #20	Position	Recommended for GrafNet users; should be requested last.
ID #22	Ephemeris	Required.

NovAtel OEM / SPAN

The following describes the options available for this converter:

[NovAtel OEM/SPAN Options dialog box image]

Perform pre-processing checks
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 173 for more information.

Decode RANGE*_1 log
This is applicable to SAASM receivers and to those logging data from both the primary and secondary antenna when using a dual antenna ALIGN system.

Enable this option to decode the RANGEB_1, RANGECMPB_1, RANGECMP2B_1 or RANGECMP4B_ 1 log to GPB. Please note, only one of these messages should be requested.

Verbose messaging mode
Displays additional warning messages.

Create separate file for each MARKNTIME record
Enabling this option decodes the event marks from multiple inputs into separate station files.

Show receiver status event warnings
Displays any receiver status event warnings output by the receiver. These messages can be helpful for determining the cause of data logging anomalies.

Write GPB gaps to summary
Displays a summary of any data gaps in the GPB file. For this feature to report a gap, the epochs must be missing from the GPB file. If epochs exist in the GPB file, but do not contain any measurements, they will not be counted as gaps.

Create trajectory files for supported records
This option generates a separate FP file for each supported position record that is logged. The files can be loaded into a Waypoint project or used to compare against the post-processed solution.

Ignore clock model status for MARKNTIME records
Decode MARKNTIME records regardless of clock model status. This option may be useful for indoor surveys with no GNSS.

L2C phase correction
The default L2C correction for NovAtel receivers is 0.25 cycles. This value will be written to the GPB header and applied prior to processing. Correctly applying the L2C offset is required to correctly resolve carrier phase integer ambiguities in differential processing.

Static/Kinematic Mode
This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

SPAN/IMU and Distance Measurement Instrument (DMI)
These options are only for users of NovAtel's SPAN Technology and is only available in Inertial Explorer.
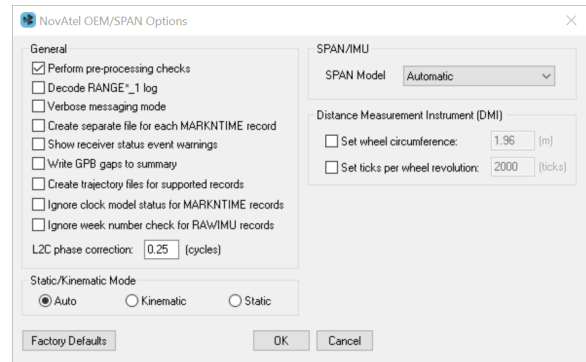
Logging data

See the *SPAN Data Logging for Inertial Explorer* application note (available at hexagondownloads.blob.core.windows.net/public/Novatel/assets/Documents/Bulletins/APN-076-

SPANLoggingEI8-7/APN-076-SPANLoggingEI8.7.pdf) for detailed instructions and examples for data logging.

Table 23: Records Supported for NovAtel OEM/SPAN below contains a full list of supported records, both for GNSS only and GNSS+INS (NovAtel SPAN) applications. Below are suggestions on how to request these logs from your NovAtel receiver or SPAN system.

Table 23: Records Supported for NovAtel OEM/SPAN

Record	Type	Comment
VERSIONB (ID #37)	Version information for all components of a system	Optional
RANGEB (ID #43)	Measurements (expanded)	One of these records is required. Do not request more than one as duplicate measurements will result.
RANGEB_1	Measurements (expanded)	
RANGECMPB (ID #140)	Measurements (compressed)	
RANGECMP2B (ID #1273)	Measurements (compressed)	
RANGECMP2B_1	Measurements (compressed)	
RANGECMP4B (ID #2050)	Measurements (compressed)	
RANGECMP4B_1	Measurements (compressed)	
RAWEPHEMB (ID #41)	GPS Ephemeris	Required
GLOEPHEMERISB (ID #723)	GLONASS Ephemeris	Required if logging GLONASS data
BDSEPHEMERISB (ID #1696)	BeiDou Ephemeris	Required if logging BeiDou data
GALEPHEMERISB (ID# 1122) GALINAVEPHEMERISB (ID# 1309) GALFNAVEPHEMERISB (ID# 1310)	Galileo Ephemeris	Required if logging Galileo data
QZSSEPHEMERISB (ID# 1336)	QZSS Ephemeris	Required if logging QZSS data

Record	Type	Comment
BESTPOSB (ID #42) RTKPOSB (ID #141) OMNIHPPOSB (ID #495) PSRPOSB (ID #47)	Position	Only required for comparison of real time trajectory to post-processed
MARKTIMEB (ID #231)	Event Mark Time	Written to STA file
MARK**n**TIMEB (ID #1130, 616, 1075, 1076) TAGGEDMARK**n**PVAB (ID #1258, 1259, 1327, 1328)	Event Mark Time	Written to STA file
IONUTCB (ID #8)	Ionospheric Parameters	Optional. If present will be written to EPP file. This will be applied in single frequency processing but ignored in dual frequency processing.
RAWIMUSB (ID #325) RAWIMUSXB (ID #1462)	IMU Measurements	SPAN users only. RAWIMUSXB is recommended. Only one of these is required, do not log both as duplicate measurements will result.
BESTLEVERARMB (ID #674)	IMU to GNSS Lever Arm	SPAN users only. IMUTOANTOFFSETSB is recommended as both primary and (if applicable) secondary lever arms are logged. Lever arms must be set first through the SETIMUTOANTOFFSET and SETIMUTOANTOFFSET2 commands.
BESTLEVERARM2B (#1256)	IMU to secondary lever arm	
IMUTOANTOFFSETSB (ID #1270)	Primary and secondary lever arms	
BESTGPSPOSB (ID #423) BESTGNSSPOSB (ID# 1429) IMURATEPVAB (ID #1778) IMURATEPVASB (ID #1305) INSPVAB (ID #507) INSPVASB (ID #508) INSPOSB (ID #265) INSPOSSB (ID #321)	Position, velocity and attitude	Optional for SPAN users only. Can be used to compare real time and post-processed solutions.
SETIMUTYPE (ID #569)	IMU Type	Optional for SPAN users only. Recommended if RAWIMUSB is logged, not needed if RAWIMUSXB is logged.

Record	Type	Comment
VEHICLEBODYROTATION (ID #642)	Angular offset between vehicle frame and SPAN frame	SPAN users only. Allows vehicle body rotation to be automatically read by Inertial Explorer.
MARK**n**PVAB (ID #1067, 1068, 1118, 1119)	Event Mark Time	Written to STA file
HEADINGB (ID #971) HEADING2B (ID #1335)	Heading from dual antenna	Written to HMR file. the HEADINGB log has been deprecated and replaced with HEADING2B.
SITEDEFB (ID #153)	Site definitions	
TIMEDWHEELDATAB (ID #622)	Odometer Measurements	SPAN users only. Written to DMR file.
WHEELSIZEB (ID #646)	Circumference of Wheel	SPAN users only. Written to DMR file.
RAWDMIB (ID #2269)	Odometer Measurements	Only applicable to SPAN firmware 7.07 and newer. Written to DMR file.
DMICONFIGB (ID #2270)	DMI Operation Configuration	Only applicable to SPAN firmware 7.07 and newer. Required if logging RAWDMI. Velocity input is not currently supported.

RINEX

Receiver INdependent EXchange (RINEX) data is a standard, manufacturer independent ASCII format for raw GNSS data. Most GNSS manufacturers provide tools to convert their native data to RINEX format, or third party utilities may be available. If your receiver type is not directly supported, first convert the data to RINEX using a third party utility and then import the RINEX data to the project.

The following describes the options available for this converter:

General Options

Perform pre-processing checks
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 173 for more information.

Static/Kinematic Mode

This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.

Advanced Options

L2C phase correction
If the RINEX file contains L2C measurements, then the phase offset must be set. The default value is 0 cycles, as most manufacturers remove the offset at the firmware level, but this is not always the case.

Shift time to user interval
The decoder attempts to determine the data interval by reading the header or scanning the observation file. If this fails, enable this option to force an interval. Setting the interval here may be required for successful conversion of RINEX data that contains data gaps in the first minute of the file. This is because data gaps early in the file may cause errors computing the expected data interval.

Doppler Source

These options allow you to choose a method of obtaining Doppler measurements.

Automatic/use raw values
This is the default value and will decode the Doppler measurements as provided in the RINEX file when available. If no Doppler values are present, they will be automatically recomputed using the C/A code.

Calculate from carrier phase
Calculates Doppler from the change in carrier phase measurements between consecutive epochs. This will produce an average velocity with comparatively little noise as compared to recomputing Doppler values from the pseudorange. This option is generally preferred over using pseudorange measurements, however pseudorange measurements should be used if surveying in challenging environments where carrier phase tracking is poor.

Calculate from pseudorange
Recomputes Doppler using pseudorange measurements between consecutive epochs. This will produce average velocity values between measurement samples that are relatively noisy. Use this option if Doppler values are missing in the RINEX observation file and if carrier phase tracking is poor.
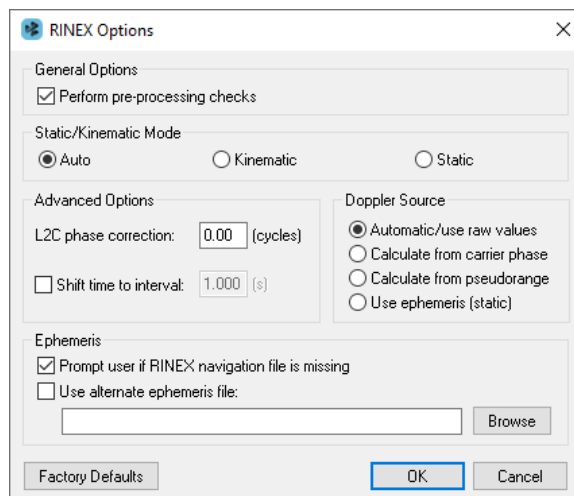
Use ephemeris (static)

Recomputes Doppler using predicted satellite motion from the broadcast ephemeris. This requires the data to be static and is the best method for recomputing Doppler data for static data.

Ephemeris

Prompt user if RINEX Nav file is missing

If a navigation file is either missing or has a different name than the observation file, you will be prompted to select a navigation file. This may either be a RINEX navigation file or a Waypoint EPP file.

Use alternative ephemeris file

You may define a path to the navigation file manually. This will override the previous option.

Table 24: Files Supported for RINEX

File	Type	Comment
*.yyo, *.obs, *.rxo	Measurements	One of these files is required.
*.yyd	Measurements (compressed)	
*.yyn, *yyp, *.nav, *.rxn	GPS Ephemeris	Required.
.yyg	GLONASS Ephemeris	Required only if logging GLONASS data.
.yyc	BeiDou Ephemeris	Required only if logging BeiDou data.

The yy in the file extensions found in the table above designate the last two digits of the year that the observations were collected in.

RTCM Version 3.0

The following describes the options available for this converter:

Perform pre-processing checks
If enabled, data is scanned after conversion to correct potential issues. See _Pre-processing Checks_ on page 173 for more information.

Verbose messaging mode
Displays additional warning messages.

Static/Kinematic Mode
This option controls how the static/kinematic flags are set in the final GPB file. _Auto_ will set the entire file static or kinematic according to the detected processing environment.
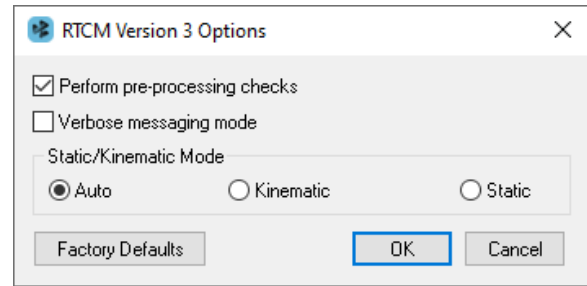
Table 25: Records Supported for RTCM Version 3.0

Record	Type	Comment
1002	L1 only measurements	One of these is required for GPS users.
1004	L1/L2 measurements	
1010	GLONASS L1 only measurements	One of these is required for GLONASS users.
1012	GLONASS L1/L2 measurements	
1013	System Parameters	Required to extract GPS week number.
1019	GPS Ephemeris	Recommended for GPS users.
1020	GLONASS Ephemeris	Recommended for GLONASS users.

The RTCM decoder has been expanded to support MSM4, MSM5, MSM6 and MSM7 messages, which can be used for multi-constellation operation. See _Table 26: Supported MSM Messages_ below.

> ⓘ MSM6 and MSM7 messages are more precise than MSM4 and MSM5 messages, but also larger. MSM4 and MSM6 do not have Doppler measurements.

Table 26: Supported MSM Messages

Record	Type	Comment
1074	MSM4 GPS measurements	One of these is required for GPS users.
1075	MSM5 GPS measurements	
1076	MSM6 GPS measurements	
1077	MSM7 GPS measurements	

Record	Type	Comment
1084	MSM4 GLONASS measurements	One of these is required for GLONASS users.
1085	MSM5 GLONASS measurements	
1086	MSM6 GLONASS measurements	
1087	MSM7 GLONASS measurements	
1094	MSM4 Galileo measurements	One of these is required for Galileo users.
1095	MSM5 Galileo measurements	
1096	MSM6 Galileo measurements	
1097	MSM7 Galileo measurements	
1114	MSM4 QZSS measurements	One of these is required for QZSS users.
1115	MSM5 QZSS measurements	
1116	MSM6 QZSS measurements	
1117	MSM7 QZSS measurements	
1124	MSM4 BeiDou measurements	One of these is required for BeiDou users.
1125	MSM5 BeiDou measurements	
1126	MSM6 BeiDou measurements	
1127	MSM7 BeiDou measurements	
1013	System Parameters	Required to extract the week number.
1019	GPS Ephemeris	Recommended for GPS users.
1020	GLONASS Ephemeris	Recommended for GLONASS users.
1045	Galileo F/Nav Ephemeris	Recommended for Galileo users.
1046	Galileo I/Nav Ephemeris	
1044	QZSS Ephemeris	Recommended for QZSS users.
1042	BeiDou Ephemeris	Recommended for BeiDou users.

Septentrio SBF

The following describes the options available for this converter:

Perform pre-processing checks
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 173 for more information.

Verbose messaging mode
Displays additional warning messages.

Extract multi-antenna data
Usage of this option is required to extract GNSS data from one antenna at a time, if logging data from a multi-antenna system.

Static/Kinematic Mode
This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.
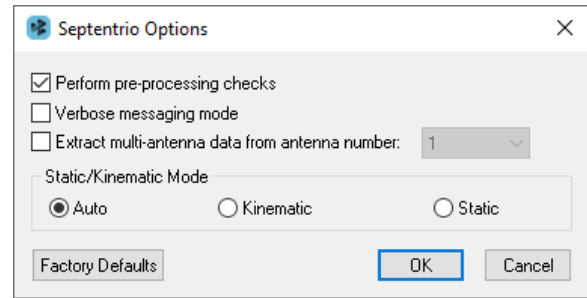
Table 27: Records Supported for Septentrio SBF

Record	Type	Comment
4027	Measurements	One of these records is required
5889	Measurements	
5890	Measurements (compressed)	
5944	Measurements	
5891	GPS ephemeris	Required
4044	GLONASS ephemeris	Required for GLONASS users
4002	Galileo ephemeris	Required for Galileo users
4081	BeiDou ephemeris	Required for BeiDou users
5902	Receiver Setup	Automatically adds antenna profile
5904	Position	Recommended for GrafNet users
5924	Event	Written to STA file

u-blox UBX

The following describes the options available for this converter:

Perform pre-processing checks
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 173 for more information.

Verbose messaging mode
Displays additional warning messages.

Static/Kinematic Mode
This option controls how the static/kinematic flags are set in the final GPB file. *Auto* will set the entire file static or kinematic according to the detected processing environment.
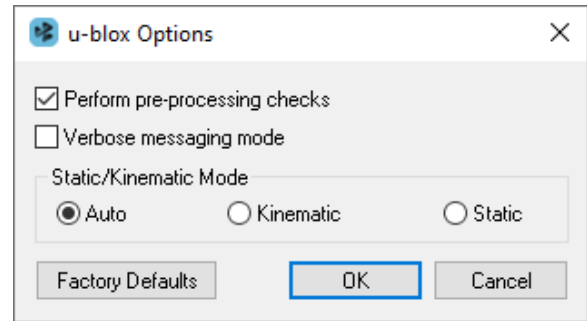
Table 28: Records Supported for u-blox UBX

Record	Type	Receiver Format	Comment
ID #10	Measurement	ANTARIS	Required
ID #31	Ephemeris	ANTARIS	Required
UBX-RXM-RAWX (0x02 0x15)	Measurement	M8 and F9	Required
UBX-RXM-SFRBX (0x02 0x13)	Ephemeris	M8 and F9	Required
UBX-NAV-POSLLH (0x01 0x02)	Position	All	Recommend
UBX-NAV-CLOCK (0x01 0x22)	Clock	All	Recommend
UBX-TIM-TM2 (0x0D 0x03)	Mark	All	If collecting time stamped events

5.4   Raw IMU Data Converter

The *IMU Data Converter* utility is a Win32 application program that converts custom data formats into a generic raw IMU data format. This utility is available exclusively to users of Inertial Explorer and may be accessed from *File | Convert | Raw IMU Data to Waypoint Generic (IMR)*.

5.4.1   Inertial Explorer Data Formats

In theory, virtually any IMU sensor can be used with Inertial Explorer. The only requirement is that the data be logged in the format provided in this section, which allows easy decoding with the *IMU Data Conversion* utility described in *Waypoint IMU Data Conversion* on the next page.

The following table presents the binary structure required by the Raw IMU Converter.

ⓘ   The variable types in the table below are taken from the C standard library header "cstdint"/"stdint.h".

Table 29: Binary Structure of Raw Data

Word	Size (bytes)	Type	Description
GpsTime	8	double	time of the current IMU rate measurements in GPS seconds of the week
GyroX	4	int32_t	scaled X-body axis gyro measurement as an angular increment or angular rate
GyroY	4	int32_t	scaled Y-body axis gyro measurement as an angular increment or angular rate
GyroZ	4	int32_t	scaled Z-body axis gyro measurement as an angular increment or angular rate
AccelX	4	int32_t	scaled X-body axis accelerometer measurement as a velocity increment or acceleration
AccelY	4	int32_t	scaled Y-body axis accelerometer measurement as a velocity increment or acceleration
AccelZ	4	int32_t	scaled Z-body axis accelerometer measurement as a velocity increment or acceleration

5.4.2   Waypoint IMU Data Conversion

Input/Output Files

Refers to the names and locations of all input and output files.

Input Binary IMU File
Click the *Browse* button to locate the raw IMU data file.

Output Waypoint Binary File
By default, the binary output file created is given the same filename as the input file, but with an IMR extension. It is saved to the directory containing the input file.

Path
Displays the path to the directory containing the input file. All output files created by this utility are saved to this directory.
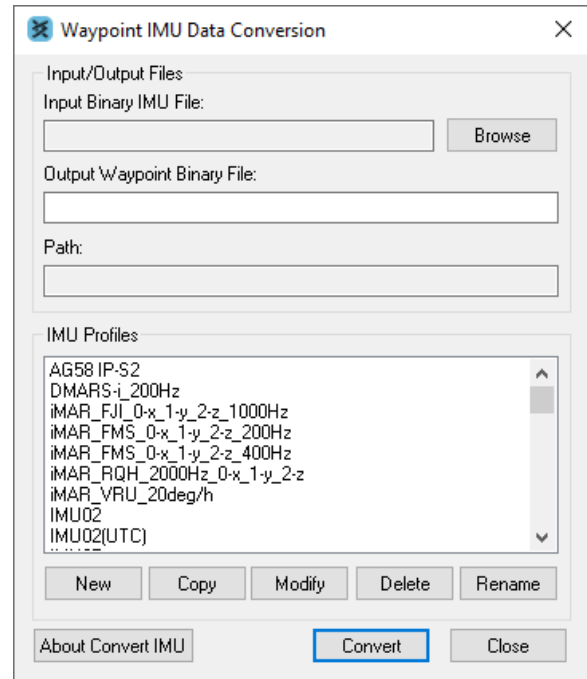
IMU Profiles

Displays a scroll-down list of profiles available for use during conversion. Each profile contains a set of conversion parameters designed to decode measurement data files produced by the indicated sensor. Choose one profile from the list, or, if necessary, create one. See *Creating / Modifying a Conversion Profile* on the next page for help. After all the appropriate fields have been entered, click the *Convert* button to start converting IMU data into IMR format. A message window appears to show the status of the conversion process.

New
Creates a customized profile to convert a unique format into Waypoint's generic IMR format. This is used for custom scale factors, data rates, and orientations in raw data files.

Copy
Copies an existing profile to a new name. Useful if you want to modify an existing profile without overwriting it.

Modify
Allows changes to be made to an existing profile.

Delete
Deletes an existing profile.

Rename
Renames an existing profile.

5.4.3   Creating / Modifying a Conversion Profile

Sensor/Timing Settings

Gyroscope Measurements

Pertains to the measurements made by the gyroscopes.

The inverse value of the scale factor is required. For example, a scale factor of 0.0004, which can be represented fractionally by 1/2500, should be entered as 2500.

The gyro measurements can take the form of *delta theta*, where angular increments are being observed, or *angular rate*.

Accelerometer Measurements

Similar to the scale factor of the gyro measurements, the inverse of the accelerometer scale factor is required. As well, the accelerometer measurements can take two forms, the first being *Delta velocities*, and the other being *Accelerations*.

Timing Settings

Enter the data collection rate of the IMU sensor and specify the time system (GPS time or UTC time) of the IMU measurements.

Sensor Orientation Settings

Define the orientation of the IMU here using the steps below.

The orientation will always be right-handed.

How to define the orientation of the IMU

1. Specify the X-direction by selecting the direction that corresponds to the X-axis of the sensor frame.

2. Click *Select* to set that direction to the X-axis.

3. Specify the Y-direction by selecting the direction that corresponds to the Y-axis of the sensor frame.

4. Click *Select* to set that direction to the Y-axis.

> (i) Given the constraint that the frame is right-handed, the z-axis direction will be automatically determined by the software.

5. Click *Update* to apply the new sensor orientation to the profile.

> (i)   If a mistake is made at any point during the process, click *Clear* to start over.

6. Click *Save* to save the new profile.

    It should immediately appear in the scroll-down list under the *IMU Profiles* box of the main window.

Decoder Settings

Specifies which library is used to perform the conversion, based on the input format of the raw data file. For most sensors, this should be left untouched.

> (i)   For SPAN, the IMU decoding is handled through the GNSS decoder.

Chapter 6   File Format Overview

This section describes the format of the files used by Waypoint software.

6.1   GNSS Data Files

The following files are produced by the raw GNSS data conversion utility.

6.1.1   GPB File

Raw code, carrier and Doppler measurements are converted to a GPB file. These are the raw measurements required for post-processing. Also written to the GPB file is a position for each measurement epoch, date, time and other information.

GPB files can be opened within the *GPB Viewer*, which allows you to view the raw measurements collected and perform basic editing functions if needed.

6.1.2   STA File

A station file contains any decoded camera marks, antenna heights and station names. It is read automatically when adding a GPB file to a project. The first line of a station file should contain $STAINFO.

The station file may have a header record. If a *Pos* record is detected, it will be imported automatically when adding the GPB file as a base station to the project. The following is a description of the header format.

Hdr {

Proj:	"Name of Project"	Field project name
User:	"User Name"	Name of field operator
Time:	hh:mm:ss LOCAL/GMT	Start time
Date:	mm/dd/yyyy	Start date
RxName:	Receiver	Receiver type
RxSub:	Model	Receiver sub type
Hi:	Hi_m VERT/SLANT	Antenna height, measured vertically or slanted
Ant:	V_Offset H_Offset "Name"	Antenna info (vertical offset to phase center, horizontal distance to measurement mark, antenna model name)
Pos:	phi lamda ht ELL/ORTHO	Computed position of antenna
Mode:	SP/DGPS/RTFL/RTFX/RTK/FIX	Mode of solution (RTFL=float, RTFX=fixed, RTK=float/fixed not known, SP=single point, GPS=DGPS, FIX=known)

}

The following is the format for the stationary station marks:

Sta {

*ID:	"Station ID"	
*GTim:	SecOfWeek [WeekNo]	GPS Time
UTim:	SecOfWeek [WeekNo]	UTC Time could be used instead of GTim but this is not recommended and often not supported.
Pos:	phi lamda ht ELL/ORTHO	Computed position of antenna

Mode:	SP/DGPS/RTFL/RTFX/RTK/FIX	Mode of solution (RTFL=float, RTFX=fixed, RTK=float/fixed not known, SP=single point, DGPS=DGPS, FIX=known)
Std:	SdE SdN SdH	Standard deviation, in meters
Hi:	Hi_m VERT/SLANT	Antenna height, measured vertically or slanted
Ant:	V_Offset H_Offset "Name"	Antenna info (vertical offset to phase center, horizontal distance to measurement mark, antenna model name)
OffR:	Range TrueAzimuth DH	Offset to actual point (2D range in meters, azimuth in degrees, height difference in meters)
OffL:	DE DN DH	Offset in local level frame, in meters
OffB:	DX DY DZ	Body frame offset, where X-RightWingPos, Y-ForwardPos, Z-UpPos
Att:	roll pitch heading	Attitude, in degrees
Desc:	"description"	
Rem:	"remarks"	
Nsv:	NumSats NumGPS NumGlonass	
Dop:	PDOP HDOP VDOP	
Rms:	L1Phase CACode	
Age:	Sec	Age of last correction or RTK receipt
Enable:	1/0	
}		

ⓘ *** indicates a required field.**

The station file format also handles event marks. Saving a project with event marks loaded brings the event marks into the station file. The following is the event mark format.

Mrk {

*Event:	Number	Event number or name (no spaces)
Desc:	"Name"	Roll name
*GTim:	SecOfWeek [WeekNo]	GPS Time
*UTim:	SecOfWeek [WeekNo]	UTC Time could be used instead of GTim but this is not recommended and often not supported
Pos:	phi lamda ht ELL/ORTHO	Computed position
Mode:	SP/DGPS/RTFL/RTFX/RTK/FIX	Mode of solution (RTFL=float, RTFX=fixed, RTK=float/fixed not known, SP=single point, DGPS=DGPS, FIX=known)
Std:	SdE SdN SdH	Standard deviation, in meters
Vel:	VE VN VH	Velocity, in m/s
Att:	roll pitch heading	Attitude, in degrees
Rem:	"remarks"	
Nsv:	NumSats NumGPS NumGlonass	
Dop:	PDOP HDOP VDOP	
Rms:	L1Phase CACode	
Age:	Sec	Age of last correction or RTK receipt
Enable:	1/0	
}		

ⓘ   ***** indicates a required field.

6.1.3   EPP File

Waypoint's software uses a custom ASCII file format for the ephemeris records. These records are created by the *Convert Raw GNSS data to GPB* utility. Duplicate records will be automatically ignored by the software. Requests for the EPP file format should be made to support.novatel@hexagon.com.

6.2   FML, FSS, RML, RSS, FSL and RSL Files

Message log files echo all error and warning messages sent to the Processing Window during GNSS processing.

The forward and reverse GNSS and PPP message log files contain all messages output by the processing engine. GrafNav and Inertial Explorer assign priority levels to all messages generated by the processor and only high priority messages are output to the Process Window during GNSS and INS data processing. All messages generated by the processor (regardless of priority) are output to the message log files. These files can be useful in helping to find problems that have not been automatically solved by Inertial Explorer's outlier detection routines.

6.3   FG, RG, CG, FP, RP and CP Files

FG, RG and CG files are created in differential processing whereas FP, RP and CP files are created in PPP. A trajectory record is written for each processed measurement epoch.

For a copy of the binary structure definitions that define these files contact support.novatel@hexagon.com. The legacy ASCII files, output by version 8.60 and earlier, can be output using the *Output | Export to Waypoint Legacy Format* option.

6.4   Inertial Explorer File Formats

6.4.1   IMR File

Waypoint converts all custom IMU raw binary formats into a generic format (IMR), which is read from Inertial Explorer following the decoding process in *IMU Data Converter*. See *Raw IMU Data Converter* on page 195 for more details.

Because it contains vital information for reading and decoding the data, the first 512 bytes of the generic IMU data format is a header which must be filled in, read and interpreted. In a C/C++ structure definition, the generic format header has the following fields:

Table 30: IMR Header Struct Definition

Word	Size (bytes)	Type	Description
szHeader	8	char[8]	"$IMURAW\0" – NULL terminated ASCII string
bIsIntelOrMotorola	1	int8_t	0 = Intel (Little Endian), default 1 = Motorola (Big Endian)
dVersionNumber	8	double	Inertial Explorer program version number (e.g. 8.80)

Word	Size (bytes)	Type	Description
bDeltaTheta	4	int32_t	0 = Data to follow will be read as scaled angular rates 1 = (default), data to follow will be read as delta thetas, meaning angular increments (i.e. scale and multiply by *dDataRateHz* to get degrees/second)
bDeltaVelocity	4	int32_t	0 = Data to follow will be read as scaled accelerations 1 = (default), data to follow will be read as delta velocities, meaning velocity increments (i.e. scale and multiply by *dDataRateHz* to get m/s^2)
dDataRateHz	8	double	The data rate of the IMU in Hz. e.g. 0.01 second data rate is 100 Hz
dGyroScaleFactor	8	double	If *bDeltaTheta* == 0, multiply the gyro measurements by this to get degrees/second If *bDeltaTheta* == 1, multiply the gyro measurements by this to get degrees, then multiply by *dDataRateHz* to get degrees/second
dAccelScaleFactor	8	double	If *bDeltaVelocity* == 0, multiply the accel measurements by this to get m/s^2 If *bDeltaVelocity* == 1, multiply the accel measurements by this to get m/s, then multiply by *dDataRateHz* to get m/s^2
iUtcOrGpsTime	4	int32_t	Defines the time tags as GPS or UTC seconds of the week 0 = Unknown, will default to GPS 1 = Time tags are UTC seconds of week 2 = Time tags are GPS seconds of week
iRcvTimeOrCorrTime	4	int32_t	Defines whether the time tags are on the nominal top of the second or are corrected for receiver time bias 0 = Unknown, will default to corrected time 1 = Time tags are top of the second 2 = Time tags are corrected for receiver clock bias
dTimeTagBias	8	double	If you have a known bias between your GPS and IMU time tags enter it here
szImuName	32	char[32]	Name of the IMU being used
reserved1	4	uint8_t[4]	Reserved for future use
szProgramName	32	char[32]	Name of calling program
tCreate	12	time_type	Creation time of file

Word	Size (bytes)	Type	Description
bLeverArmValid	1	bool	True if lever arms from IMU to primary GNSS antenna are stored in this header
lXoffset	4	int32_t	X value of the lever arm, in millimeters
lYoffset	4	int32_t	Y value of the lever arm, in millimeters
lZoffset	4	int32_t	Z value of the lever arm, in millimeters
Reserved[354]	354	int8_t[354]	Reserved for future use

The single header, which is a total of 512 bytes long, is followed by a structure of the following type for each IMU measurement epoch:

Table 31: IMR Record Struct Definition

Word	Size	Type	Description
Time	8	double	Time of the current measurement
gx	4	int32_t	Scaled gyro measurement about the IMU X-axis
gy	4	int32_t	Scaled gyro measurement about the IMU Y-axis
gz	4	int32_t	Scaled gyro measurement about the IMU Z-axis
ax	4	int32_t	Scaled accel measurement about the IMU X-axis
ay	4	int32_t	Scaled accel measurement about the IMU Y-axis
az	4	int32_t	Scaled accel measurement about the IMU Z-axis

The angular increments (or angular rates) are signed integers. The scale factor to obtain a double precision word must be supplied by the *dGyroScaleFactor* variable in the IMR header. Similarly, the accelerations (or velocity increments) are signed integers and must be scaled by the *dAccelScaleFactor* variable in the IMR header.

6.4.2 DMR File

All odometer data must be written into Waypoint's generic format (DMR) before it can be used within Inertial Explorer.

Table 32: DMR Header Struct Definition

Word	Size	Type	Description
szHdr	8	char[8]	"$DMIRAW\0" – NULL terminated ASCII string
sHdrSize	2	int16_t	Size of the header in bytes, must be set to 512

Word	Size	Type	Description
sRecSize	2	int16_t	Size of each record (refer to *dmi_lrec_type* or *dmi_drec_type*) 12 + 8 if *sValueType* = DMI_VALUE_DOUBLE 12 + 4 if *sValueType* = DMI_VALUE_LONG
sValueType	2	int16_t	0 = logging data using 4 byte integer values 1 = logging data using double precision values
sMeasType	2	int16_t	1 = logging a distance measurement 2 = logging a speed measurement
sDim	2	int16_t	Number of DMI sensors. Supports up to 3 wheel sensors, but the software applies DMI updates from the first wheel sensor only.
sRes	2	int16_t	Measurement resolution of the DMI 1 = low resolution, measurements on full wheel revolutions 2 = high resolution, measurements on partial wheel revolutions or fixed time intervals
sDistanceType	2	int16_t	Must be set if sMeasType == 1 1 = logging accumulated tick count 2 = logging distance in meters 3 = logging accumulated distance in meters
sVelocityType	2	int16_t	Must be set if *sMeasType* == 2 1 = logging velocity in meters/second 2 = logging velocity in ticks/second
dScale	8	double	DMI scale factor in meters/count or meters/second/count. Must be set if *SValueType* == 0 1.0 if logging accumulated tick count or ticks/second
szAxisName	48	char[3][16]	Name of axes of each DMI. Optional
dWheelSize	8	double	Circumference of the wheel sensor in meters. Must be set if logging accumulated tick count
lTicksPerRevolution	4	int32_t	Number of tick counts per revolution of the wheel sensor. Must be set if logging accumulated tick count or ticks/second
cExtra2	420	int8_t[420]	Reserved for future use

The single header, which is a total of 512 bytes, is followed by one of the following structure types for each DMI measurement record:

Table 33: DMR Long Record Struct Definition

Word	Size	Type	Definition
sSync	2	int16_t	Sync byte, 0xFFEE
sWeek	2	int16_t	GPS week number, set to -1 if unknown
dTime	8	double	GPS seconds into week
lValue	4 x sDim	uint32_t	Value for DMI sensor as an integer.

Table 34: DMR Double Record Struct Definition

Word	Size	Type	Description
sSync	2	int16_t	Sync byte, 0xFFEE
sWeek	2	int16_t	GPS week number, set to -1 if unknown
dTime	8	double	GPS seconds into week
dValue	8 x sDim	double	Value for DMI sensor as a double.

6.4.3   HMR File

The 256 byte header contains information that is vital to processing and must be filled in. The C/C++ structure definition of the HMR header is as follows:

Table 35: HMR Header Struct Definition

Word	Size	Type	Definition
szTitleStr	12	char[12]	"$IMUHEADING\0" – NULL terminated ASCII string
ucType	1	uint8_t	1 = values from external source 2 = values form dual antenna source
dBoreSightRotationZ	8	double	Heading boresight between the forward direction of travel and the vector between antennas. Positive rotation is clockwise about Z
dBoreSightRotationZStdDev	8	double	Accuracy of the boresight, 0.0 if not known
Extra	227	int8_t[227]	Reserved for future use

The single header is then followed by the 34-byte structure type below for each heading update record:

Table 36: HMR Record Struct Definition

Word	Size	Type	Definition
dGpsTime	8	double	GPS seconds of week
sGpsWeek	2	int16_t	GPS week

Word	Size	Type	Definition
dHeading	8	double	The heading update value in decimal degrees, positive rotation is clockwise from North
fHeadingStdDev	4	float	Standard deviation of the update in decimal degrees., 0.0 if not known
fBaselineLength	4	float	Distance between antennas in meters. Only use if *ucType* == 2
fPitch	4	float	Pitch between the two antennas in decimal degrees. Only use if *ucType* == 2
fPitchStdDev	4	float	Standard deviation of the pitch in decimal degrees, 0.0 if not known

6.4.4   MMR File

Gyro-stabilized mount data must be written to Waypoint's MMR format before it can be applied within Inertial Explorer.

Table 37: MMR Header Struct Definition

Word	Size	Type	Definition
szHdr	8	char[8]	"$MOUNT\0" – NULL terminated ASCII string
sHdrSize	2	uint16_t	Size of this header in bytes, must be set to 256
sRecSize	2	uint16_t	Size of each record, must be set to 28 bytes
sWeek	2	int16_t	Week number corresponding to first record (-1 if unknown)
sReserved	2	int16_t	Reserved for future use
szProgName	32	char[32]	Name of the program that created the file
dVersion	8	double	Version of program that created the file
cExtra	200	int8_t[200]	Reserved for future use

Table 38: MMR Record Struct Definition

Word	Size	Type	Definition
usHdr	2	uint16_t	Must be set to 0xff77
sWeek	2	int16_t	Current week (or -1 if unknown)
dTime	8	double	TOW (seconds)
lAtt	12	Int32_t[3]	Attitude values (x,y,z) * 1.0E7
uReserved	4	uint8_t[4]	Reserved for future use

6.4.5   PVA File

The PVA binary format is directly supported by Waypoint's inertial processing engines. It is used to store external coordinate updates. Two types of update are supported: absolute (CUPTs) and relative position updates. Each PVA file can only have a single update type. Absolute CUPTs provide updates in geographic frame, whereas relative position updates provide the translation vector between two epochs in the ENU frame.

If you have any questions, contact NovAtel Support at support.novatel@hexagon.com.

File Header

This header appears once at the start of the file. The position reference location defaults to IMU.

Field	Variable Name	Type	Description	Bytes
1	szHdr[12]	char	Must be "$PVABIN\r\n\0"	12
2	usFileVersion	uint16_t	File version, set to 1	2
3	usHdrSize	uint16_t	Size of file header, set to 3848 bytes	2
4	usFileType	uint16_t	File type, set to 1	2
5	usVersion[3]	uint16_t	Version numbers of creating program [major, minor, build]	6
6	szProgramName[32]	char	Name of program that created file	32
7	ulNumRec	uint32_t	Number of records (set to 0 for auto-detect)	4
8	usRecSize	uint16_t	Size of each record, set to 232 bytes	2
9	usReserved1[6]	uint8_t	Reserved (set to 0)	6
10	usPosSys	uint16_t	Position coordinate system GEOGRAPHIC=0 (for absolute updates) ENU=2 (for relative updates)	2
11	usReserved2[6]	uint8_t	Reserved (set to 0)	6
12	usOffsetAvail	uint16_t	Must be set to 1	2
13	usReserved3[3770]	uint8_t	Reserved (set to 0)	3770

Total size = 3848 bytes

If the position reference location is not the IMU, shift the location from sensor to IMU by adding the **PVA_ LEVER** user command to the project:

- PVA_LEVER = [ON/OFF] [x] [y] [z] (in meters)
  - The offsets are body-frame lever arm values.

Input Data Record

This record repeats for every PVA data record.

Field	Variable Name	Type	Description		Bytes
			Absolute Update	**Relative Update**	
1	dUpdateTime	double	TOW (s)	TOW (s), end of update	8
2	dRelStartTime	double	Set to 0	Start of update in TOW (s)	8
3	usUpdateWeek	uint16_t	GPS week number	End of update week number	2
4	usRelStartWeek	uint16_t	Set to 0	Start of update week number	2
5	uUpdate	uint32_t	Update flag/type, refer to *Update Bit Definitions* below		4
6	szID[16]	char	Optional event 'ID', max 15 characters, NULL to terminate string		16
7	usCheck	uint16_t	Must be 0xC0DE, used as internal check for file validity		2
8	usReserved1[6]	uint8_t	Reserved (set to 0)		6
9	dPos[3]	double	Geographic coordinate [deg]	Delta in East, North, Up [m]	24
10	usReserved2[36]	uint8_t	Reserved (set to 0)		36
11	fPosSD[3]	float	SD values for position in East, North, Up direction (m)		12
12	usReserved3[24]	uint8_t	Reserved (set to 0)		24
13	sCCUpperDiag[9]	int16_t	Optional, set to 0 if unknown Off-diagonal correlation coefficients * sCCUpperDiag[0] = pxpy sCCUpperDiag[1] = pxpz sCCUpperDiag[8] = pypz		18
14	usReserved4[70]	uint8_t	Reserved (set to 0)		70

Total size = 232 bytes

* The off-diagonal correlation coefficients are defined as:

cc = cov[i][j] / (sd_i * sd_j) scale to a signed 16-bit integer using the scale factor 65536.0

cc_int = (int) cc_float * 65536.0, so it will be [-1, 1] after scaling

Update Bit Definitions

Use the update bit definitions to define the update flag/type.

Name	Hex Value	Description
PVA_UPDATE_NONE	0	No update
PVA_UPDATE_POS	1	Absolute position update
PVA_UPDATE_RELATIVE	8	Relative position update

6.5   Inertial Explorer Output Files

This section discusses the different output files that are created when processing with Inertial Explorer.

6.5.1   FIL/RIL/FTL/RTL Files

Message Log files echo all error and warning messages sent to the *Process Window* during INS processing.

The forward and reverse loosely and tightly coupled message log files contain all messages output by the processing engine. Inertial Explorer assigns priority levels to all messages generated by the processor and only high priority messages are output to the *Process Window* during GNSS and INS data processing. All messages generated by the processor (regardless of priority) are output to the message log files. These files can be useful in helping to find problems that have not been automatically solved by Inertial Explorer's outlier detection routines.

6.5.2   FL(S)/RL(S)/CL(S)/FT(S)/RT(S)/CT(S) Files

A new output binary format has been created for version 8.70 that reduces the number of trajectory files output from Inertial Explorer. For a copy of the current binary struct definitions output by Waypoint software, please contact support.novatel@hexagon.com.

Waypoint is aware that there are some products that rely on the old data format from the SBTC/SBIC file. It is still possible to get these files using the *Output | Export to Waypoint Legacy Format* option. See *Export to Waypoint Legacy Format* on page 120 for more details.

Appendix A   Command Line Utility

This appendix documents the supported input parameters for the Waypoint GrafNav and Inertial Explorer Command Line (WPGCMD and WPGCMDIMU), which is found within the *bin* sub-directory of the respective installation directory. WPGCMD is available with the purchase of a GrafNav term license and WPGCMDIMU with an Inertial Explorer term CLI license.

A.1   Commands

Table 39: List of Available Commands

Command	Description
basefile#	Path to base station data file (raw or GPB)[1]
basetype#	Base station receiver type (NovAtel OEMV, Trimble DAT, etc)[1]
basecoord#	Coordinates of base station (latitude/longitude/height)[1]
baseant#	Base station antenna profile (using ATX format)[1]
baseht#	Base station antenna height[1]
downloadbase	Specify the number of base stations to be downloaded
remfile	Path to remote data file (raw or GPB)
remtype	Remote receiver type (NovAtel OEMV, Trimble DAT, etc)
remant	Remote antenna profile (using ATX format)
remht	Remote antenna height
remstatic	Convert remote in static mode
snserver	Address of HxGN SmartNet server
snusername	Username for HxGN SmartNet account
snpassword	Password for HxGN SmartNet account
imufile	Path to IMU data file (IMR only)[2]
imutype	For NovAtel SPAN only – specifies the IMU model (CPT/LN200/etc)[2]
imula	IMU-to-GNSS antenna lever arm[2]
imurot	IMU-to-body frame rotation[2]
dmifile	Path to DMI data file (DMR only)[2]
dmistddev	Standard deviation of DMI measurements[2]
hmrfile	Path to heading update file (HMR only)[2]

Command	Description
hmrla	IMU-to-secondary GNSS antenna lever arm[2]
proccfg	Name of project file to use for output
procmode	Processing mode (TC/DGPS/PPP/etc)
procdata	Data processing type (C/A, L1, L1+L2)
procdir	Processing direction (both or multi-pass)
procdatum	Processing datum
procint	Processing data interval
procstatic	Static processing mode (float/ARTK or fixed static)
procprecise	Path to precise files (SP3/CLK or COR)
procprofile	Name of processing profile
procmsg	Write processing messages to disk
expprofile#	Export Wizard profile[3]
expfile#	Export Wizard output file name[3]
expsrc#	Export Wizard source (epochs, static sessions, features)[3]
expla#	Export Wizard lever arm for coordinate transfer[3]
exputmzone#	UTM zone number to use for export[3]
exprot#	Apply body-to-user frame rotation[3]
expkml	Output KML file
expsbet	Output SBET file[2]
expsbetkernel	Append kernel text to SBET file name[2]
expsbetsmrmsg	Output SMRMSG file along with SBET[2]
expsbetsmrmsgposscale	Scale position standard deviations in SMRMSG file[2]
expsbetsmrmsgattscale	Scale attitude standard deviations in SMRMSG file[2]
expsbetimuframe	Output SBET parameters in the IMU frame[2]
expsbetcustomframe	Output SBET parameters in a provided frame[2]
expsbetutctime	Output SBET with UTC time[2]
expriegl	Output RIEGL file[2]
exprieglgeodeticsystem	Set the geodetic system string in the RIEGL header[2]
exprieglprojectname	Set the project name string in the RIEGL header[2]

Command	Description
exprieglcompanyname	Set the company name string in the RIEGL header[2]
expriegltimezone	Set the time zone string in the RIEGL header[2]
exprieglocation	Set the location string in the RIEGL header[2]
exprieglnavigationdevice	Set the navigation device string in the RIEGL header[2]
exprieglposscale	Set the position error scale factor for the RIEGL data[2]
exprieglattscale	Set the attitude error scale factor for the RIEGL data[2]
1 This command can be used up for up to 100 base stations; use the # designator to uniquely identify the base station (# = 1…100)	
2 This command is only available with WPGCMDIMU	
3 This command can be used to generate up to 8 different exports	

> ⓘ All commands must be preceded by a hyphen (-).

A.2 Base Station Commands

The following commands are related to the base station and are only applicable if you are doing differential processing (i.e. DGPS or TC).

Command	-basefile# [input]
Example	-basefile1 "C:\My Data\base.gpb"
Description	Specifies the location of the GNSS base station data file.
Input	Full file path to the GPB or raw data file.
Notes	If this file is not in GPB format, the command-line utility will convert it (see -basetype). Wrap the path in quotation marks if it contains spaces. The # designator must be 1…100 to uniquely identify the base station(s).
Required?	No. For differential processing, a base station file will be downloaded if this command is not present.

Command	-basetype# [input]
Example	-basetype2 GPS_LEICA1200
Description	Specifies the receiver/format used for the base station data.
Input	See *Table 40: List of Receiver Types (for -basetype and -remtype)* on page 214

Notes	Check with Waypoint Support if your receiver type is not listed here.
	Only applicable if the -basefile command is used.
	The # designator must be 1…100 to uniquely identify the base station(s).
Required?	No. If the file specified by -basefile is not already in GPB format and this command is not used, then the utility will attempt to auto-detect the receiver type.
	Use this command if auto-detection fails.

Command	-basecoord# [latitude] [longitude] [height]
Example	-basecoord1 36.161066211 -121.137349121 101.484
Description	Specifies the coordinates of the base station.
Input	Latitude (decimal degrees), longitude (decimal degrees), ellipsoidal height (meters)
Notes	These coordinates must be in the same datum specified by the -procdatum command.
	Only applicable if the -basefile command is used.
	The # designator must be 1…100 to uniquely identify the base station(s).
Required?	No. If the -basefile command is used but no coordinates are specified, the utility will automatically compute them using PPP.

Command	-baseht# [input]
Example	-baseht3 1.094
Description	Specifies the height of the base station antenna.
Input	Antenna height to absolute L1 phase center (meters).
Notes	This vertical height is measured relative to the coordinates passed by -basecoord.
	Only applicable if the -basefile and -basecoord commands are used.
	The # designator must be 1…100 to uniquely identify the base station(s).
Required?	No. If not used, then the coordinates specified by -basecoord will be assumed to represent the ARP if the -baseant command is set, or else the absolute L1 phase center if the -baseant command is not set.

Command	-baseant# [input]
Example	-baseant1 LEIATX1230+GNSS
Description	Specifies the antenna profile to be used at the base station.
Input	Name of the antenna profile (IGS format for absolute antenna calibrations).
Notes	Consult the NGS or IGS website to find the proper name of your antenna's profile.
	Only applicable if the -basefile and -basecoord commands are used.
	The # designator must be 1…100 to uniquely identify the base station(s).
Required?	No

Command	-downloadbase [number] [distance]
Example	-downloadbase 5 100
Description	Specifies the maximum number of base stations to be downloaded within a maximum distance from the remote file
Input	The maximum number of base stations to be downloaded and the maximum distance (km) to use for the search.
Notes	Cannot be used in conjunction with the enumerated -base commands. Once the number of downloaded stations reaches the specified maximum, the software will stop searching even if more stations exist within the specified distance. Similarly, the software will not download stations beyond the maximum specified distance even if the number of downloaded stations is less than the specified maximum.
Required?	No. If not specified, only the nearest base station will be downloaded.

Table 40: List of Receiver Types (for -basetype and -remtype)

Receiver Type	Input
NovAtel OEM/SPAN	GPS_NOVATEL_OEM4
NovAtel CMC	GPS_NOVATEL_CMC
Javad/Topcon	GPS_TOPCON_JAVAD
Leica LB2 (System 500)	GPS_LEICASR5
Leica MDB (System 1200)	GPS_LEICA1200
NavCom NCT	GPS_NAVCOM
NavCom Sapphire	GPS_NAVCOM_SAPPHIRE
RINEX	GPS_RINEX
RTCMV3	GPS_RTCM3
Septentrio SBF	GPS_SEPTENTRIO
Thales B-File	GPS_THALES_BFILE
Thales Real-Time	GPS_THALES_REALTIME
Trimble DAT	GPS_TRIMBLE_DAT
Trimble Real-Time	GPS_TRIMBLE_REALTIME
u-Blox UBX	GPS_UBLOX

A.3 Remote Data Commands

The following commands are related to the remote data and are applicable to all projects.

Command	-remfile [input]
Example	-remfile "C:\My Data\Rover.pdc"
Description	Specifies the location of GNSS remote file.
Input	Full file path to the GPB or raw data file.
Notes	If this file is not in GPB format, the command-line utility will convert it (see -remtype). Wrap the path in quotation marks if it contains spaces. For NovAtel SPAN users, this file will contain GNSS, IMU and DMI (if applicable) data.
Required?	Yes

Command	-remtype [input]
Example	-remtype GPS_NOVATEL_OEM4
Description	Specifies the receiver/format used for the remote data.
Input	See *Table 40: List of Receiver Types (for -basetype and -remtype)* on the previous page
Notes	Check with Waypoint Support if your receiver type is not listed here.
Required?	No. If the file specified by -remfile is not already in GPB format and this command is not used, then the utility will attempt to auto-detect the receiver type. Use this command if auto-detection fails.

Command	-remht [input]
Example	-remht 0.957
Description	Specifies the height of the remote antenna.
Input	Antenna height to absolute L1 phase center (meters).
Notes	By default, GNSS coordinates are computed at the L1 phase center. Using this command will result in a vertical shift in the computed trajectory. Inertial users should not pass this command (see -imula for information).
Required?	No

Command	-remant [input]
Example	-remant "ASH701941.B SCIS"
Description	Specifies the antenna calibration profile to be used for the remote.
Input	Name of the antenna profile (IGS format for absolute antenna calibrations).
Notes	Consult the NGS or IGS website to find the proper name of your antenna's profile.
Required?	No

Command	-remstatic [on/off]
Example	-remstatic on
Description	Specifies whether or not the entire file should be converted as static.
Input	**on** to have the entire file converted in static mode. **off** to let pre-processing checks determine the mode automatically.
Notes	This command is intended for customers performing static processing. It should be set to **on** if you are processing static baselines (see -procstatic) or doing static coordinate determination via PPP. It is only applicable if the remote file is being converted to GPB.
Required?	No. Default is **off**.

A.4 IMU Data Commands

The following commands are related to the IMU data and are only applicable if you are doing inertial processing.

Command	-imufile [input]
Example	-imufile "C:\My Data\Rover.imr"
Description	Specifies the location of the IMU data file.
Input	Full file path to the IMR file.
Notes	This file must be in IMR format. No other format is accepted. NovAtel SPAN users should ignore this command (see –remfile). Wrap the path in quotation marks if it contains spaces.
Required?	Required for inertial users if IMU data was not collected from a NovAtel SPAN system.

Command	-imutype [input]
Example	-imutype SPAN_CPT
Description	Specifies the NovAtel SPAN IMU type.
Input	See *Table 41: List of IMU Types (for -imutype)* on the next page.
Notes	This command is only for NovAtel SPAN users.
Required?	No. Use this command only if the utility fails to auto-detect the SPAN IMU type.

Command	-imula [X] [Y] [Z]
Example	-imula 0.458 -1.112 1.012
Description	Specifies the IMU-to-GNSS antenna lever arm.
Input	The X/Y/Z spatial offsets, in meters, from the IMU to the GNSS antenna.

Notes	The offsets must be referenced in the X-right, Y-forward, Z-up frame. The IMU's center of navigation is the origin of the frame.
Required?	Only if the values are not already written in the header of the IMR file.

Command	-imurot [X] [Y] [Z]
Example	-imurot 0.0 -90.0 180.0
Description	Specifies the body-to-IMU rotations.
Input	The X/Y/Z angles, in decimal degrees, needed to rotate the IMU into the vehicle frame.
Notes	The IMU must be rotated into the X-right, Y-forward, Z-up frame.
Required?	Only if the values are not already written in the header of the IMR file.

Table 41: List of IMU Types (for -imutype)

NovAtel SPAN IMU Types	Input
SPAN CPT	SPAN_CPT
SPAN LN200	SPAN_LN200
SPAN AG58	SPAN_AG58
SPAN AG62	SPAN_AG62
SPAN FSAS	SPAN_FSAS
SPAN LCI	SPAN_LCI
SPAN µIRS	SPAN_UIRS
SPAN ADIS16488	SPAN_ADIS16488
SPAN STIM300	SPAN_STIM300
SPAN KVH1750	SPAN_KVH1750
SPAN HG1900	SPAN_HG1900
SPAN HG1930	SPAN_HG1930
SPAN LCI-100C	SPAN_LCI100C
SPAN EPSON G320	SPAN_EPSONG320
SPAN EPSON G370	SPAN_EPSONG370
SPAN µIMU	SPAN_UIMU
SPAN CPT7	SPAN_CPT7
SPAN IAM-20680	SPAN_IAM20680
SPAN CPT7 400Hz	SPAN_CPT7_400HZ
SPAN µIMU 400Hz	SPAN_UIMU_400HZ

A.5   DMI Data Commands

The following commands are related to the DMI data and are only applicable if you are doing inertial processing.

Command	-dmifile [input]
Example	-dmifile "C:\My Data\Rover.dmr"
Description	Specifies the location of the DMI data file.
Input	Full file path to DMR file.
Notes	This file must be in DMR format. No other format is accepted. NovAtel SPAN users should ignore this command (see –remfile). Wrap the path in quotation marks if it contains spaces.
Required?	Required for inertial users if DMI data was not collected from a NovAtel SPAN system.

Command	-dmistddev [input]
Example	-dmistddev 0.10
Description	Specifies the standard deviation of the measurements contained within the DMI file.
Input	Standard deviation, in m/s.
Notes	This command controls the weighting placed on the DMI measurements.
Required?	No. Default is 0.30 m/s.

A.6   Heading Update Data Commands

The following commands are related to heading update data and are only applicable if you are doing inertial processing.

Command	-hmrfile [input]
Example	-hmrfile "C:\My Data\Rover.hmr"
Description	Specifies the location of the heading update (HMR) data file.
Input	Full file path to Heading update (HMR) file.
Notes	This file must be in the HMR format. No other format is accepted. NovAtel SPAN users should ignore this command (see –remfile). Wrap the path in quotation marks if it contains spaces.
Required?	Required for inertial users if heading update data was not collected from a NovAtel SPAN system.

Command	-hmrla [X] [Y] [Z]

Example	-hmrla 0.200 0.465 2.114
Description	Specifies the IMU-to-secondary GNSS antenna lever arm.
Input	The X/Y/Z spatial offsets, in meters, from the IMU to the secondary GNSS antenna.
Notes	The offsets must be referenced in the X-right, Y-forward, Z-up frame. The IMU's center of navigation is the origin of the frame.
Required?	Only if the values are not already written in the header of the HMR file.

A.7   HxGN SmartNet Commands

The following commands allow HxGN SmartNet customers to ensure that the relevant base stations are included during the download search.

Command	-snserver [address]
Example	-snserver xpos.country.com
Description	Specifies the address of the HxGN SmartNet server to be logged into.
Input	The server's address.
Notes	Using HxGN SmartNet credentials does not guarantee that a SmartNet base station will be downloaded. It only ensures that they will be considered during the base station search. If a HxGN SmartNet base station is downloaded, the tool will request a minimum of 8 hours using a 15-second data rate. The data will be interpolated as needed prior to processing.
Required?	No.

Command	-snusername [username]
Example	-snusername jsmith
Description	Specifies the username of the HxGN SmartNet account.
Input	The username associated with the SmartNet account.
Notes	Only applicable if the -snserver command is used.
Required?	Only if the -snserver command is used.

Command	-snpassword [password]
Example	-snpassword pw12345
Description	Specifies the password of the HxGN SmartNet account.
Input	The password associated with the SmartNet account.
Notes	Only applicable if the -snserver command is used.
Required?	Only if the -snserver command is used.

A.8   Processing Commands

The following commands relate to data processing and are applicable to all projects.

Command	-procmode [input]
Example	-procmode tc
Description	Specifies the type of processing to be performed.
Input	See *Table 42: List of Processing Modes (for -procmode)* on page 222.
Notes	This command determines how the data will be processed. AR will automatically be selected if you have an NRT subscription and a NovAtel receiver. It also affects which commands are available for use. See *Table 44: List of Commands Supported for Each Processing Mode* on page 223.
Required?	Yes

Command	-proccfg [input]
Example	-proccfg "C:\My Data\Project.proj"
Description	Specifies the project file to be created.
Input	Full file path and name of the PROJ file to be created.
Notes	This command will be used to determine the name of the project file and all other files generated during processing.
Required?	No. If this command is not used, the project files will be given the same name as the remote data file and saved to the same folder.

Command	-procdata [input]
Example	-procdata L1L2
Description	Specifies the type of data to be processed.
Input	See *Table 43: List of Data Processing Types (for -procdata)* on page 223.
Notes	Dual frequency processing is only available if L1/L2 measurements are available at the base station(s) and remote.
Required?	No. If not specified, the utility will scan the input file(s) to determine which data types are available for processing.

Command	-procdatum [input]
Example	-procdatum nad83
Description	Specifies the datum to be used for processing and output.
Input	The name of the datum.

Notes	If this command is not used, the utility will use the default datum. The default can be set via *File*	*Preferences* within GrafNav or Inertial Explorer.
Required?	Only required if using -basefile and -basecoord.

Command	-procdir [input]
Example	-procdir both
Description	Specifies if data should be processed in **both** or **multi-pass** modes.
Input	**both** to process the data in the forward and reverse directions independently. **multi** to process in multi-pass mode.
Notes	**both** is applicable to all processing modes. **multi** is applicable to all modes except GNSS-only differential and LC differential.
Required?	No. The default is **both**.

Command	-procint [input]
Example	-procint 1.00
Description	Specifies the data interval at which the data will be processed.
Input	The data interval in seconds.
Notes	Supported values: 0.05, 0.10, 0.20, 0.50, 1.00, 5.00, 10.00, 15.00, 30.00 For PPP, the processing rate cannot be higher than the remote data rate. For differential, the base station(s) will be resampled to the specified value, if necessary.
Required?	No. The default is to process at the highest rate possible based on the input data.

Command	-procprofile [input]
Example	-procprofile "SPAN Airborne (AG58)"
Description	Specifies the profile from which to load the processing settings.
Input	The name of the processing profile.
Notes	Processing profiles are loaded first and may have their settings overridden by other commands available here.
Required?	No, but strongly recommended. If not used, the utility will attempt to detect the best profile based on the pre-processing checks performed during decoding.

Command	-procprecise [input1] [input2] … [input*n*]
Example	-procprecise "C:\My Data\COD17254.clk" "C:\My Data\COD17254.sp3"

Description	Specifies the precise clock and orbit files to use during processing.
Input	Full file paths and names of the SP3 and CLK files or COR files (for TerraStar NRT users).
Notes	This command is mostly intended for PPP, but is available to all projects. This command can read multiple input files for projects spanning more than one day.
Required?	No. If performing PPP processing and this command is not used, the utility will download the required precise files.

Command	-procstatic [input]
Example	-procstatic fixed
Description	Specifies the mode of processing to use for static data.
Input	**float** for float static processing. **fixed** for fixed static processing.
Notes	Only applicable for static data. See -remstatic for more information.
Required?	No. Default is to perform float static processing.

Command	-procmsg [on/off]
Example	-procmsg on
Description	Specifies whether or not to write all messages to disk.
Input	**on** to have all messages written to a file on disk (in addition to the console). **off** to have all messages written only to the console.
Notes	The output file name will use this convention: "<project name>_ProcMsg.log" Processing messages will always be written to the console. The log file will also capture messages relating to any download attempts for base station and corrections data. These messages do not appear in the console.
Required?	No. By default the messages will only be written to the console.

Table 42: List of Processing Modes (for -procmode)

Processing Mode	Input
GNSS-only differential	dgps
GNSS-only precise point positioning (PPP)	ppp
GNSS+IMU tightly-coupled (differential)	tc
GNSS+IMU loosely-coupled (differential)	lc
GNSS+IMU tightly-coupled (PPP)	ppptc
GNSS+IMU loosely-coupled (PPP)	ppplc

**Table 43: List of Data Processing Types
(for -procdata)**

Data Processing Types	Input
Single frequency (L1) processing	L1
Dual frequency (L1 & L2) processing	L1L2
Code-only (C/A) processing	CA

Table 44: List of Commands Supported for Each Processing Mode

	-procmode					
	DGPS	PPP	TC	LC	PPPTC	PPPLC
basefile#	X		X	X		
basetype#	X		X	X		
basecoord#	X		X	X		
baseant#	X		X	X		
baseht#	X		X	X		
downloadbase	X		X	X		
remfile	X	X	X	X	X	X
remtype	X	X	X	X	X	X
remant	X	X	X	X	X	X
remht	X	X	X	X	X	X
remstatic	X	X				
snserver	X		X	X		
snusername	X		X	X		
snpassword	X		X	X		
imufile			X	X	X	X
imutype			X	X	X	X
imula			X	X	X	X
imurot			X	X	X	X
dmifile			X	X	X	X
dmistddev			X	X	X	X
hmrfile			X	X	X	X
hmrla			X	X	X	X
proccfg	X	X	X	X	X	X

	-procmode					
	DGPS	PPP	TC	LC	PPPTC	PPPLC
procdata	X	X^1	X	X	X^1	X^1
procdir		X	X		X	X^2
procdatum	X	X	X	X	X	X
procint	X	X	X	X	X	X
procstatic	X	X	X	X	X	X
procprecise	X	X	X	X	X	X
procprofile	X	X	X	X	X	X
procmsg	X	X	X	X	X	X
expprofile	X	X	X	X	X	X
expfile	X	X	X	X	X	X
expla	X	X	X	X	X	X
expsrc	X	X	X	X	X	X
exputmzone	X	X	X	X	X	X
expkml	X	X	X	X	X	X
exprot			X	X	X	X
expsbet			X	X	X	X
expsbetkernel			X	X	X	X
expsbetsmrmsg			X	X	X	X
expsbetsmrmsgposscale			X	X	X	X
expsbetsmrmsgattscale			X	X	X	X
expsbetimuframe			X	X	X	X
expsbetcustomframe			X	X	X	X
expsbetutctime			X	X	X	X
expriegl			X	X	X	X
exprieglgeodeticsystem			X	X	X	X
exprieglprojectname			X	X	X	X
exprieglcompanyname			X	X	X	X
expriegltimezone			X	X	X	X
expriegllocation			X	X	X	X

	-procmode					
	DGPS	PPP	TC	LC	PPPTC	PPPLC
exprieglnavigationdevice			X	X	X	X
exprieglposscale			X	X	X	X
exprieglattscale			X	X	X	X

1 PPP processing requires dual frequency carrier phase data.

2 Multi-pass will be performed during the GNSS-only PPP portion, not during IMU processing.

A.9   Export Commands

The following commands relate to the export of the final solution and are applicable to all projects.

Command	-expprofile# [input]
Example	-expprofile1 Geographic
Description	Specifies the profile to be used when writing the formatted solution to disk.
Input	Name of the Export Wizard profile to be used.
Notes	You can use one of the software's built-in profiles or customize one through the interface. The # designator must be 1...8 to uniquely identify the export.
Required?	No. But if the -expprofile# is used, then this command is required.

Command	-expfile# [input]
Example	-expfile1 "C:\My Data\final_solution.txt"
Description	Specifies the name given to the output file.
Input	Full file path and name of the output file to be created during the export process.
Notes	Only applicable if the -expprofile command is used. If the file already exists, it will be over-written. The # designator must be 1...8 to uniquely identify the export.
Required?	No. If the -expprofile command is used but the output file name is not specified, the utility will use the project name (see -proccfg).

Command	-expsrc# [input]
Example	-expsrc1 epochs
Description	Specifies the source to be used when generating the output file.

Input	**epochs** to output the trajectory at a fixed time interval.
	features to output data only for the loaded camera events/features.
	static to output data only for the static sessions.
Notes	Only applicable if the -expprofile command is used.
	In order to use the **features** option, there must be valid features/events loaded.
	The **static** option will not output solutions for any kinematic epochs.
	The # designator must be 1...8 to uniquely identify the export.
Required?	No. If the -expprofile command is used but the output source is not specified, the utility will output in **epochs** mode.

Command	-expla# [X] [Y] [Z]
Example	-expla1 -0.145 0.986 0.883
Description	Specifies the lever arm to be applied during export.
Input	The X/Y/Z spatial offsets, in meters, from the IMU to the point of interest.
Notes	Only applicable if the -expprofile command is used.
	Only applicable for inertial processing.
	The offsets must be referenced in the X-right, Y-forward, Z-up frame. The IMU's center of navigation is the origin of the frame.
	The # designator must be 1...8 to uniquely identify the export.
Required?	No. If not specified, the output file will be generated with respect to the IMU.

Command	-exputmzone# [input]
Example	-exputmzone1 11
Description	Specifies the UTM zone number to be applied during export.
Input	**0** to have the software automatically determine the zone number.
	1…60 to force the UTM zone number to a specific value.
Notes	Only applicable if the -expprofile command is used.
	Only applicable if the export profile contains UTM grid output variables.
	The # designator must be 1...8 to uniquely identify the export.
Required?	No. If not specified, the software will use whichever UTM zone number was most recently used with the export profile.

Command	-expkml [on/off]
Example	-expkml on

Description	Enables the export of the KML file after processing
Input	**on** to enable **off** to disable (off is the default)
Notes	Available in all processing modes
Required?	No

Command	-exprot# [Rx] [Ry] [Rz]
Example	-export1 90 0 180
Description	Specifies a body-to-user frame rotation to be applied during export.
Input	The rotations, in degrees, to rotate from the body frame to the user-defined frame.
Notes	Only applicable if the -expprofile command is used. Only applicable for inertial processing. Rotation order is about Z, then about X, then about Y. The # designator must be 1...8 to uniquely identify the export.
Required?	No. If not specified, no rotations will be applied.

Command	-expsbet [on/off]
Example	-expsbet on
Description	Enables the export of the SBET file after processing
Input	**on** to enable **off** to disable (off is the default)
Notes	Only applicable for inertial processing
Required?	Required to enable all other export "-expsbet…" commands

Command	-expsbetkernel [input]
Example	-expsbetkernel text_to_append
Description	Appends text to the SBET output file name
Input	Desired text to append
Notes	Only applicable if the -expsbet command is used Results in the exported file: SBET_<kernel_text>.OUT
Required?	No

Command	-expsbetsmrmsg [on/off]

Example	-expsbetsmrmsg on
Description	Enables the export of the SMRMSG in addition to the SBET
Input	**on** to enable **off** to disable (off is the default)
Notes	Only applicable if the -expsbet command is used
Required?	No

Command	-expsbetsmrmsgposscale [input]
Example	-expsbetsmrmsgposscale 2.0
Description	Scale the position standard deviations in the SMRMSG file
Input	Must be a positive floating-point number (1.0 is the default)
Notes	Only applicable if the -expsbet command is used
Required?	No

Command	-expsbetsmrmsgattscale [input]
Example	-expsbetsmrmsgattscale 2.0
Description	Scale the attitude standard deviations in the SMRMSG file
Input	Must be a positive floating-point number (1.0 is the default)
Notes	Only applicable if the -expsbet command is used
Required?	No

Command	-expsbetimuframe [on/off]
Example	-expsbetimuframe on
Description	Output the SBET attitude with respect to the IMU frame rather than the default X-forward, Y-right, Z-down frame
Input	**on** to enable **off** to disable (off is the default)
Notes	Only applicable if the -expsbet command is used Cannot be used in conjunction with the -expsbetcustomframe command or else processing will halt
Required?	No

Command	-expsbetcustomframe [X] [Y] [Z]

Example	-expsbetcustomframe 0 0 180
Description	Define the desired output frame of the SBET attitude
Input	The rotations about the XYZ axis to apply to get to the desired custom output frame
Notes	Only applicable if the -expsbet command is used Rotation order is first about Z, then about X, then about Y. The starting frame is the Inertial Explorer body frame of X-right, Y-forward, Z-up Cannot be used in conjunction with the -expsbetimuframe command or else processing will halt
Required?	No

Command	-expsbetutctime [on/off]
Example	-expsbetutctime on
Description	Output UTC time in the SBET file rather than GPS time
Input	**on** to enable **off** to disable (off is the default)
Notes	Only applicable if the -expsbet command is used
Required?	No

Command	-expriegl [on/off]
Example	-expriegl on
Description	Enables the export of the RIEGL file after processing
Input	**on** to enable **off** to disable (off is the default)
Notes	Only applicable for inertial processing
Required?	Required to enable all other export "-expriegl…" commands

Command	-exprieglgeodeticsystem [input]
Example	-exprieglgeodeticsystem WGS84
Description	Sets the geodetic system string in the RIEGL header. The string will be truncated at 32 characters.
Input	The desired geodetic system string (empty by default)
Notes	Only applicable if the -expriegl command is used
Required?	No

Command	-exprieglprojectname [input]
Example	-exprieglprojectname "My project name"
Description	Sets the project name string in the RIEGL header. The string will be truncated at 32 characters.
Input	The desired project name string (empty by default)
Notes	Only applicable if the -expriegl command is used
Required?	No

Command	-exprieglcompanyname [input]
Example	-exprieglcompanyname "My company name"
Description	Sets the company name string in the RIEGL header. The string will be truncated at 32 characters.
Input	The desired company name string (empty by default)
Notes	Only applicable if the -expriegl command is used
Required?	No

Command	-expriegltimezone [input]
Example	-expriegltimezone "GMT-6"
Description	Sets the time zone string in the RIEGL header. The string will be truncated at 16 characters.
Input	The desired time zone string (empty by default)
Notes	Only applicable if the -expriegl command is used
Required?	No

Command	-expriegllocation [input]
Example	-expriegllocation "Canada"
Description	Sets the location string in the RIEGL header. The string will be truncated at 32 characters.
Input	The desired location string (empty by default)
Notes	Only applicable if the -expriegl command is used
Required?	No

Command	-exprieglnavigationdevice [input]
Example	-exprieglnavigationdevice "IMU"

Description	Sets the navigation device string in the RIEGL header. The string will be truncated at 32 characters.
Input	The desired navigation device string (empty by default)
Notes	Only applicable if the -expriegl command is used
Required?	No

Command	-exprieglposscale [input]
Example	-exprieglposscale 2.0
Description	Scale the position standard deviations in the RIEGL file
Input	Must be a positive floating-point number (1.0 is the default)
Notes	Only applicable if the -expriegl command is used
Required?	No

Command	-exprieglattscale [input]
Example	-exprieglattscale 2.0
Description	Scale the attitude standard deviations in the RIEGL file
Input	Must be a positive floating-point number (1.0 is the default)
Notes	Only applicable if the -expriegl command is used
Required?	No

A.10   General Notes

- The program returns *0* upon successful completion or *1* if an error is encountered. Note that a return value of 0 is not a guarantee of accuracy – only that the program did not encounter any serious errors. It is left to you to ensure that the final solution meets your requirements.

- If the input value for a command is a string containing spaces (i.e. file path or file name), it must be wrapped in quotation marks.

- Waypoint software contains many processing options, most of which are not available to be set via the command line. If you wish to customize the processing options, it is suggested that you create your own processing profile and pass it in using the -procprofile command. Processing profiles can be created within Inertial Explorer or GrafNav under *Tools | Profile Manager*.

- When downloading base station data, the utility will first search the Favorites for coordinates. If none are found, it will compute them using PPP. User-provided base station data will be processed with PPP if no coordinates are passed via the -basecoord command.

- You cannot load an existing project file (*.PROJ) for processing.

- This utility supports the input of up to 100 base stations. However, for differential users who do not pass in their own base station data, only one base station will be downloaded. If you require more, you may use the -downloadbase command to specify additional parameters. Alternatively, you may download the desired data first using the *Download Service Data* utility and then pass it in using the appropriate

command.

- Precise files are required for PPP or PPPTC processing. If the files are not provided, and the utility fails to download them, then processing will not continue.

- The commands themselves are not case-sensitive, but some inputs are (i.e. antenna profile names).

- All messages written to the console are preceded by a designator to indicate the nature of the message. See the table below for more information.

Table 45: List of Message Types

Message Designator	Description
MSG	General message; for informational purposes only.
WARNING	Non-critical message; should be reviewed and addressed.
ERROR	Critical message; only output if the utility cannot continue.

Appendix B   Output Variables

Table 46: List of Output Variables

Variable	Description
Absolute ECEF-XYZ	XYZ coordinates in the Earth Centered Earth Fixed Frame which is a Cartesian frame centered at the ellipsoid origin
Antenna Height	Height of the pole or tripod above the station marker
Azimuth (1 ◊ 2)	Angle between true north and the baseline made between FROM and TO stations
Azimuth (2 ◊ 1)	Angle between true north and the baseline made between TO and FROM stations
Body Frame Acceleration - XYZ	Acceleration components in the vehicle body frame after removal of gravity, Earth rotation and estimated sensor errors
Body Frame Velocity - XYZ	Velocity components in the vehicle body frame
Azimuth StdDev	Estimated error of the computed azimuth.
British-East, North	East and North coordinates in the British State Plane projection
C/A RMS	Root mean square of C/A code signal
Checksum (8-bit)	The absolute value calculated by using XOR, ADD, or NMEA methodology on the 8 data bits of each character in the sentence; decimal and hexadecimal formats may be selected (user will be prompted for these options after the profile is created)
Combined Scale Factor	Scale factor used by surveyors. It applies the map scale factor combined with the ellipsoidal height correction, which can be used to scale distances on the ellipsoid to the earth's surface.
Combined Standard Deviation	Combines east, north and up position standard deviations into one value. Same value is written by Write Coordinates.
Computed Azimuth	Azimuth from base antenna to remote antenna in moving baseline projects.
Convergence	Meridian convergence for the current location in the current map projection
Corrected GPS Time	GPS time corrected for receiver clock bias
Course Over Ground (Track)	Direction of travel indicated by velocity vector.
Date	Date of the epoch or feature
Description	Description of the station or feature from the STA file
Distance Error (Azimuth)	Error in the computed baseline length in moving baseline projects.
Double Difference DOP	Double Difference DOP which is approximately equivalent to PDOP^2

Variable	Description
East, North, Height Fwd/Rev Separations	Separations between the forward and reverse solution in the east, north and height axes
East, North, Height Fwd/Rev RMS	Root mean square of the separations between the forward and reverse solution in the east, north and height axes
East, North, Up Standard Deviations	Estimated east, north and up position standard deviations in the local level frame
East, North, Up Velocities	East, North and Up velocity components in the local level frame
East, North, Up Velocity Standard Deviations	Estimated east, north up velocity standard deviations in the local level frame
East, North, Up Offset Applied	When a 3-D offset is applied to camera event marks, this field can be used to verify that the proper offset is applied. This offset is oriented to local level that is, true-north.
ECEF Covariance Matrix	Estimated ECEF position covariance matrix
ECEF Vector XYZ	XYZ components of the vector between base and remote in the ECEF frame
ECEF Velocity Covariance Matrix	Estimated ECEF velocity covariance matrix
ECEF XYZ Standard Deviations	Estimated ECEF position standard deviations in the XYZ axes
ECEF XYZ Velocities	XYZ velocity components in the ECEF frame
ECEF XYZ Velocity Standard Deviations	Estimated ECEF velocity standard deviations in the XYZ axes
Ellipsoidal Height	Height above current ellipsoid; based on datum selected during processing
Ellipsoidal Height Scale Factor	Used to scale distances on the ellipsoid to the earth's surface.
End Time	End time of the static session
Error Ellipse Orientation	Orientation of the error ellipse (theta)
Error Ellipse Semi-Major	Estimated error along the semi-major axis of the error ellipse (a)
Error Ellipse Semi-Minor	Estimated error along the semi-minor axis of the error ellipse (b)
Extended Ambiguity Status	Indicates if KAR fixed the ambiguities
Field Separator	User can select what character separates each variable in a record
Float/Fixed Ambiguity Status	Indicates if carrier phase ambiguities have been fixed
Gauss Kruger-East, North	East and North coordinates in the Gauss Kruger projection
Geoidal Undulation	Height of the ellipsoid above or below the geoid
GPS Corrected Time	Exact time of measurement in the GPS time frame.

| Variable	Description
GPS Time/Date	Time of the epoch or feature; time format may be changed to user's preference
GPS Week Number	Week number for GPS data starting from January 4, 1980; Depending in the format, this week number may or may not reset after 1023
Heading Angle	Negative yaw (see IMU angle definition).
Height Difference	Vertical height difference between stations
Height Error Estimate	Estimated error along the vertical axis (dh)
Horizontal Distance	Horizontal distance on the ellipsoid between stations (geodesic)
Horizontal Standard Deviation	Estimated position standard deviation in the east and north axes of a local level frame
Irish-East, North	East and North coordinates in the Irish State Plane projection
L1 Doppler RMS	Root mean square of L1 Doppler signal; useful for INS integration
L1 RMS	L1, or Iono-free root mean square
Lambert-East, North	East and North coordinates in the Lambert Conformal projection
Latitude	North/South geographic coordinate
Local Level Covariance Matrix	Estimated local level position covariance matrix; needs extended output in GrafNav
Local Level Velocity Covariance Matrix	Estimated local level velocity covariance matrix; needs extended output in GrafNav
Local Level XYZ	Local level left hand side frame where the x axis is pointing east, the y axis is pointing north and the z axis is pointing up; the frame is centered at the master station
Local Plane XYZ	XYZ axes of a coordinate frame defined by two or more points (see local plane options)
Local Time/Date	GPS time and date with time-zone offset applied
Longitude	East/West geographic coordinate
Map Scale Factor	Map projection scale computed for a location
Master File Name	Name of Master GPB file
Num BEIDOU Satellites	Number of BeiDou satellites
Num Fwd+Rev or Comb Baselines	Number of baselines used in the combined solution.
Num GALILEO Satellites	Number of Galileo satellites
Num GLONASS Satellites	Number of GLONASS satellites

Variable	Description
Num GPS Satellites	Number of GPS satellites
Num QZSS Satellites	Number of QZSS satellites
Number of Satellites	Total number of GPS and GLONASS satellites
Orthometric Height	Height above the geoid (mean sea level height)
PDOP, HDOP, VDOP	Position dilution of precision, horizontal position dilution of precision and vertical DOP. May be slightly different than values from other sources due to the differential computation
Pitch Angle	IMU pitch angle (see IMU angle definition)
Project Name	Name of current project
Quality Number	Quality factor; 1 (best) to 6 (worst)
Relative Azimuth	Azimuth between current and previous feature or epoch.
Relative Height Difference	Relative height difference between current and previous epochs or features
Relative Horizontal Distance	Uncorrected horizontal distance on the ellipsoid between the current and previous epochs. Multiply by Combined Scale Factor to bring to mapping plane and surface
Relative Slope Distance	Free-air distance between neighboring epochs or features. Distance between current and previous.
Remarks	Remarks of the station or feature from the STA file
Remote File Name	Name of Remote GPB file
Roll Angle	IMU roll angle (see IMU angle definition)
Roll, Pitch, Heading Separation	The difference between the combined solutions in terms of Roll, Pitch and Heading.
Roll, Pitch, Heading StdDev	Estimated attitude accuracy.
Scale Factor	Horizontal distance ratio between the globe and the map distance for the current point in the current map projection.
Selectable Grid	Allows user to enter a north and east value for a user defined grid. Grids can be modified and added using the Grid Manager (see Tools Menu).
Sequence Number	Allows the user to number epochs in the data with a user defined start and end sequence number, as well as, an incremental value.
Slope Distance	Free air distance between stations
Solution Type	Type of solution used. In GrafNav, possible solution types include SF-Carrier, DF-Carrier, IonoFree, RelIono, CaOnly, SingPoint. In GrafNet, FixedSoln, FloatSoln.

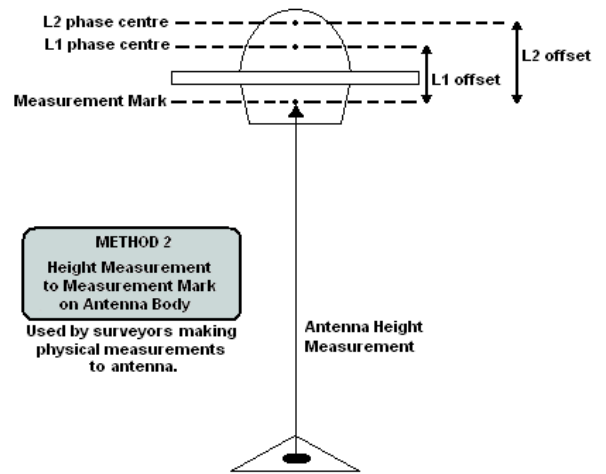| Variable	Description
Standard Dev. (NO PPM)	Trace of the covariance matrix expressed as a standard deviation; no distance dependent errors included.
Start Time	Start time of the static session.
State Plane-East, North	East and North coordinates in the US State Plane projection.
Static/Kinematic Status	Indicates if an epoch is static or kinematic.
Station Name	Name describing the station, feature or camera mark.
Surface Distance	Horizontal distance between the two stations on the surface (corrected geodesic).
Sun Angle	Angle of the sun above the horizon.
Time Length	Time length of the static session.
TM-East, North	East and North coordinates in the Transverse Mercator projection.
Total Slope Distance	Spatial distance between two points.
Total Horizontal Distance	The shortest path between two points on the surface of a sphere (for example, Great circle).
Transformed Grid	Allows for scaling, rotating and translating of a selectable grid.
User Frame Rotation X	Local Level to user frame rotation about X-axis.
User Frame Rotation X StdDev	Estimated standard deviation of Local Level to user frame rotation about X-axis.
User Frame Rotation Y	Local Level to user frame rotation about Y-axis.
User Frame Rotation Y StdDev	Estimated standard deviation of Local Level to user frame rotation about Y-axis.
User Frame Rotation Z	Local Level to user frame rotation about Z-axis.
User Frame Rotation Z StdDev	Estimated standard deviation of Local Level to user frame rotation about Z-axis.
User Text String	String of text defined by user.
UTC Corrected Time	Same as UTC Time, but a correction for the receiver clock bias is applied. This is the most precise time. Only applicable for epochs.
UTC Date	Date in UTC time.
UTC Time	Time which is available in various format. This is the epochs or feature time offset from GPS seconds by the GPS-UTC time offset. This time is uncorrected for the receiver clock bias.
UTM-East, North	East and North coordinates in the Universal Transverse Mercator projection.
VSF Ellipsoidal Height	Ellipsoidal height corrected by the map scale factor.

| Variable	Description
VSF Orthometric Height	Orthometric height corrected by the map scale factor. Used in photogrammetry applications to create an elevation that is more compatible with measured ground coordinates.
XYZ Accelerometer Bias	This is the apparent output in acceleration when there is no input acceleration present. It is computed by the GNSS/INS Kalman filter and the effects may be sinusoidal or random.
XYZ Gyro Drift	This is the apparent change in angular rate over a period of time. It is computed by the GNSS/INS Kalman filter and the effects are usually random.

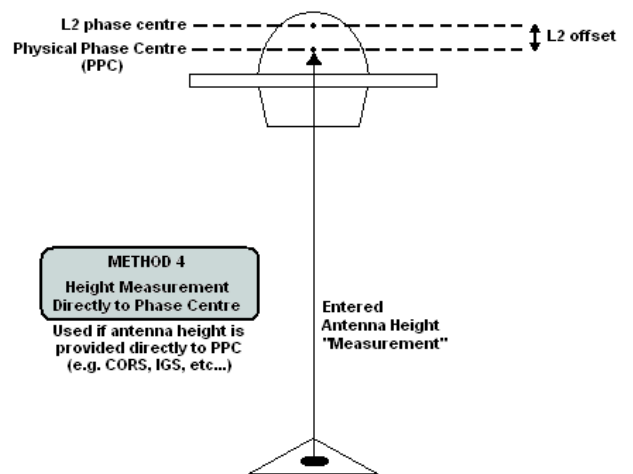# Appendix C   Antenna Measurements

Figure 7: Antenna Measurements
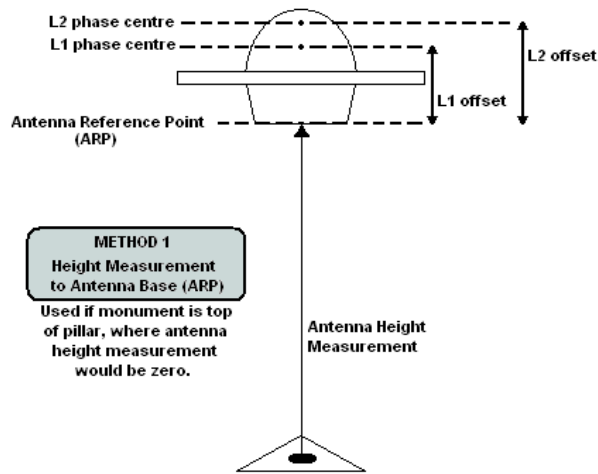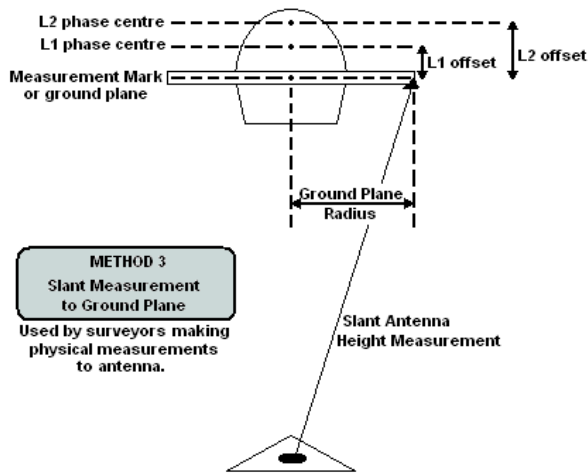
Appendix D   Mathematical Equations Used with Boresighting

This section provides information regarding the equations used by the boresighting module. The photogrammetric equation is typically presented as Equation 1.

Equation 1

$$\begin{bmatrix} x - x_p \\ y - y_p \\ -f \end{bmatrix} = k \cdot R_{\omega\phi\kappa}^{cam} \cdot \begin{bmatrix} X_g - X_o \\ Y_g - Y_o \\ Z_g - Z_o \end{bmatrix}$$

Where: x,y   image coordinates

x_p, y_p principal point offset

f   focal length

k   scale factor

X_g, Y_g, Z_g ground coordinates

X_o, Y_o, Z_o perspective center coordinates

The boresighting feature solves for a rotation required in the derivation of the $R_{\omega\phi\kappa}^{cam}$ matrix, which represents the attitude of the image coordinate system with respect to the ground coordinate system. This matrix is defined through Equation 2.

Equation 2

$$R_{\omega\phi\kappa}^{cam} = \Delta R_{\omega\phi\kappa} \cdot R_{\omega\phi\kappa}^{imu}$$

Inertial Explorer's boresighting module provides the rotation angles that form the ΔR_{wok} matrix. The other rotation matrix, $R_{\omega\phi\kappa}^{imu}$, is computed from Equation 3. In this equation, R_c accounts for the different axes definition between the camera and the IMU.

Equation 3

$$R_{\omega\phi\kappa}^{imu} = R_c \cdot R_{rpy}^T \cdot R_g$$

In general, when a conventional image frame is employed, the R_c is computed by Equation 4.

Equation 4

$$R_c = R_{0,0,\frac{\pi}{2}}\left(\omega = 0, \phi = 0, k = \pi/2\right)$$

The quantity R_g corrects for the map convergence and is computed by Equation 5.

Equation 5

$$R_g = \begin{bmatrix} \cos(\alpha) & \sin(\alpha) & 0 \\ -\sin(\alpha) & \cos(\alpha) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Where: α   is the difference between grid north and true north

The final quantity required to solve for $R_{\omega\phi\kappa}^{imu}$ is R_{rpy}, which represents the rotation required to orientate the IMU into the ground coordinate system and is computed by Equation 6.

Equation 6

$$R_{rpy} = \begin{bmatrix} \cos(y)\cos(r) - \sin(y)\sin(p)\sin(r) & -\sin(y)\cos(p) & \cos(y)\sin(r) + \sin(y)\sin(p)\cos(r) \\ \sin(y)\cos(r) + \cos(y)\sin(p)\sin(r) & \cos(y)\cos(p) & \sin(y)\sin(r) - \cos(y)\sin(p)\cos(r) \\ -\cos(p)\sin(r) & \sin(p) & \cos(p)\cos(r) \end{bmatrix}$$

Where: r   roll angle
p   pitch angle
y   yaw angle

> ℹ yaw = –heading

It is also useful to present the matrix required to rotate a ground coordinate system into an alternate coordinate system. This matrix is defined through Equation 7.

Equation 7

$$R_{\omega\phi\kappa} = \begin{bmatrix} \cos(\phi)\cos(\kappa) & \cos(\omega)\sin(\kappa) + \sin(\omega)\sin(\phi)\cos(\kappa) & \sin(\omega)\sin(\kappa) - \cos(\omega)\sin(\phi)\cos(\kappa) \\ -\cos(\phi)\sin(\kappa) & \cos(\omega)\cos(\kappa) - \sin(\omega)\sin(\phi)\sin(\kappa) & \sin(\omega)\cos(\kappa) + \cos(\omega)\sin(\phi)\sin(\kappa) \\ \sin(\phi) & -\sin(\omega)\cos(\phi) & \cos(\omega)\cos(\phi) \end{bmatrix}$$

Glossary

B

Baseline

Connection between two stations with one or more sessions. Normally, a session and a baseline can be considered the same. However, in some cases there may be more than one session per baseline. This is called a duplicate session baseline and it is plotted yellow on the screen.

C

Check Point

A station with known coordinates, but these coordinates are only used as a check against GrafNet's computed coordinates.

Control Point

See Station or GCP.

G

Ground Control Point (GCP)

A reference station with known latitude, longitude and height coordinates. The user may also assign horizontal and vertical standard deviations for these values. There can be horizontal, vertical or 3-D points, and there must always be at least one 3-D point or else one horizontal and one vertical point per project.

O

Observation

A raw measurement file collected from a receiver set up over a stationary point. GrafNet only accepts GPB files and, thus, other formats must be converted first. See the table Supported Data Formats for Post-Processing for supported formats. GrafNet also requires single frequency carrier phase data as a minimum, and accepts dual frequency if available. Users wishing to perform code-only processing should use GrafNav.

S

Session

Concurrent period of time between two observation files at two different stations. One of the two stations will be the remote and the other will be the master. The arrow on the screen will be pointing from the master to the remote. The direction is determined by GrafNet in order to form loop closures as well as to minimize the number of legs from a control point. Each session will be processed individually and combined in either a network adjustment or traverse solution. A session can have different statuses and colors depending on whether certain tests passed or failed.

Station

A point where the GPS receiver was setup over and there might be multiple observation files for a single station. However, one set of position values will be produced for each station as a final product of GrafNet. There are several types of stations.

T

Tie Point

Such a point may also be called a loop tie closure and is formed when two or more sessions point to it. Thus, there is a redundant determination at this point.

Traverse Station

This is a point with no tie or control information. It might have two stations connected to it, but one is pointing to it and the other is pointing from it.