



**A NovAtel Precise Positioning Product**

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

**User Manual**

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# Inertial Explorer 8.70 User Manual

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## **APPENDIX A Output Variables**

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**6.2.2** Expert phone and e-mail support

**6.3** For software Updates and Upgrades (defined below), and regular customer support, contact the NovAtel Support\ Hotline at 1-800-NOVATEL (U.S. or Canada only), or 403-295-4900, Fax 403-295-4901, e-mail to support@novatel.com, website: <http://www.novatel.com> or write to: NovAtel Inc., 1120 - 68 Avenue NE, Calgary, Alberta, Canada T2E 8S5.

**6.4 Software Version Support.** NovAtel will support versions of the SOFTWARE PRODUCT for a minimum of three (3) years from the SOFTWARE PRODUCT release date. This support period includes version-specific auto-download content such as manufacturer files.

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**10.2.3** Intentional violations of export laws and regulations will not be tolerated. If You intentionally or knowingly participate in violation of export regulations, this EULA is subject to immediate termination and possible legal action. You may also be exposed to criminal or civil litigation, fines or imprisonment; and

**10.2.4** Where there is any doubt, uncertainty or suspicion of possible impropriety with respect to any law surrounding any proposed transaction, the transaction will be forfeited without question.

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You agree to comply with all export laws, rules and regulations of the United States and their respective foreign export compliance agencies or authorities, and not to export or re-export the SOFTWARE PRODUCT in violation of any such laws, rules or regulations, or without all necessary authorizations. You have the obligation to obtain and bear all expenses relating to any necessary licenses and/or exemptions with respect to its export of the SOFTWARE PRODUCT from your country.

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THIS EULA MAY NOT BE AMENDED OR MODIFIED UNLESS SO DONE IN WRITING SIGNED BY AUTHORIZED REPRESENTATIVE OF NOVATEL. THE PRE-PRINTED TERMS AND CONDITIONS OF

ANY PURCHASE ORDER OR ANY OTHER TERMS AND CONDITIONS OF A PURCHASE ORDER WHICH MAY CONFLICT IN ANY WAY WITH THE TERMS AND CONDITIONS OF THIS EULA SHALL BE VOID, EVEN IF ISSUED SUBSEQUENT TO THE EFFECTIVE DATE OF THIS EULA, AND SHALL NOT BE DEEMED TO CONSTITUTE A CHANGE TO THIS EULA.

**11.2 Severability.** If a provision of this EULA is or becomes or is found by a court or other competent authority to be illegal, invalid or unenforceable, in whole or in part, under any law, such provision will to that extent only be deemed not to form part of this EULA and the legality, validity and enforceability of the remainder of this EULA will not be affected or impaired. The parties will negotiate in good faith to replace any such illegal, invalid or unenforceable provision with a valid and enforceable provision which, as far as possible, has the same legal and commercial effect as that which it replaces.

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# Foreword

Inertial Explorer® and Inertial Explorer Xpress 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 and Inertial Explorer Xpress. It allows you to effectively navigate and post-process 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 Inertial Explorer and Inertial Explorer Xpress. It is intended to be used in conjunction with the corresponding version of Waypoint's Inertial Explorer or Inertial Explorer Xpress 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 Inertial Explorer and Inertial Explorer Xpress. The conventions include the following:



This is a note box that contains important information before you use a command or log, or to give additional information afterwards.



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).

## Customer Service

If the software was purchased through a vendor, contact them for support. Otherwise, for software updates and customer service, contact Waypoint using the following methods:

Call: 1-800-NovAtel (1-800-668-2835) for North American access  
1-403-295-4900 for International access

Email: [support@novatel.com](mailto:support@novatel.com)

Web: [www.novatel.com/support/info/view/software](http://www.novatel.com/support/info/view/software)

# Chapter 1 Inertial Explorer

## 1.1 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 and tightly coupled 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.

## 1.2 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 1.5 km from the project centroid ( $\sim 7 \text{ km}^2$  area). 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
- IEX will not compute marine heave
- IEX includes a simplified list of QC plots that are relevant to the capabilities of the product

## 1.3 Installation

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

### 1.3.1 What You Need To Start

#### 1.3.1.1 Activation ID

A license is required to convert raw GNSS data<sup>1</sup>, 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.

---

<sup>1</sup>No license is required to convert NovAtel data to Waypoint format.

### 1.3.1.2 Installation file

The latest software installation files can be found at the following password protected website:

[www.novatel.com/waypoint-installation-files-8-70](http://www.novatel.com/waypoint-installation-files-8-70)

The password to this website should have been provided with your software license. If not, contact NovAtel Support at [support@novatel.com](mailto:support@novatel.com) with your activation ID.

See *Prerequisites* below for the hardware requirements.

### 1.3.2 Prerequisites

Only a user with administrator privileges can successfully install all of the components required to run Waypoint software. To run Waypoint software packages, your personal computer must meet or exceed this minimum configuration:

#### 1.3.2.1 Operating System

Windows 7, 8, 8.1 or 10.

### 1.3.3 How to install Waypoint software

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



It is recommended that a license be returned prior to any significant computer maintenance or changes (i.e. upgrading of the operating system, motherboard replacements 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 both an FTP site and a password protected website. Contact [support@novatel.com](mailto:support@novatel.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 8.60, you will need to upgrade your license. For upgrade instructions, see *How to Activate Your License* below or *How to Manually Activate/Return Your License* on page 20.
4. See *Copy User Files* on page 21 for instructions on how to copy user created content from previous major versions.

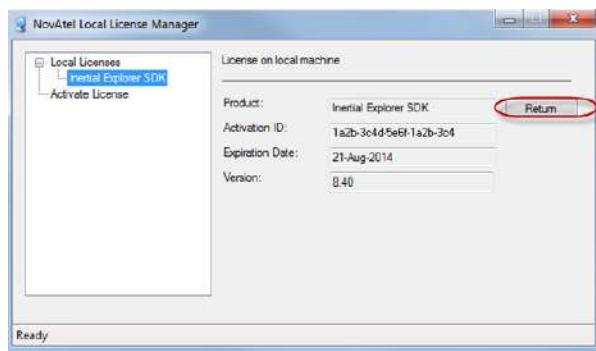
### 1.3.4 How to Activate Your License

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

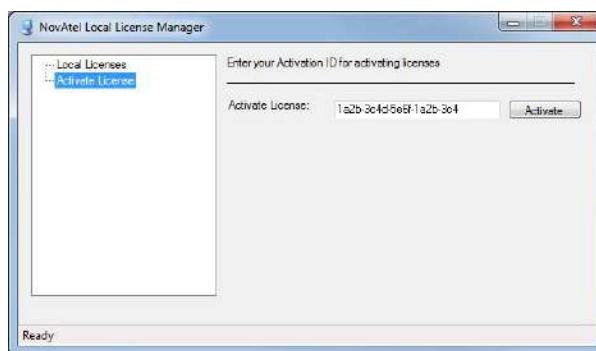


This procedure requires an Internet connection. If you do not have an Internet connection, go to *How to Manually Activate/Return Your License* on page 20.

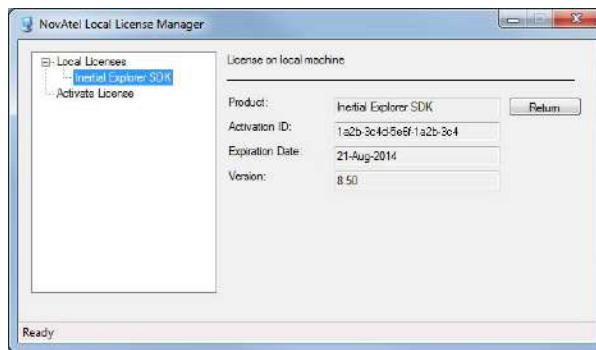
1. Install the Waypoint software that you intend to use. Contact [support@novatel.com](mailto:support@novatel.com) with your activation ID if you need help locating the setup file.
2. From the Start menu, navigate to the *Utilities* folder within the software's program group and open the *Local License Manager*.  
Alternatively, you can navigate to the software's installation folder on your computer and open the *LLMForm.exe* file.
3. If you are upgrading an existing license, you will first need to return the original license. Do this by selecting your existing license under *Local Licenses* and then clicking the *Return* button.



4. Copy the alpha-numeric Activation ID that was provided to you by Customer Support and paste it into the box under the *Activate License* branch.



5. After the Activation ID has been entered, click the *Activate* button.
6. If the license was successfully activated, you will see it appear under the Local Licenses branch. Click on the license to see the relevant information.



If you have activated a term license, then the expiration date will be displayed here.

If the activation fails, contact Customer Support ([support@novatel.com](mailto:support@novatel.com)).

### 1.3.5 How to Manually Activate/Return Your License

This section describes how to activate and/or return a license when no Internet connection is available or you are unable to access NovAtel's license server.



If you are upgrading an existing license, your original license will need to be returned prior to activating the upgrade (see the manual return instructions first).

#### 1.3.5.1 Manual Activation Process

1. Open a console window and navigate to the software's installation folder (e.g. C:\NovAtel\InertialExplorer870\bin).
2. Enter the following command to generate a Manual Activation Request.

```
LLMForm -am ActivationID OutputFile
```

Where:

*ActivationID* is the alpha-numeric Activation ID provided to you by Customer Support

*OutputFile* is the output XML file that will contain the request

Sample usage:

```
LLMForm -am 1a2b-3cf4-5e6f-1a2b-3c4d-5e6 c:\temp\activate_req.xml
```

3. Using your activation ID, login to the FlexNet customer portal here: <https://license.novatel.com/flexnet/operationsportal/showActivationIdLogon.do>.
4. Select *Manual Activation* under *Offline Operations*.
5. Select *Choose File* and browse to the request XML file you generated in step 2 and then select *Submit*.
6. A response will be generated and displayed to the screen. Select *Save* and a *responseXML.xml* file will be saved to the Windows default download directory. Optionally, move this file to the same directory as the activation request.
7. To process this response, navigate back to the installation directory and enter the following command:

```
LLMForm -p InputFile
```

Where:

*InputFile* is the full name and path of the *responseXML.xml* file generated from the FlexNet customer portal

Sample usage:

```
LLMForm -p c:\temp\responseXML.xml
```

8. If this is the first manual activation on a machine, the license will not be activated on the machine at this point, because the first response file is simply a configuration response. You will need to repeat step 1 - 7 in order to re-submit the request and complete the activation.
9. The license should now be activated. To check, enter the following command:

```
LLMForm -v
```

Alternately, open the Local License Manager and look under the Local Licenses branch.

### 1.3.5.2 Manual Return Process

1. Open a console window and navigate to the software's installation folder (e.g. C:\NovAtel\InertialExplorer870\bin).
2. Enter the following command to generate a Manual Return Request:

```
LLMForm -rm ActivationID outputFile
```

Where:

*ActivationID* is the alpha-numeric Activation ID provided to you by NovAtel Order Management or Customer Support

*OutputFile* is the output XML file that will contain the request

Sample usage:

```
LLMForm -rm 1a2b-3cf4-5e6f-1a2b-3c4d-5e6 c:\temp\return_req.xml
```

3. Using your activation ID, login to the customer FlexNet portal here: <https://license.novatel.com/flexnet/operationsportal/showActivationIdLogon.do>
4. Select *Manual Return* under *Offline Operations*.
5. Select *Choose File* and browse to the manual return request file generated in step 2 and then select *Submit*.
6. A response will be generated and displayed to the screen. Select *Save To File* and a *responseXML.xml* file will be saved to the default Windows download directory. Optionally, move this file to a temporary directory or to the root of your hard drive.
7. To process this response, navigate back to the installation directory and enter the following command:

```
LLMForm -p inputFile
```

Where:

*InputFile* is the full name and path of the *responseXML.xml* file generated through the FlexNet customer portal

Sample usage:

```
llmform -p c:\temp\responseXML.xml
```

8. The license should now be returned. To check, open the Local License Manager and look under the Local Licenses branch to ensure that the license is no longer listed.

## 1.3.6 Software Utilities

The following utilities are installed automatically and can be accessed from *Start | Programs | Waypoint GPS 8.70 | Utilities*.

### 1.3.6.1 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 138.

### 1.3.6.2 Copy User Files



Prior to version 8.70, the CopyUser utility could be used to migrate any user created content from a previous version to the current version. This utility has been discontinued in 8.70. See the following for instructions on copying user created content from previous software versions to 8.70.

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 *Settings | 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 favourite 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 only)
- User created IMU error models (user imu, Inertial Explorer only)
- User created vehicle profiles (user.vpf, Inertial Explorer only)

To find your 8.70 User directory, navigate to the installation directory of your 8.70 software and read the *waypoint.settings* file. This is an ASCII file that you can read with any ASCII text editor. Your 8.70 User directory path will be saved in the node labeled *UserDir*. By default UserDir will be in your 8.70 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 8.70 software.

All user files from 8.60 are fully compatible with 8.70 and you can copy them directly from 8.60 to 8.70. Waypoint cannot guarantee 8.70 User file compatibility for older software versions (e.g. the lever arm favourites – user.lvf – file is not supported in 8.70). If a user file is incompatible with 8.70, you will have to recreate the file using 8.70 utilities.

### 1.3.6.3 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.

### 1.3.6.4 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 134 for more information.

### 1.3.6.5 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 139 for more information.

You will also see the Local License Manager utility.

**Table 1: Supported Data Formats**

Make	Model
NovAtel	All Models
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 M-8
RINEX	2.x 3.x

## 1.4 Getting Started with Inertial Explorer

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

### 1.4.1 How to start Inertial Explorer

1. Verify installation.
2. Click on *Inertial Explorer* to start the program.

### 1.4.2 Convert and Process GNSS Data

Raw GNSS data files must be converted into Waypoint's GPB format. If creating a project through the New Project Wizard, there is no need to convert your data first. If creating an empty project, the Raw GNSS Converter must be used before adding the data to an empty project. See *GNSS Data Converter Overview* on page 139 for a complete description of the *Convert* utility.



For NovAtel SPAN users, all available GNSS, IMU, DMI (odometer), dual antenna heading and mount data will automatically be extracted by the GNSS converter.

### 1.4.3 Convert IMU Data

IMU data must be converted to Waypoint's generic IMR format for processing. To do this, follow the steps below.



NovAtel SPAN users do not have to follow these steps because this is done automatically when



converting the raw GNSS data.

#### 1.4.3.1 How to convert SPAN IMU data

1. Open the *Convert Raw GNSS to GPB* utility through *File | Convert | Raw GNSS to GPB*.
2. Use the *Get Folder* button to navigate to the directory containing the raw data.
3. Use the *Auto Add All* button to automatically add any detected raw GNSS data files to the *Convert Files* list.
4. Select *Convert*. All available GNSS, INS, DMI (odometer), dual antenna heading data and/or mount data will be converted.

#### 1.4.3.2 How to convert third party IMU data



Before using the *Waypoint IMU Data Conversion* tool, a generic IMU file must be formed as this is used as input. See *Inertial Explorer Data Formats* on page 156 for the format of this file.

1. Open the conversion utility via *File | Convert | Raw IMU Data to Waypoint Generic (IMR)*.
2. Click the *Browse* button to locate the raw IMU data file.
3. Under the *IMU Profiles* box, select the appropriate conversion profile.
4. Click *Convert* to create the IMR file. See *Raw IMU Data Converter* on page 156 for more information.
5. Add the file to the project via *File | Add IMU File*.

#### 1.4.4 Process SPAN IMU Data

The steps for processing SPAN IMU data are below.

1. Click the *Process* menu and then select *Process LC (Loosely Coupled)* or *Process TC (Tightly Coupled)*.



If you are processing in loosely-coupled mode, make sure that you have processed the GNSS data first.

2. Ensure that an appropriate processing profile for your application (aerial, ground vehicle, marine, pedestrian or UAV) and your SPAN IMU type has been automatically selected. If this needs to be changed, access the profile pull down menu.
3. Ensure the IMU to GNSS lever arm has been correctly loaded. If the IMU to GNSS lever arm was not saved during data collection, enter it.
4. Ensure the body to IMU rotation has been correctly loaded. If the body to IMU rotation was not saved during data collection, enter it.
5. Click *Process*.



The *Process* option on the LC and TC dialog features two additional options:

#### **Process without pre-processing:**

Using this option skips Inertial Explorer's 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:**

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.

### **1.4.5 Plotting and Quality Control**

Once processing is complete, view the quality of the results by analyzing the IMU plots. Under the *Output* menu, choose *Results* to access the following IMU plots:

#### **1.4.5.1 Attitude (Roll and Pitch)**

This plot shows the roll and pitch profile of the processed IMU data.

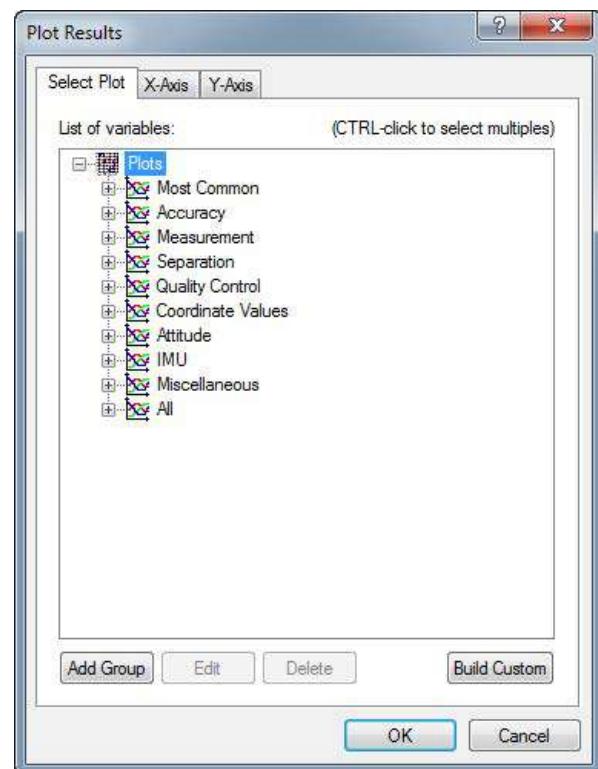
#### **1.4.5.2 Attitude (Azimuth/Heading)**

This plot shows the heading/azimuth of the IMU and the GNSS course-over-ground (COG). They should be in reasonable agreement when the vehicle is moving forward.

If the GNSS COG and the IMU azimuth are biased by a large and constant amount (i.e. +/- 90 degrees or 180 degrees) it indicates the IMU sensor frame has not been rotated to the vehicle body frame (Y-forward, X-right and Z-up). If this is not intentional, a body to IMU rotation should be applied in the LC or TC processing dialog boxes. This will ensure Inertial Explorer's output roll, pitch and heading values are referenced to the vehicle frame.

#### **1.4.5.3 Attitude Separation**

This plot requires that forward and reverse have both been processed. It shows the difference between their attitude values. Ideally, they should agree to a reasonable level considering the quality of the IMU and the dynamics of the survey.



#### 1.4.5.4 IMU-GNSS Position Misclosure

This plot shows the difference between the GNSS solution projected to the IMU center of navigation and the mechanized INS positions obtained from GNSS/INS processing. They should agree to a reasonable level, largely dependent on the quality of the GNSS trajectory (i.e. severity of the GNSS signal conditions).



Use the *Build Custom* button to add some of these plots to a customized list.



Consider adding your preferred Q/C 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.

#### 1.4.5.5 Smooth Solution

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 *Settings | Preferences*. If this has been disabled, it is strongly recommended to run the Smoother (*Process | Smooth Solutions*) prior to using the Export Wizard.

#### 1.4.6 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.



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

### 1.5 File menu

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

#### 1.5.1 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.

### 1.5.1.1 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.



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.



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.

If you plan to process with PPP, you can skip the previous step and download the precise satellite clock and orbit files from the Internet.



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

### 1.5.1.2 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.

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*.



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.
7. Select *Process | Process GNSS*.
8. Ensure an appropriate processing profile is selected prior to processing.

## 1.5.2 Open Project

This option allows you to open existing projects.

### 1.5.2.1 How to open a project

1. Choose *File | Open Project*. A dialog box appears that asks you to select the name of an existing project (CFG file).
2. Choose the name of the project and click the OK button.

## 1.5.3 Save Project

When this option is selected, all project settings are saved to a Inertial Explorer configuration (.cfg) file. The project is automatically saved when processing and thus accessing the save option from the File menu is not typically necessary.

### 1.5.3.1 How to save a project

1. Choose *File | Save Project*.

## 1.5.4 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.

### 1.5.4.1 How to save as a project

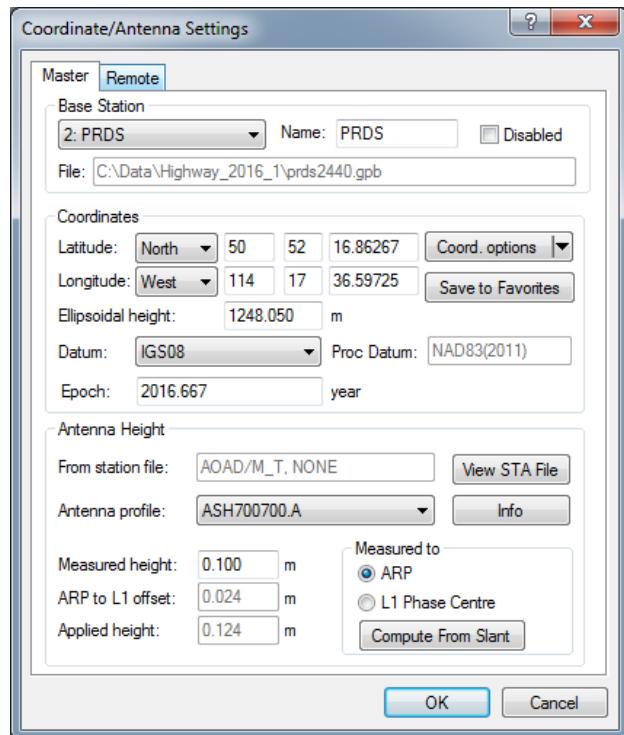
1. Choose *File | Save As*.
2. Enter the name and where you would like to save your project.



Entering the name of a project that already exists overwrites the file contents.

### 1.5.5 Add Master File(s)

Up to 32 base stations can be added to a single Inertial Explorer 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.



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

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 32 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.

Refer to the following links for information about the fields on this dialog.

- *Master Station Position* on the next page
- *Datum Selection* on the next page
- *Epoch Selection* on the next page
- *Antenna Height* on the next page
- *Antenna Models* on page 31

### 1.5.5.1 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 Inertial Explorer's Precise Point Processor. When using this option, the differences between the loaded and computed coordinates are displayed. Note that PPP accuracy is largely dependent on the length of the survey and the quality of the data.

### 1.5.5.2 Datum Selection

Inertial Explorer 8.70 distinguishes 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.

### 1.5.5.3 Epoch Selection

Inertial Explorer allows users to 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).

### 1.5.5.4 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.

### 1.5.5.5 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

Inertial Explorer supports absolute antenna models as provided by the NGS. 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.

### 1.5.6 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.

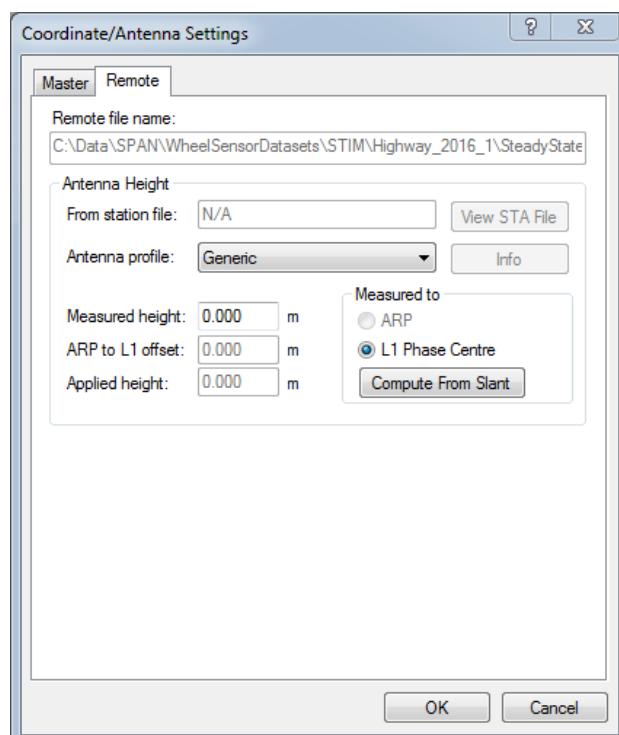
When adding a remote GPB file, ensure the *Measured height* of the antenna is set to zero. Inertial Explorer uses the entered IMU to GNSS lever arm in order to transfer the GNSS position updates to the IMU center of navigation during processing. A vector can be entered from the IMU to any other sensor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

#### 1.5.6.1 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.

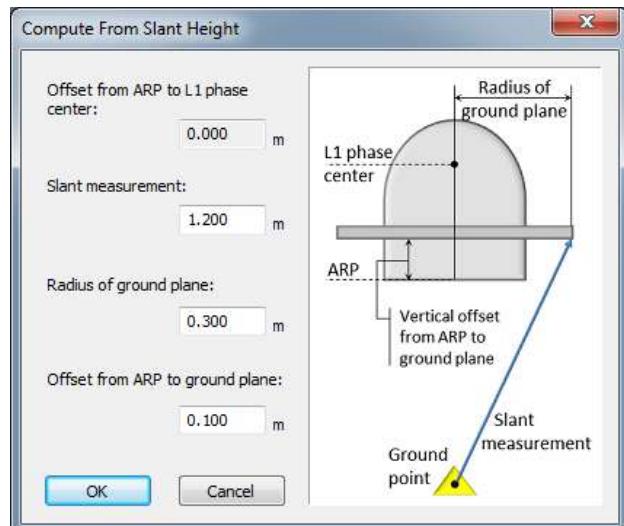


### 1.5.6.2 Compute from Slant

The *Compute from Slant* feature enables the automatic computation of the true vertical *Applied height* required by Inertial Explorer given a slant measurement, the radius of the ground plane edge and the offset from the ARP to the ground plane edge.

### 1.5.7 Add IMU File

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.

### 1.5.8 Add Precise/Alternate Files

The *Precise Files* dialog primarily facilitates the easy download of precise products. Users can choose between GPS, GPS+GLONASS, and 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.

#### 1.5.8.1 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 heavily 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, Inertial Explorer combines all ephemeris information collected at the base station(s) and remote. 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.

### 1.5.8.2 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), the IGS, 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 2 hours to 3 weeks. The difference in accuracy between rapid and final products is marginal, generally 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 cancelled 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 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.

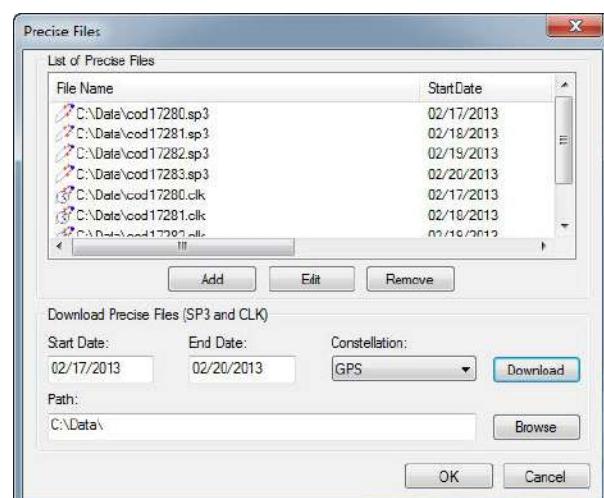
#### How to download precise ephemeris files

1. Select *File | Add Precise 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) and clock files (.clk) 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 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.

### 1.5.8.3 IONEX Files

IONEX (Ionosphere Map Exchange) files contain a model of the TEC (Total Electron Content) of the ionosphere. These files can be applied to assist long distance L1 only processing. As such, these corrections are not applicable to the majority of Inertial Explorer users. These files are ignored if dual frequency ionospheric processing is engaged.

### 1.5.8.4 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*.

## 1.5.9 Load

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

### 1.5.9.1 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.

### 1.5.9.2 PPP Solution

Inertial Explorer's 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.

### 1.5.9.3 LC Solution (Loosely Coupled)

Loads the loosely coupled solution.



Loosely coupled processing is not supported in Inertial Explorer Xpress.

### 1.5.9.4 TC Solution (Tightly Coupled)

Loads the tightly coupled solution.

### 1.5.9.5 Any Solution

This option allows any Inertial Explorer 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.

### 1.5.9.6 Single Point Solution (from .gp 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.

### 1.5.9.7 Camera Event Marks

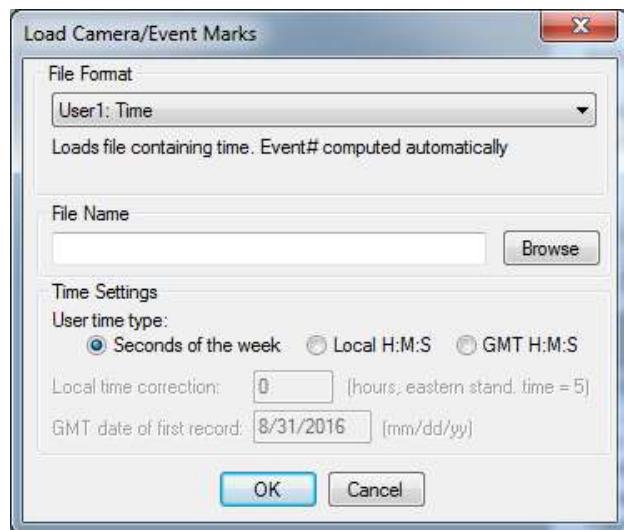
Events from supported GNSS formats are automatically written to a station file (.sta) during conversion of the raw GNSS data to GPB, and automatically loaded into the project and displayed on the map window.

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 *Settings | 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).

*GMT H:M:S* – GMT hours, minutes and seconds (HH:MM:SS.SSSS).

### **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.

## 1.5.9.8 Station File (.sta/nst)

Inertial Explorer automatically loads the station file (.sta) associated with the remote GPB file. 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.

### 1.5.9.9 Stations with Known Lat/Long

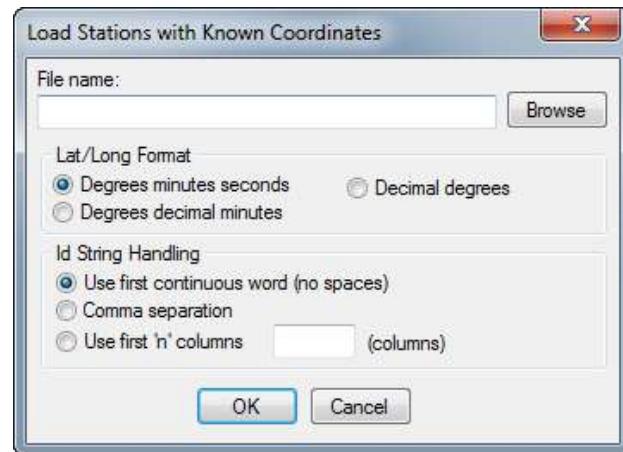
This option allows you to load and display a file that contains stations with known coordinates. The coordinates are displayed with pink triangles.

#### 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 for the program to begin at. Each character is a column.

### 1.5.10 Convert

#### 1.5.10.1 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 139 for more information regarding this utility.

### 1.5.10.2 Raw IMU Data to Waypoint Generic (IMR)

IMU data must be converted to IMR format in order to be processed by Inertial Explorer. Use this utility to perform this conversion. See *Convert IMU Data* on page 23 for more information.

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.

## 1.5.11 GPB Utilities

The GPB Utilities are available for use with GPB files and includes the following:

### 1.5.11.1 Concatenate, Slice and Resample

See *Concatenate, Slice and Resample Files* on page 138.

### 1.5.11.2 View Raw GNSS Data

See *GPB Viewer Overview* on page 134.

## 1.5.12 Recent projects

Provides a list of recent projects for quick access.

## 1.5.13 Exit

Exits Waypoint software.

## 1.6 View Menu

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

### 1.6.1 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.

### 1.6.2 GNSS Observations

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

#### 1.6.2.1 View Raw GNSS Data

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

#### 1.6.2.2 View Ephemeris File

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

#### 1.6.2.3 View Station File

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

#### 1.6.2.4 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.

### 1.6.2.5 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.

## 1.6.2.6 Remove

Removes the master file completely from the project.

### **1.6.3 Forward and Reverse Solutions**

### **1.6.3.1 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.

### 1.6.3.2 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. See *FML*, *RML*, *FSL* and *RSL Files* on page 162 for an example of this summary file.

#### 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.

### 1.6.3.3 IMU LC / TC Message Log

These files display IMU messages generated by the processing engine. Inertial Explorer outputs a forward message log (.fli/.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 166, *DMR File* on page 168 and *HMR File* on page 170.

### 1.6.4 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<sup>2</sup>.
- 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 85 for information about the *Export Wizard*.

### 1.6.5 Features

The *Feature Editor* window lists all of the features loaded into the project. If the data has been processed, a summary of processing quality is also displayed. 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*.

### 1.6.5.1 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. To show the time in HH:MM:SS, select *Show HMS*.

#### **Q**

Reports Inertial Explorer's computed quality number. Quality numbers range from 1 (best) to 6 (worst).

- 1 represents a fixed integer solution with good satellite geometry
- 2 & 3 represent either fixed integers with marginal geometry or converging float solutions
- 4 & 5 indicate qualities similar to DGPS
- 6 represents a C/A only solution

The quality number is only meant to communicate, at a high level, the overall processed data quality. For more information, access Inertial Explorer's quality control plots.

#### **Std(m)**

Combined standard deviation of the north, east and height components, including additive PPM based error.

#### **Fix**

Shows the ambiguity status of the feature's solution:

**Y** = fixed integer

**N** = float solution

#### **Azimuth**

Azimuth, in degrees-minutes-seconds, from previous feature to current feature.

#### **Dist(m)**

Distance, in metres, from previous point to current point.

#### **Dt(s)**

Time difference, in seconds, between current and previous point.

#### **Height**

Height, in metres, of the feature. This is normally an ellipsoidal height, but if the master station height was entered as orthometric then this height is more orthometric. Use the *Export Wizard* to get the exact orthometric height. For stations, like STA and GIS, with antenna heights, this height is of the monument and not the antenna.

#### **AntHgt**

The height of the antenna above the monument. Camera marks do not have an antenna height and so *N/A* is displayed.

#### **Desc/Info**

Describes the feature or line information for the camera mark.

### 1.6.5.2 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.

#### **Add Station**

Lets you manually add a station. Also add stations by right-clicking on epochs in the map 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.

#### **View Info**

Shows processing information for any selected feature enabled during processing.

#### **Global Edit**

Make changes to multiple selected features. Modifications can be made to the antenna height and time offset.

#### **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.

#### **Move to Static**

This feature is used to assist in the quality control of surveys where multiple short static sessions are collected in challenging GNSS signal environments. When used, it allows you to see the difference between the forward and reverse solution for each static session in your survey when exporting from the Wizard.

An example of an application that may use the *Move to Static* feature is seismic surveying. Move to Static requires that a station mark be present within each static session.



*Edit, Re-Number and Move to Static* work with multiple features selected. To select a continuous block, hold down the *Shift* key while clicking on features. To select individual features, use the *Ctrl* key.

### 1.6.6 ASCII File(s)

The *View ASCII File(s)* option allows you to view any of the ASCII files generated by the software using Inertial Explorer's 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)
- Configuration files (CFG).

## 1.6.7 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 134 for more information.

## 1.6.8 Current CFG File

This option opens a Waypoint configuration file (.cfg) within Waypoint's ASCII viewer. The CFG file contains all of the installation and processing settings in a project.

# 1.7 Process Menu

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

## 1.7.1 Process GNSS

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

### 1.7.1.1 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)

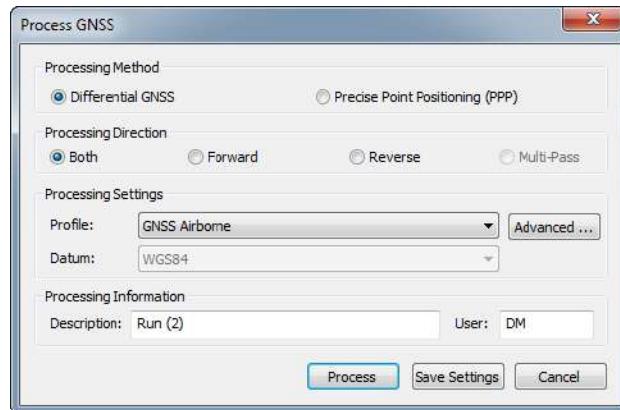
PPP is an autonomous positioning method where data from only the remote receiver is used. If base station data has been added to the project, it will not be used when processing PPP. By design, both differential and PPP trajectories can be processed within the same project without over-writing each other.

Inertial Explorer's PPP processor requires dual frequency data, single frequency PPP is not supported.

Upon selecting *Process*, Inertial Explorer's pre-processing checks test whether precise ephemeris and clock data have been added to the project, which are required to remove metre-level error sources. If the project contains only broadcast orbit and clock corrections from the combined ephemeris data (.EPP files), Inertial Explorer's 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*, Inertial Explorer will call the Download Service Utility to automatically download the best available source of precise and ephemeris data given the detected constellations in the remote data file.



### 1.7.1.2 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, Inertial Explorer applies inverse variance weighting 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 only for PPP. This is because it is a method of processing designed to maximize float solution convergence. This is not normally a consideration in differential processing due to ARTK, where carrier phase ambiguities are fixed.

When choosing multi-pass processing, forward and reverse solutions are not independent. Rather, the data is processed three times sequentially (forward, reverse and forward again). After each direction finishes processing, the converged Kalman filter error states are applied to the next processing direction. The benefit of this method of processing is that float ambiguity convergence is maximized, producing in some cases near fixed integer solution quality.

### 1.7.1.3 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 *Settings | 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.



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

Processing profiles are particularly helpful for new users, as adjusting individual processing settings from the *Advanced* options are often unnecessary in order 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.

**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.

**1.7.1.4 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.

**1.7.1.5 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**

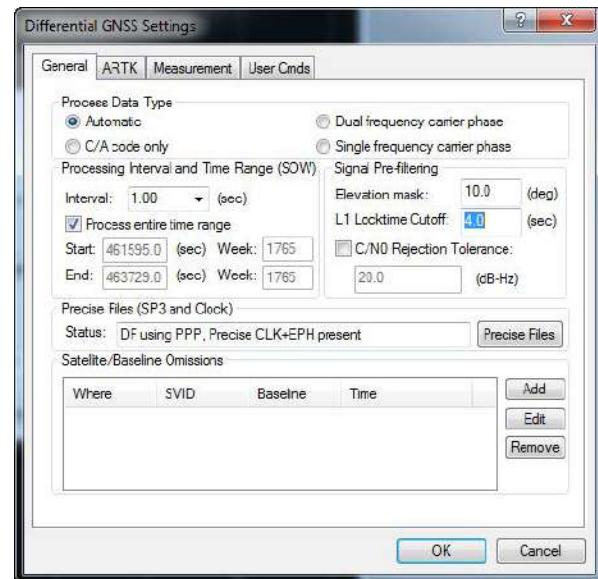
Only C/A code measurements are applied in this method of processing which is limited to metre-level accuracy.

**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 decimetre 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. Inertial Explorer's 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 Inertial Explorer 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.

## Satellite/Baseline Omissions

Inertial Explorer's pre-filtering options will often remove noisy or problematic data prior to the processing stage. During processing, Inertial Explorer's 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

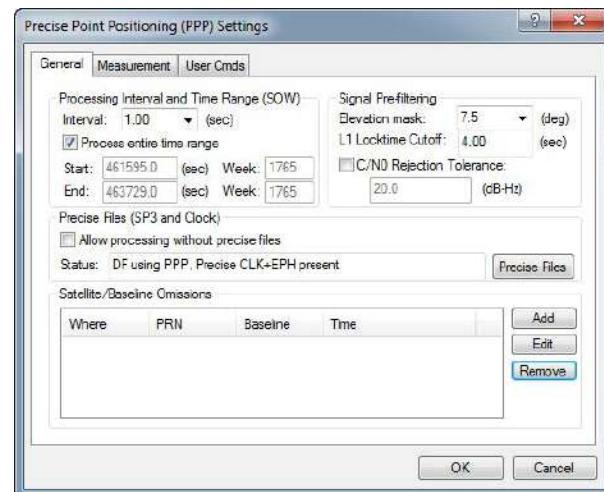
Applies the omission to a specific time period, entered in GPS seconds of the week.

### 1.7.1.6 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 44. The one exception is *Allow processing without precise files*.

#### Allow processing without precise files

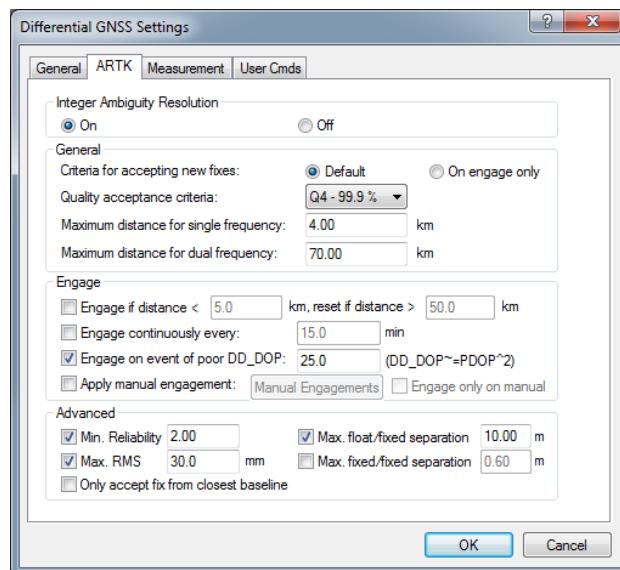
This option removes the restriction where measurements will not be used if precise clock and ephemeris data is unavailable. This enables a user to process PPP using only broadcast ephemeris data for the purposes of a quick check on the quality and quantity of data processed prior to precise products or base station data becoming available.



### 1.7.1.7 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.



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 metre-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 metres 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 decimetre-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.

### 1.7.1.8 Measurement

#### Measurement Standard Deviations

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

##### Code

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

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 or 0.25 m 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.

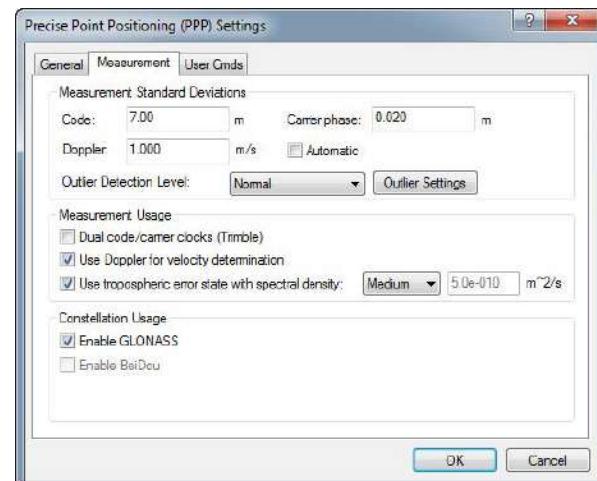
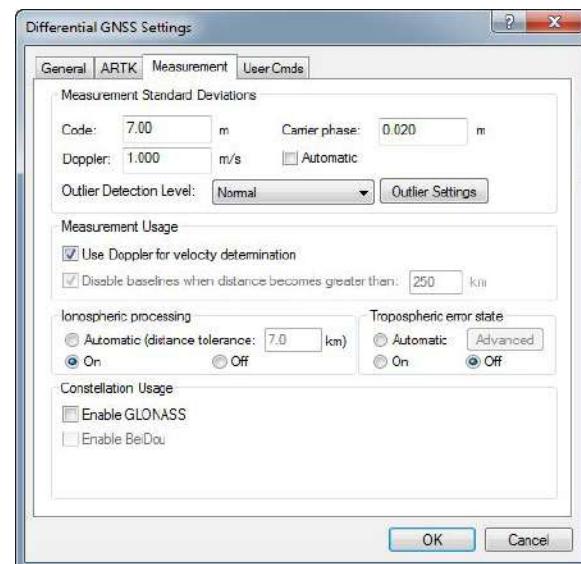
##### Outlier Detection/Rejection

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)**

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.

**Use tropospheric error state (PPP processing only)**

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.

**Tropospheric Error State (Differential processing only)**

Unlike ionospheric error, tropospheric error cannot be directly observed and removed using dual frequency measurements. This is because the troposphere is nondispersive at GNSS frequencies and affects L1 and L2 equally. Inertial Explorer uses a Saastamoinen model to estimate the tropospheric delay at the base and remote.

However regardless of what model is applied, tropospheric error is largely removed in differential processing as it is a correlated error on short baseline lengths.

As the baseline length increases (to ~150 km or more) and/or where there is a significant height difference between the base and remote (~10,000 ft), residual tropospheric error can become the largest error source; reaching magnitudes as much as 30 cm in some cases.

In order to reduce the tropospheric error under these conditions, Inertial Explorer leverages the ability of the Precise Point Positioning engine to observe the actual tropospheric delay at the base station. In PPP, tropospheric error is observed as an additional Kalman filter state. Hence, Inertial Explorer first solves the actual tropospheric delay at the base station and then, as a second step, applies this information in differential processing.

The advanced tropospheric state can reduce residual tropospheric error significantly, further preserving GNSS postprocessing accuracy as baseline length increases.

The *Automatic* setting will automatically engage this option if 10% or more of the unprocessed positions are over 150 km from each base station OR if 10% of the survey is detected as being flown in excess of 3000 metres, or 10,000 feet above the base stations. In both cases, a minimum of two hours of data is required for this option to

automatically engage, as it can perform poorly on short data sets where there is insufficient data to provide a well converged solution.

In addition to *Automatic*, the tropospheric error state can be explicitly turned on or off.

### Constellation Usage

Inertial Explorer supports GPS, GLONASS, BeiDou, Galileo and QZSS within the differential processor. The PPP processor currently supports only GPS, GLONASS and BeiDou.

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.

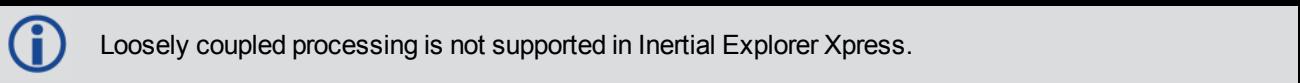
### 1.7.1.9 User Cmds

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.

## 1.7.2 Process LC (Loosely Coupled) and TC (Tightly Coupled)



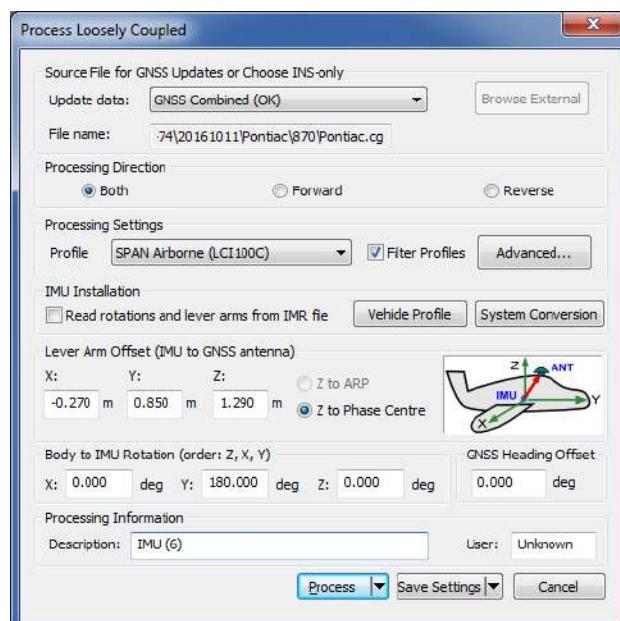
This window provides access to most settings related to IMU processing.

#### 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.



### 1.7.2.1 Process Settings

#### **Profile**

A processing profile is automatically loaded based on the detected processing environment (airborne, 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.

#### **Advanced... (LC Processing)**

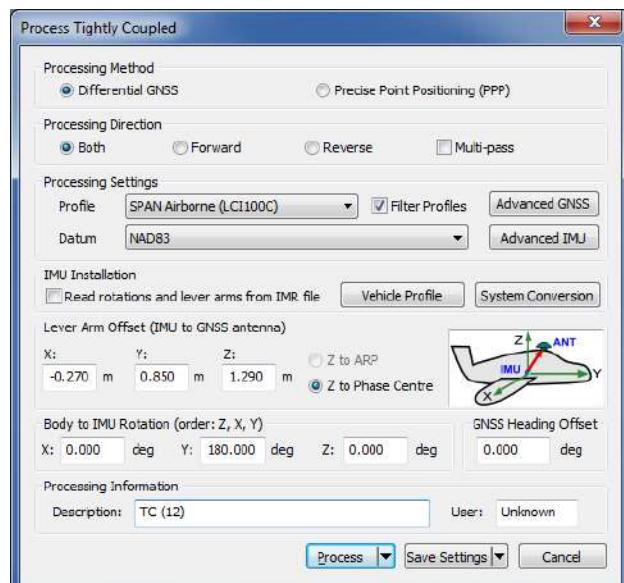
This button provides access to all IMU processing settings.

#### **Advanced GNSS (TC Processing)**

This button provides access to all GNSS processing settings. Refer to *Process GNSS* on page 42 for information.

#### **Advanced IMU (TC Processing)**

This button provides access to all IMU processing.



### 1.7.2.2 IMU Installation

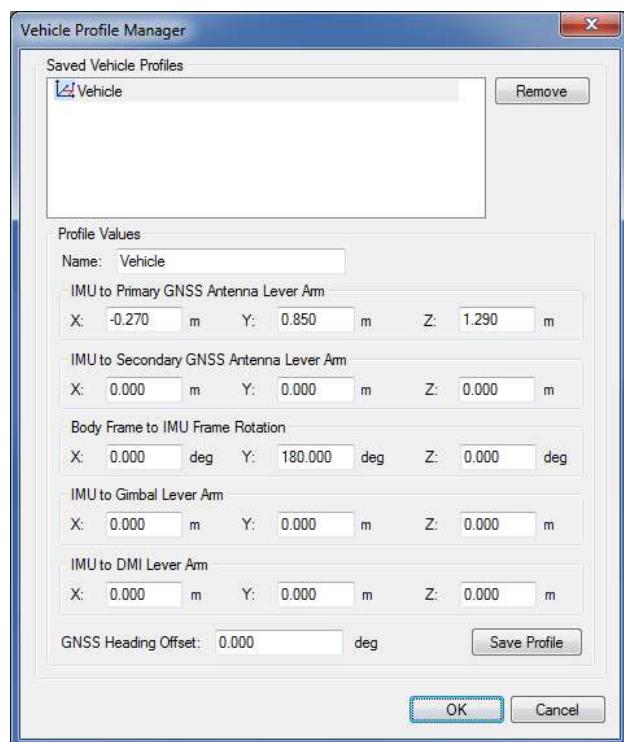
#### **Read rotations and lever arms from IMR file**

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 logs (IMUTOANTOFFSETSB, VEHICLEBODYROTATIONB and SETIMUORIENTATIONB) are 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, 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.

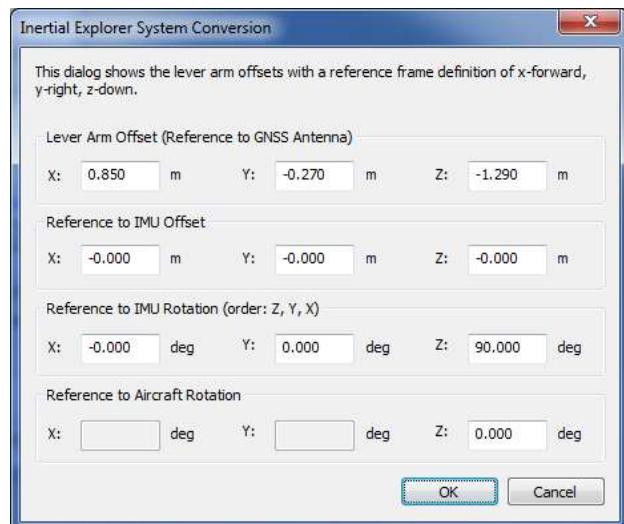
It is not necessary to save vehicle profiles if using a NovAtel SPAN system as this inform-



ation can be retrieved directly from the raw data and imported automatically. Vehicle profiles are intended to assist non-SPAN customer workflow.

### **System Conversion**

Inertial Explorer uses a vehicle frame of Y-forward, X-right and Z-up. This is different from other GNSS/INS processing software packages which use X-forward, Y-right and Z-down. If you are used to working in the latter system and are transitioning to Inertial Explorer, the System Conversion tool allows you to input your project parameters within the X-forward, Y-right and Z-down frame and converts the values to the conventions used by Inertial Explorer.



#### **1.7.2.3 Lever Arm Offset (IMU to GNSS Antenna)**

To perform GNSS updates accurately, enter the 3-D offset, in metres, 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.

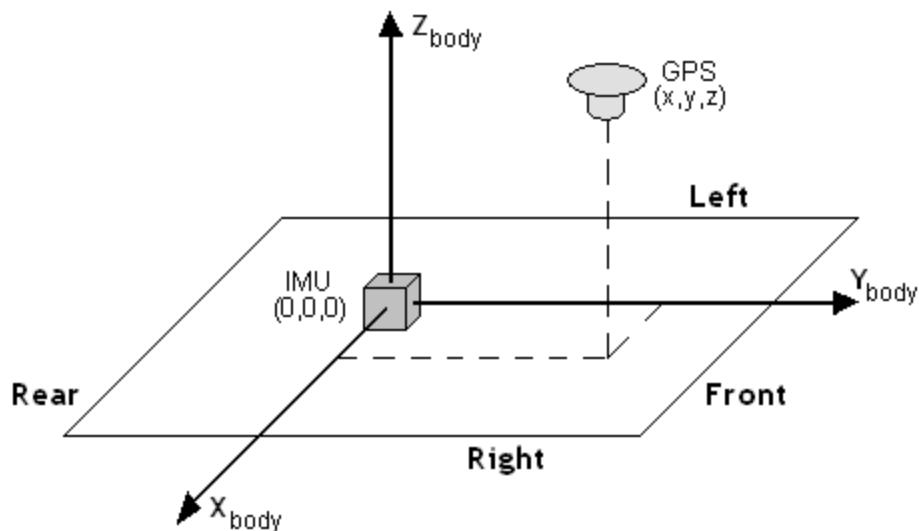
You must also specify whether the Z value applies to the antenna's reference point (ARP) or L1 phase center. To specify ARP, you must select an antenna model when you add the remote GPB file to the project. In this case, the antenna model's offset value is applied to the Z value to raise the Z value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



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

#### **Read 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.

#### 1.7.2.4 Body-to-IMU Rotations (Rotate Vehicle Frame into IMU Frame)

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.

#### 1.7.2.5 GNSS Heading Offset

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.

#### 1.7.2.6 Advanced IMU

This button provides access to all IMU processing options.

### 1.7.2.7 Alignment

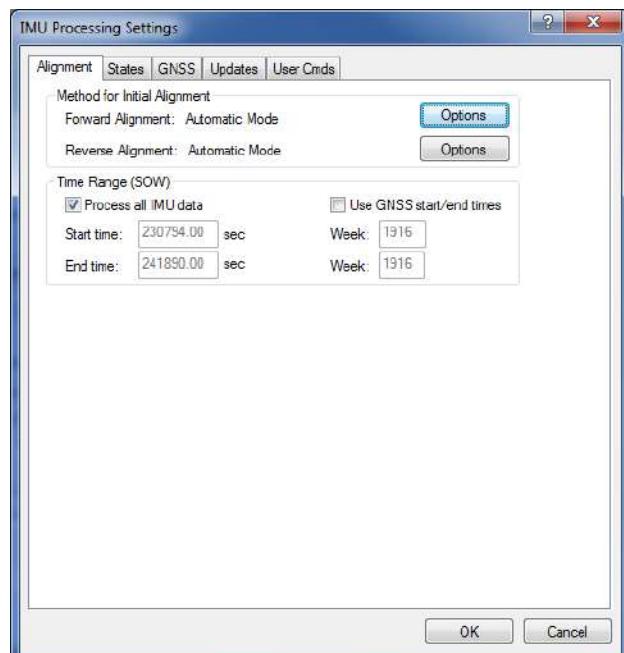
#### Method for Initial Alignment

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)**

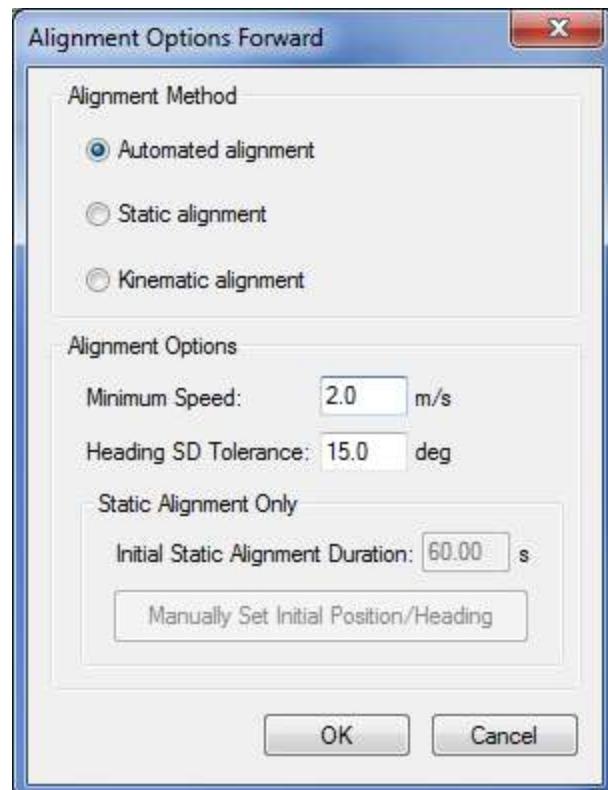
Automated alignment scans the raw IMU data in order to determine whether a static alignment can be attempted. If no usable static alignment is detected, a kinematic alignment is applied when the vehicle reaches the minimum speed set within the auto/kinematic align tolerance. If static data is detected, 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.

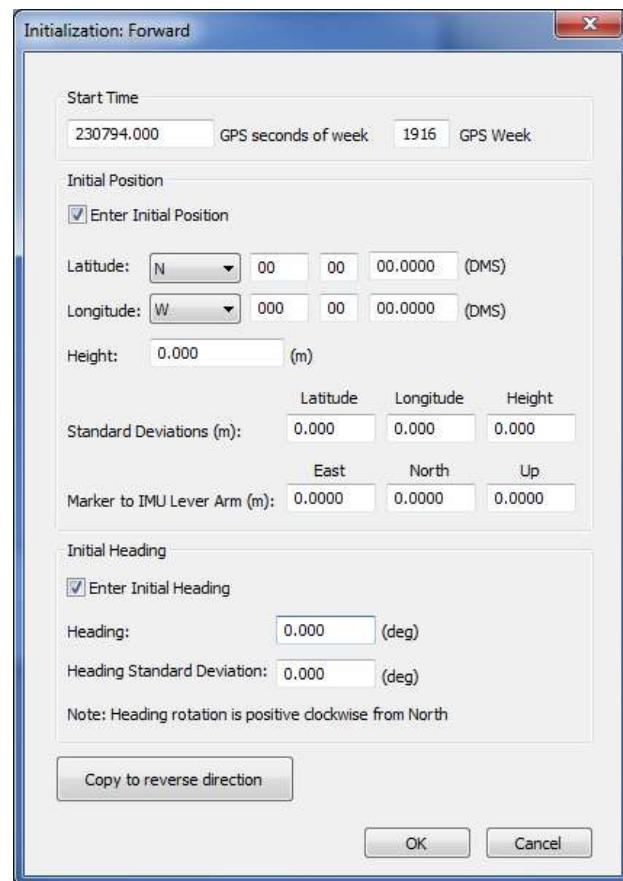
### **Manually Set Initial Position/Heading**

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.



Positive heading rotation is clockwise from North

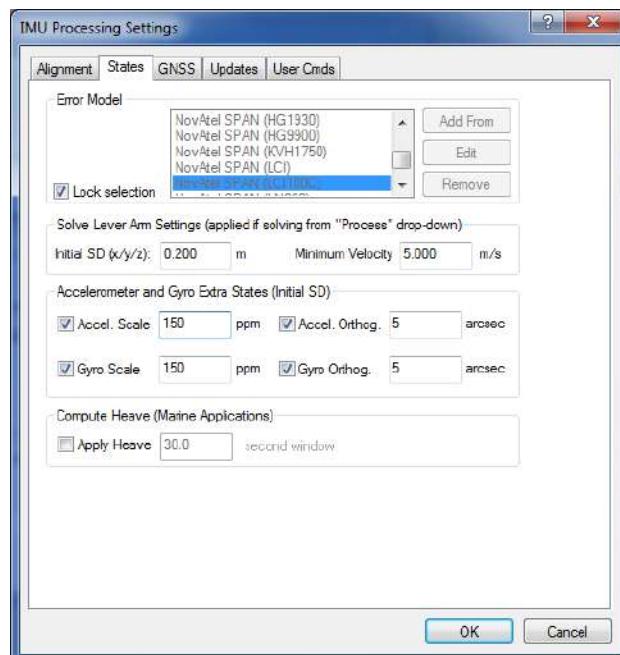
The *Copy to <opposite> direction* button may be used to copy the input parameters to the opposite direction for alignment (i.e. from forward to reverse or vice versa). This is useful if the beginning and end of the survey are on an identical position and identical orientation.

### 1.7.2.8 States

#### 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)



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

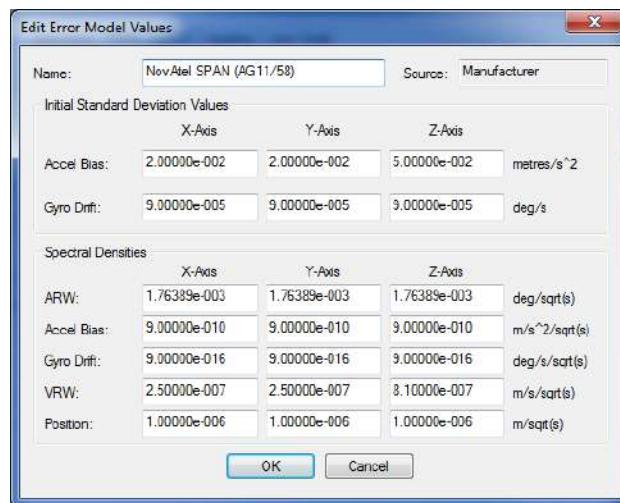
Error model editing is only necessary when developing your own error model for a new IMU. Note that when working with MEMS sensors, it may also be necessary to enable accelerometer and gyro extra states in order to achieve a reasonable level of performance in addition to error model tuning.

### 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<sup>2</sup>.



#### **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,  $\delta t$ . 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 unmodeled 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**

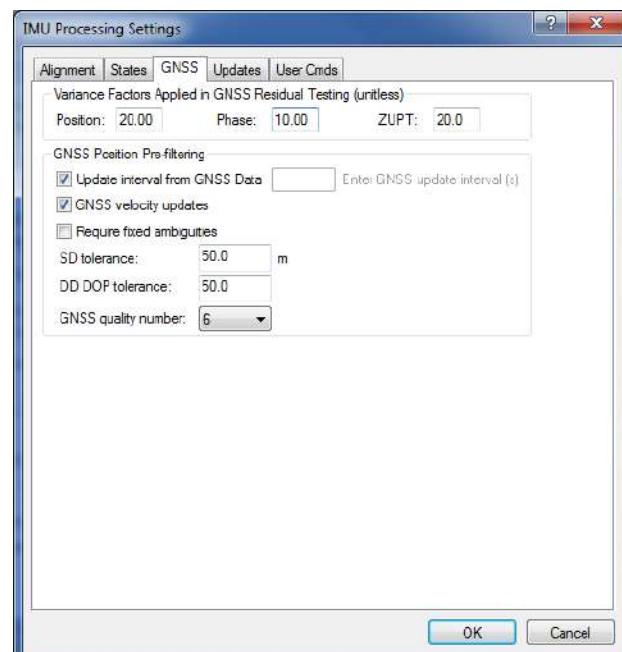
Position spectral densities are noise densities that account for unmodeled position effects during each Kalman prediction. Apply all of the considerations mentioned above for the velocity spectral densities.

## **1.7.2.9 GNSS**

### **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**

#### ***Update interval from GNSS Data***

This option is only available in tightly coupled processing. By default, Inertial Explorer will process using all available GNSS data. This results in position updates being available at the nominal GNSS logging rate. Use this option to limit the GNSS processing interval in tightly coupled processing. This can be useful if logging GNSS data at high rates (i.e. >1 Hz).

#### ***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.

**DD DOP tolerance**

Double Differenced DOP (DD DOP) is roughly equivalent to PDOP squared. GNSS position updates with large DOP values can be unreliable, however Inertial Explorer by default uses a very loose pre-filtering threshold and instead relies on GNSS variance factor testing to determine whether or not a GNSS position update should be applied. If it is desired to use a lower value, enter it here.

**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.

### 1.7.2.10 Updates

#### 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.

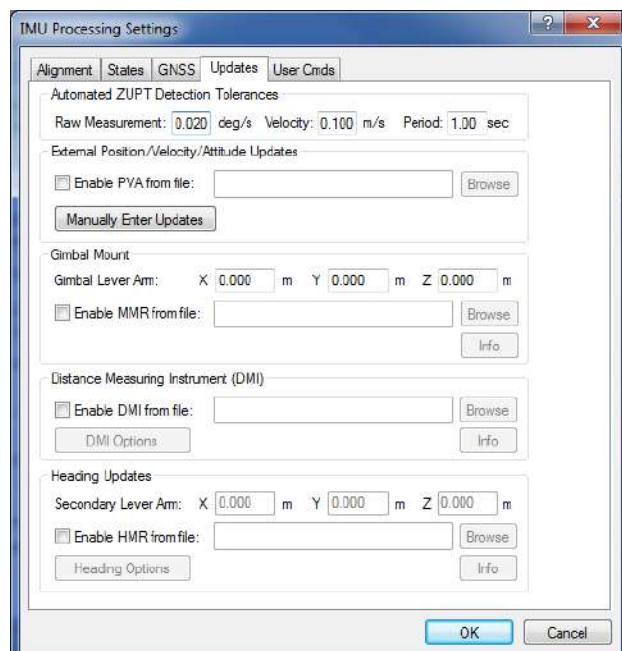
**Period**

Length of time span over which measurements are averaged.

#### External Position/Velocity/Attitude Updates

A binary PVA file can be input to Inertial Explorer if external position, velocity and/or attitude updates are available. See *PVA File* on page 171 for the format of this file. Input of this binary file is the recommended approach if large numbers of external updates are available. If using a PVA file, the following user commands are supported:

- **PVA\_ENABLE** = “NEVER”/“ALWAYS”/“SPOSSD” [tol (m)] (default is “ALWAYS”)
  - NEVER = never use update ([tol] = 0)
  - ALWAYS = always use update ([tol] = 0)
  - SPOSSD = use after solution standard deviation exceeds [tol]
- **PVA\_LEVER** = “ON”/“OFF” [x] [y] [z] [def=OFF]
  - Shift position of update to IMU using body-frame lever arm values. Sensor to IMU (m)
  - This command will override any offsets in the binary PVA file



- PVA\_MEAS\_SF = sfpos sfvel sfatt [def=1 1 1]
  - Scale input standard deviations by these scale factors
- PVA\_SIGMA\_TOL = ON/OFF pos vel att [def=OFF]
  - Unitless a-posteriori standard deviation ratio for PVA for blunder detection
- PVA\_UPDATE = "REC/POS|VEL|ATT" [def=REC]
  - REC = use record type from record
  - POS|VEL|ATT = Space separated mask for update type in file

User commands can be input through the *User Cmds* tab of the *Advanced IMU* options.

### Relative Updates

In version 8.70, 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, variable SD values is suggested.

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.

### Coordinate Systems

Currently, two coordinate systems are supported for input:

- **Local Level**

The input y-axis is aligned to true-north, x-axis to east and z-axis to up. This implies that the vectors have been aligned to a global coordinate system. In the absence of external updates or control points, a solution can drift, meaning the absolute orientation (i.e. 6-parameter transformation between the sensor frames) may vary. Furthermore, if a local rectangular system (LRS), which also called Local Cartesian in Inertial Explorer, is used and the mission covers a larger area (greater than a few kilometres), then a meridian convergence<sup>1</sup> compensation must be applied. In this mode, the relative attitude values are not used nor needed.

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<sup>1</sup>Meridian convergence is the angular orientation difference between grid north and true north

- **Body System**

By keeping the measurements in the sensor frame of the measuring system, the task of relating the relative vector to the computational system, which is ECEF, is performed by Inertial Explorer's Kalman Filter. For datasets that are non-continuous (or have gaps), not having to reference the relative vector in Local Level can be a benefit. In Body processing, Inertial Explorer will account for it by using its internal, filtered, pre-smoothed estimates of the attitude, and their associated errors. Therefore, for continuous datasets, the translation from body to Local Level may best be performed external to Inertial Explorer using a smoothed trajectory. Finally, the body system of the IMU is normally referenced as y-forward, x-right and z-up, but the imaging/LIDAR sensor system may be different, and their axes may not be aligned. Hence, the relative alignment-boresight and offset of these systems must be accounted for before entry into Inertial Explorer.

Both these input methods ultimately utilize the update in Inertial Explorer's computational system, which is ECEF/e-frame. So the main difference is how the body-to-Local Level conversion is applied. The Local Level-to-ECEF depends only on position and is not very sensitive. However, body-to-Local Level is directly affected by the attitude accuracy. So, if the pre-PVA smoothed Inertial Explorer trajectory is best, use Local Level. If the filtered Inertial Explorer trajectory using PVA updates is best, use body.

#### **Data Input**

- The relative updates need to be converted to a binary PVA file before processing in Inertial Explorer. See [PVA File](#) on page 171 for the format of this file. The following variables are needed:
  - Start TOW, week – Begin GPS time of the relative update (epoch i-1)
  - End TOW, week – End time (epoch i), called update time in the format below
  - X, Y, Z – relative vector components (m) (Body or Local Level)
  - SDx, SDy, SDz – estimated accuracy of vector components (m)
  - Covariance/CC – off-diagonal covariance values or correlation coefficients (CC). CC values are stored in PVA file. If the values are not available, leave them as zeros.
  - tx,ty,tz – relative orientation between two epochs in the frame of epoch i/end defined as roll, pitch, yaw.  
These are used only for body-frame processing in reverse because in the forward direction the XYZ relative vector is already in the correct frame.

Important points to consider are:

- Knowing or estimating the accuracy of the vector components is extremely valuable, and is preferred over the just using constant values.
- The relative orientation values are not the absolute angles and can be complicated to produce. The values stored in the PVA file are very specifically defined in the roll-pitch-yaw frame aligned but aligned to the end-time, as this is when the update is performed (for forward processing). They are ignored for Local Level and body-forward processing. Therefore, if in body mode the forward solution is satisfactory but the reverse has higher than expected errors, then the relative tx,ty,tz angles may not be correct.
- The accuracy of the relative orientation values are not needed nor used.

## Manually Enter Updates

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



Gimbal mount updates are not supported on Inertial Explorer Xpress.

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 its 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)



DMI updates are not supported on Inertial Explorer Xpress.

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 a tick count or a measured speed. If tick counts are recorded, Inertial Explorer converts them as a velocity update. If speed was recorded, then the software applies them as such.

### ***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 wheel circumference is extracted from raw SPAN data if the WHEELSIZEB log is present. The default value is 1.96 metres 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 HEADINGB 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.

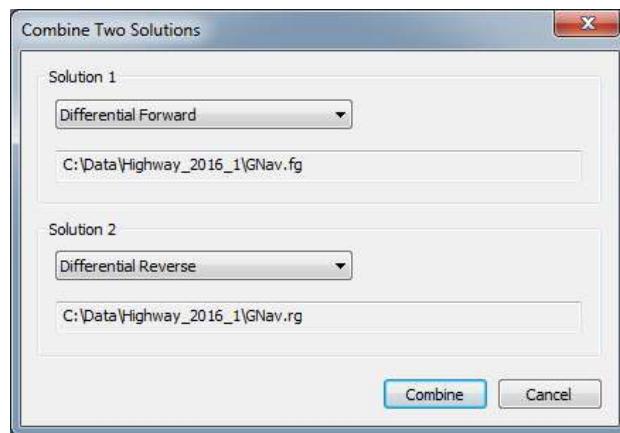
The HMR data format is described in *HMR File* on page 170.

### **1.7.3 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 Inertial Explorer's 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.

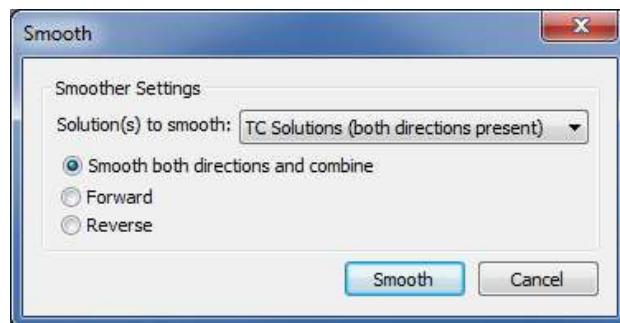
However, before exporting ensure that either the differential (.cg) or the PPP (.cp) solution is loaded, as the Export Wizard accesses whichever solution is presently loaded. One way of re-loading combined results is to choose the *Differential/PPP forward* and *Differential/PPP reverse* solutions from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



#### 1.7.4 Smooth Solutions

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.



##### Smoothen 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.

#### 1.7.5 Solve Boresighting Angles



Solving boresighting angles is not supported on Inertial Explorer Xpress.

### 1.7.5.1 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.

### 1.7.5.2 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***

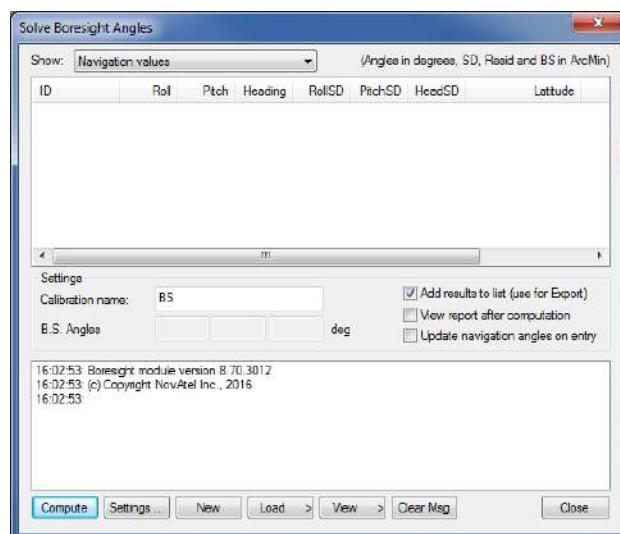
When this option is enabled, the last values computed by the program are stored so that they are easily accessible by the *Export Wizard*.

#### ***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.



### 1.7.5.3 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 cal-

ibration 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* below 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.

### **1.7.5.4 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,  $\alpha$ , 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.

## 1.8 Settings Menu

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

### 1.8.1 Coordinate/Antenna

#### 1.8.1.1 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.

**Coordinates**

The coordinates that appear in this dialog when loading a base station may come from different sources. If loading a base station that has been converted from RINEX (this includes any data retrieved by the Download Service Utility), the coordinates loaded are scanned from the RINEX header. These are by definition labeled *Approximate coordinates* and should be verified by the user. The RINEX header does not define the datum of the coordinates, and as such the user needs to make this selection for each base station loaded.

If loading your own base station data which was converted from a non-RINEX source, the coordinates displayed will be an averaged value computed from the positions extracted from the GPB file. The accuracy of this coordinate will vary and care should be made to ensure precise coordinates are entered. The datum must be selected by the user and optionally the epoch of the coordinates can also be entered.

**Datum**

Inertial Explorer distinguishes between individual base station coordinate datums and the project processing datum. Each base station may have a different coordinate datum and if so, the coordinates will be automatically converted to the processing datum prior to processing. This facilitates working directly with published coordinates in one datum, yet producing processed output in another datum as required. The processing datum cannot

be changed from this dialog but rather from the *Process GNSS* dialog. A user can also select a default processing datum through the *Solution* tab of *Settings | Preferences*.

### Epoch

This is an optional field which is used only for reporting/tracking purposes. Coordinates change over time due to plate tectonic motion, and velocities can be several cm per year for datums that are not fixed to a specific tectonic plate. As such, the coordinates produced for any precise application should have a known datum and epoch.

If entering an epoch for one base station, it is required to enter all coordinates relative to the same epoch for all other base stations in the project, even if they are in a different processing datum.

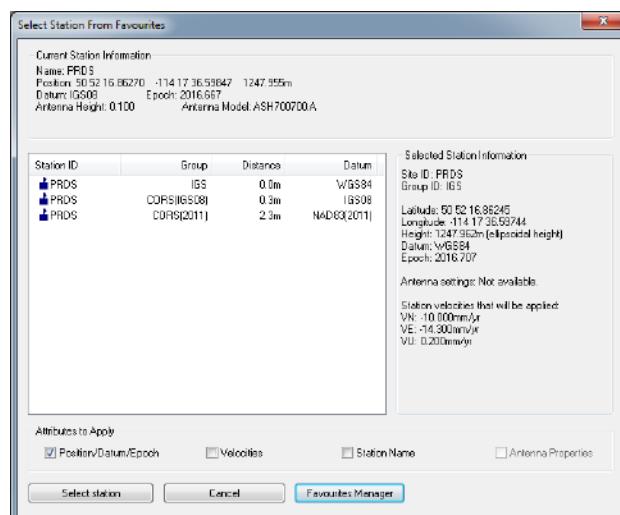
#### 1.8.1.2 Coord. Options

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

##### Select From Favorites

Precise coordinates for CORS, IGN and IGS stations are regularly maintained within Inertial Explorer's manufacturer files. If downloading base station data from one of these networks, you can load the published coordinates using the *Select 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 published velocities are applied to the published coordinates and reference epoch to update them to the epoch of data collection.



##### 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, GPS-only precise products will be downloaded before processing. 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 metres 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, Inertial Explorer still requires that an ellipsoidal height be computed from the MSL height, as all position computations within Inertial Explorer 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.novatech.com/support/waypoint-support/waypoint-geoids/> to access all of Waypoint's geoids in WPG format.

### 1.8.1.3 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.

### 1.8.1.4 Remote Settings

This option lets you customize the remote's antenna information. See *Add Remote File* on page 31 for additional information.

## 1.8.2 Grid

Inertial Explorer supports several international and regional grids, 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.

Inertial Explorer projects store grid information. 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 91 for more details.
- *Export Wizard* can use a defined grid for coordinate output. See *Export Wizard* on page 85 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 97 for more information.

## 1.8.3 Manage Profiles

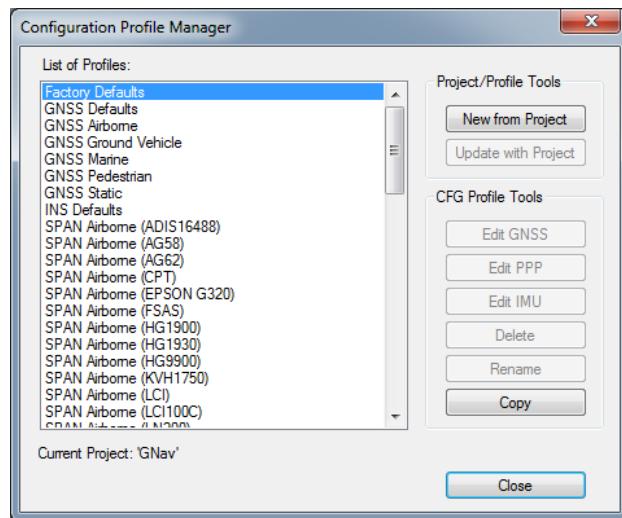
The profile manager allows new profiles to be created or existing profiles to be edited. The profile manager can also be used to edit the Inertial Explorer default settings or restore the factory default settings.

If creating a custom processing GNSS processing profile, *GNSS* must be in the name as we use this keyword to ensure only GNSS processing profiles are accessible under the GNSS processing dialog. Similarly, any Inertial Explorer customers who create custom processing profiles need to use either the keywords *INS* or *SPAN* in order to ensure they are accessible from the INS processing dialogs.

### 1.8.3.1 Project/Profile Tools

#### New from Project

Creates a new profile using the current project's settings.



***Update with Project***

Updates the processing profile with the current project settings. This option is not available for *Factory Defaults* as they cannot be altered.

**1.8.3.2 CFG Profile Tools*****Edit GNSS/PPP/IMU***

Brings up the processing settings menu to allow the selected profile to be modified.

***Rename***

Allows the profile to be renamed.

***Delete***

Deletes the selected profile.

***Copy***

Creates a copy of the currently selected profile.

**1.8.4 Compare Configuration Files**

This feature allows you to compare the settings applied in two different configuration files. This utility scans both CFG files and creates a report of the differences. This report is displayed in Inertial Explorer's ASCII viewer.

**1.8.5 Preferences**

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

**1.8.5.1 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**

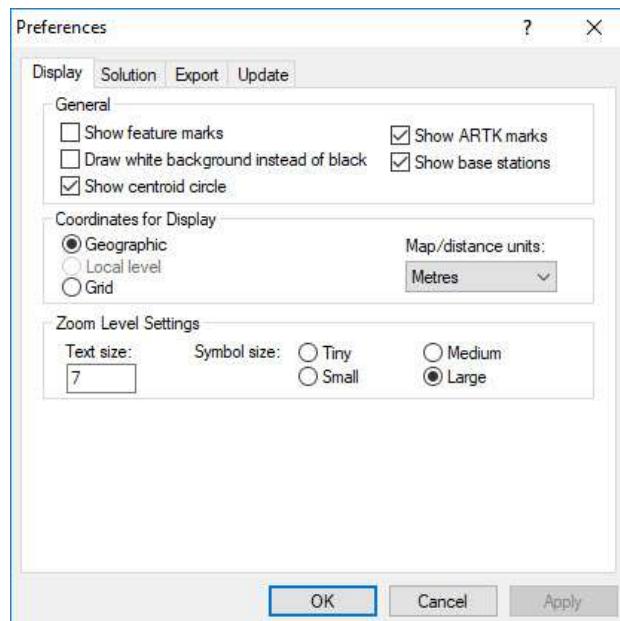
The following settings are available:

***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 1.5 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.

**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.

**Grid**

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

**Map/distance units**

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

Changes the units displayed when using the *Distance & Azimuth* tool as well. See *Distance & Azimuth Tool* on page 95 for information.

**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.

### 1.8.5.2 Solution

#### Processing

##### **Default Datum**

Allows you to select a default processing datum for all Inertial Explorer 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.

##### **Process forward/reverse directions simultaneously**

This feature improves processing speed considerably for computers with dual core or Xeon processors.

##### **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.

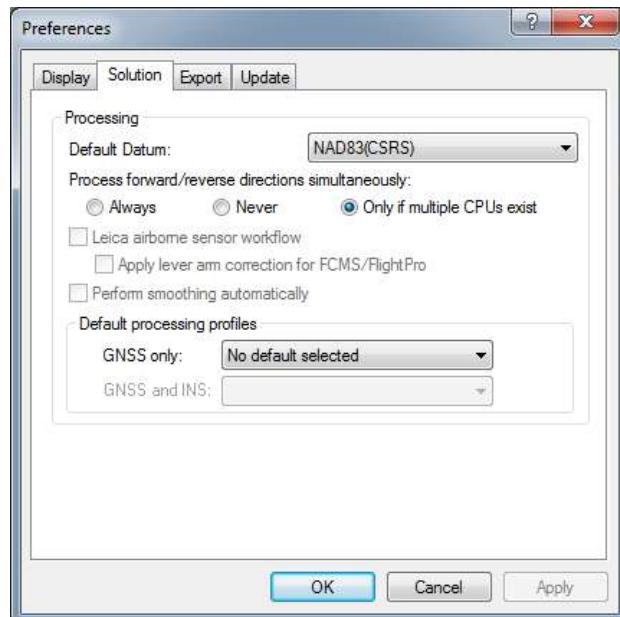
##### **Perform smoothing automatically (Inertial Explorer only)**

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 Inertial Explorer to automatically load manufacturer processing settings for the detected processing environment when the process GNSS dialog is first accessed within a project.

**GNSS-only** and **GNSS+NS** default processing profiles can be specified here. This will disable Inertial Explorer's 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).



Only UAV profiles are included with the Inertial Explorer Xpress installation.

### 1.8.5.3 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**

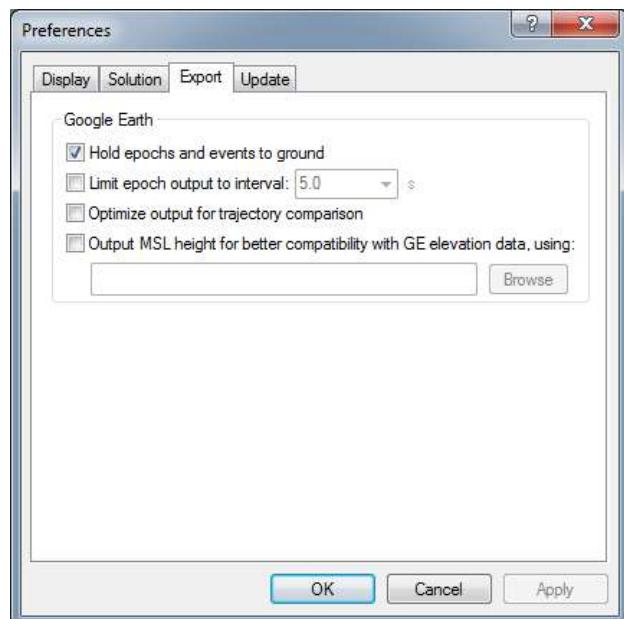
You can reduce the density of the output trajectory by specifying an interval here. This helps reduce file size and loading times in Google Earth.

##### **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/](http://www.novatel.com/support/waypoint-support/waypoint-geoids/).



### 1.8.5.4 Update

#### Auto-Update

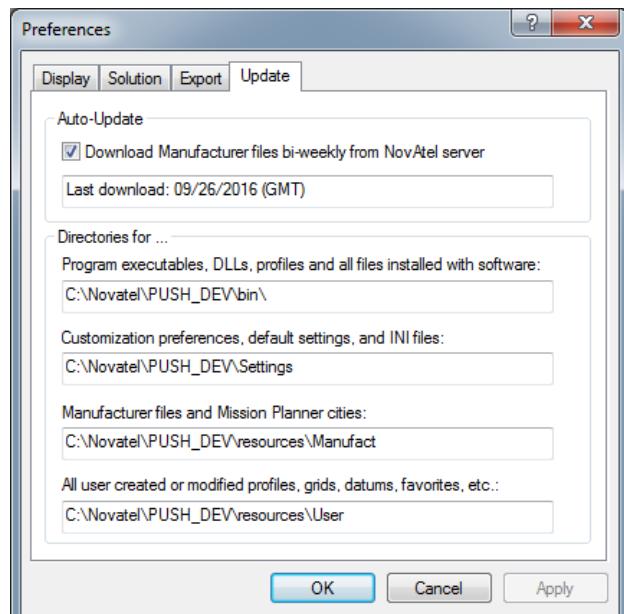
After installation, users are prompted to enable a setting which downloads manufacturer files from the NovAtel server on a bi-weekly basis.

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 as if users wish to copy any user created content from a previous version to 8.70, this is the directory



where any/all user created files from previous versions should be copied to. See *Copy User Files* on page 21 for more information.

## 1.9 Output Menu

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

### 1.9.1 Plot Results

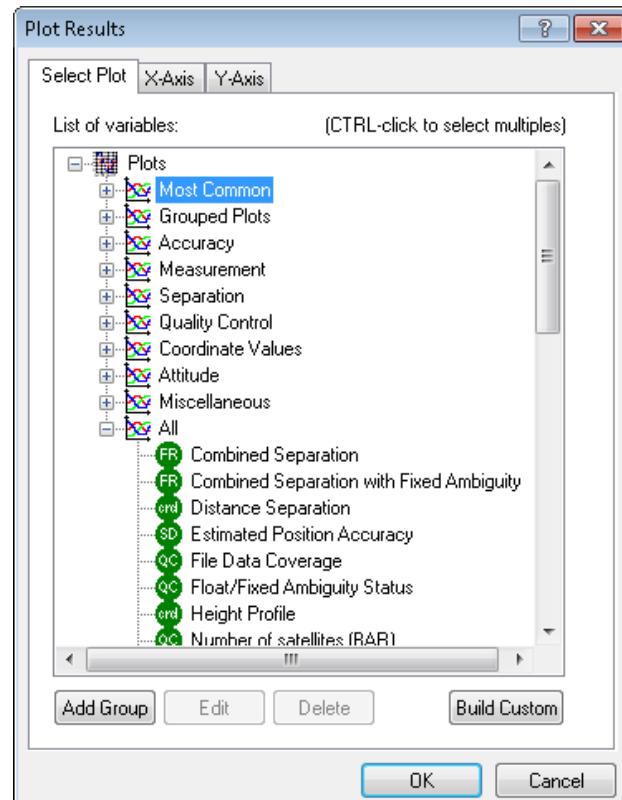
Inertial Explorer's quality control plots are organized within sub-groups, such as *Accuracy*, *Measurement*, *Coordinate Values* and others. The *Most Common* group will appear empty immediately after you install the program for the first time, but over time will be populated with up to 10 of your most commonly accessed plots. To see all of Inertial Explorer's plots, expand the *All* group.

Within each group, plots appear organized alphabetically within three colors: green, blue and black. The green plots are in general the most commonly accessed plots, the blue plots in general less so, and the black plots are in general seldom accessed except by advanced users.

Many plots support different units. For example, you can plot the *Combined Separation*, which shows the difference between forward and reverse solutions in metres or feet. The *Distance Separation*, or baseline distance, can be plotted in units of kilometres, miles or metres. 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.

Inertial Explorer contains default manufacturer plot groups for GNSS and GNSS+INS QC named *Waypoint GNSS QC*, *Waypoint INS QC* and *Waypoint GNSS+INS QC*, which appear under *Grouped Plots*. If processing GNSS-only, users are encouraged to access the *Waypoint GNSS QC* plot group as it will automatically launch most plots of interest to GNSS-only processing. After processing LC, launch *Waypoint INS QC*, which is a plot group that contains most plots of interest relevant to INS processing, without re-producing many of the same plots from the GNSS-only plot group. If processing TC, launch the *Waypoint GNSS+INS QC* group as it contains a combination of the GNSS and INS groups. When accessing a plot group, all plots are generated within the group and an HTML report is automatically generated.



### 1.9.1.1 Add Group

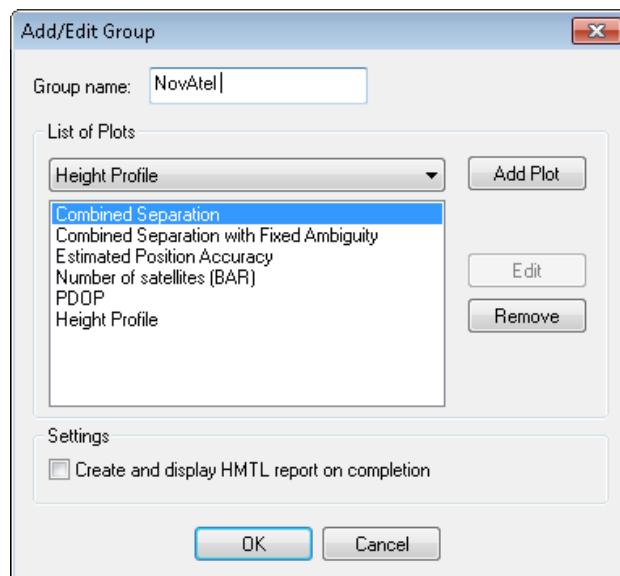
You may wish to create a group of plots for the purpose of plotting the entire group simultaneously. For example, if after processing you always want to see the *Combined Separation*, *Number of Satellites (BAR)*, *PDOP* and *Estimated Position Accuracy*, these four plots can be added to a custom group.

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.

### 1.9.1.2 Build Custom

This option allows plots to be added to the *Custom* group. Adding the plots you most commonly access here makes them more accessible than choosing them out of other groups, or from the *All* list. Note that the plots you access most commonly will already appear under the *Most Common* group.

The difference between creating a *Grouped plot* and adding plots to the *Custom* group is that grouped plots will all be plotted simultaneously, whereas plots to the *Custom* list can still be accessed individually.



### 1.9.1.3 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)...

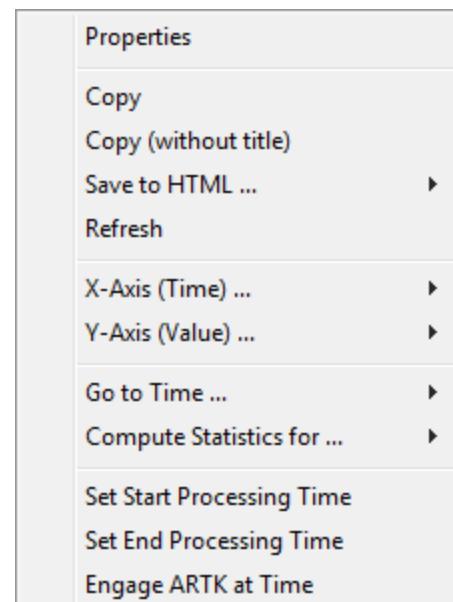
The X-Axis options are described below.

##### **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.

#### 1.9.1.4 Common Plots

**Table 2: Common Plots**

Plot	Description
<b>Accuracy</b>	
Estimated Position Accuracy	<p>Plots the standard deviation of the east, north and up directions as well as a 3D (labeled <i>trace</i>) value.</p> <p>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.</p>
Estimated Attitude Accuracy	This plot shows the standard deviation computed in the GNSS/INS Kalman filter in terms of roll, pitch and heading.
<b>Measurement</b>	
RMS – C/A Code	<p>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.</p> <p>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 <i>Measurement</i> 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.</p> <p>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.</p>
RMS – Carrier Phase	<p>Plots the RMS of the double differenced carrier phase residuals for all satellites used in the solution.</p> <p>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).</p> <p>If large differences are found in the <i>Combined Separation (fixed)</i> 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.</p>

Plot	Description
RMS-L1 Doppler	<p>Plots the RMS of the double differenced Doppler residuals for all satellites in the solution. Inertial Explorer uses Doppler to compute instantaneous velocity.</p> <p>Also plotted is the measurement weighting applied to the Doppler measurements within the Inertial Explorer 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.</p> <p>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 <i>Measurement</i> tab of the GNSS processing options.</p>
Satellite Lock – Cycle Slips	<p>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.</p> <p>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.</p> <p>It is normal for cycle slips to occur on low elevation satellites (&lt; 10 degrees) due to signal blockages or due to attenuation by the GNSS antenna.</p> <p>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.</p> <p>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.</p>
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.
<b>Separation</b>	

Plot	Description
Combined Separation	<p>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 <i>Combine Two Solutions</i> dialog.</p> <p>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.</p> <p>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.</p> <p>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 <i>Combined Separation with Fixed Ambiguity</i> plot can sometimes be more helpful.</p>
Combined Separation with Fixed Ambiguity	<p>Similar to the <i>Combined Separation</i> plot, however only the position differences between forward and reverse processing are plotted where both solutions have fixed integer ambiguities.</p> <p>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 (decimetre or metre level) are obtained, an incorrect ambiguity was very likely obtained in one or both directions.</p> <p>In this event, loading each solution into the project individually and plotting the <i>RMS - Carrier Phase</i> can be useful in determining which processing direction the problem occurred. See the description for the <i>RMS - Carrier Phase</i> plot for more information.</p>
Attitude Separation	<p>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.</p>
Quality Control	
PDOP	<p>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.</p> <p>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.</p> <p>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).</p>

Plot	Description
Float/Fixed Ambiguity Status	<p>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.</p> <p>This plot can be helpful to view in conjunction with the <i>Combined Separation</i> 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 <i>Combined Separation with Fixed Ambiguity</i> plot is recommended to quickly check for the presence of incorrect ambiguity fixes.</p>
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.
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	<p>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.</p> <p>This plot is useful in determining whether any base station data does not overlap with the time range collected by the remote receiver.</p>
<b>Coordinate Values</b>	
Distance Separation	This plot shows the distance between the master and remote. For multi-base distance separation, see <i>Plot Multi-Base</i> on page 85.
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.
<b>IMU</b>	
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 <i>IMU Heading COG Difference</i> 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	<p>This plot shows the components of acceleration in the vehicle body frame.</p> <p>Not available in Inertial Explorer Xpress.</p>

Plot	Description
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.
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.

Plot	Description
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.

### 1.9.2 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 Inertial Explorer 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.

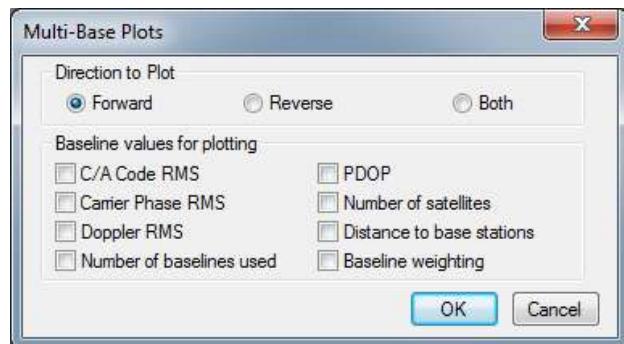


Table 3: Common Multi-base Plots

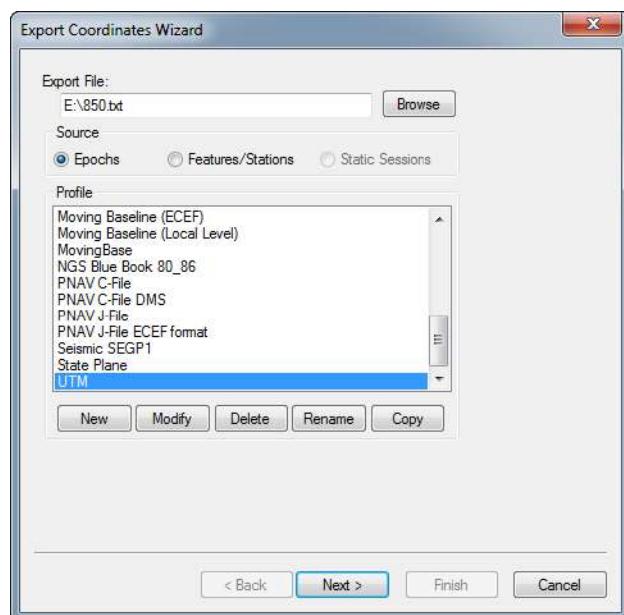
Plot	Description
Baseline Weighting	Plots the relative weighting applied to each baseline. This is largely dependent on the distance to each base station.
Number of baselines used	Shows the number of base stations used as a function of time.

### 1.9.3 Export Wizard

Inertial Explorer's 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. Inertial Explorer 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.

### 1.9.3.1 How to create a new Export Wizard profile

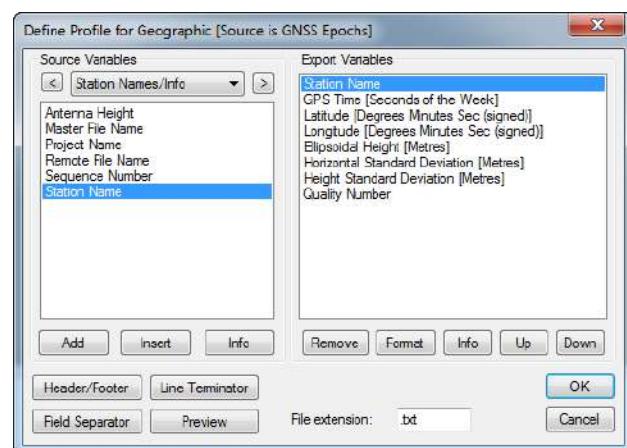
1. Click the *New* button and type a unique name for the profile.

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 177 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 177 describes the many variables that you can include your output profiles. Not all variables are available for use with each source.

### 1.9.3.2 How to use the Export Wizard

1. By default, the export file name is the same name and directory as the project file (.cfg), 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 Inertial Explorer's internal ASCII viewer.

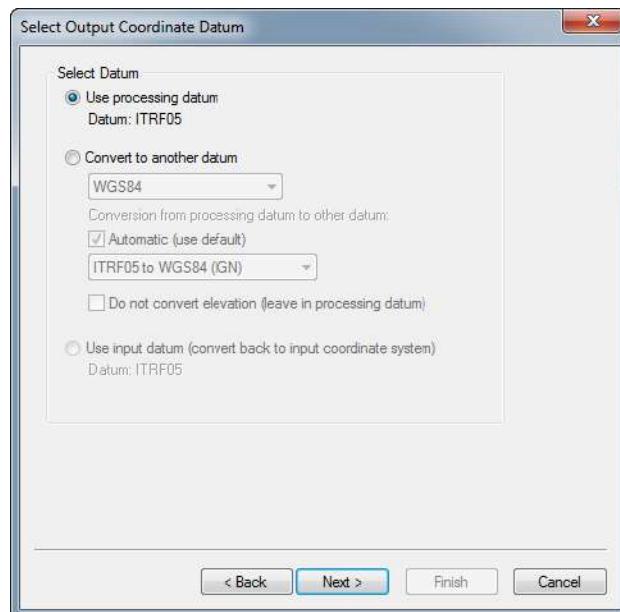
### 1.9.3.3 Creating an Output File

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

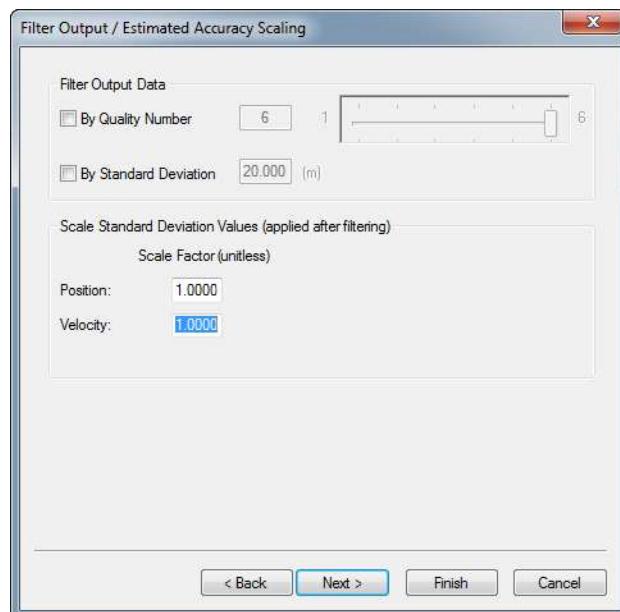
The first page of the Wizard provides an opportunity to apply a datum transformation during export. This is required if the datum you wish to export to is not the same as the processing datum.



## Filter Output/Estimated Accuracy Scaling

Results can be filtered using either Inertial Explorer's 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.

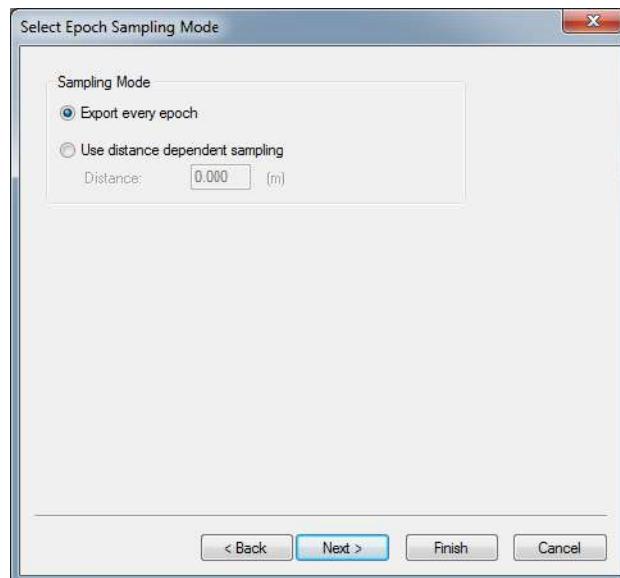
This dialog also provides an opportunity to scale the standard deviations output by Inertial Explorer to a higher confidence interval. By default Inertial Explorer outputs 1-sigma values. However due to the conservative measurement weighting applied in Inertial Explorer to code, carrier, and Doppler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



## Select Epoch Sampling Mode (GNSS+INS only)

When exporting epochs, you can choose to export all processed epochs or apply distance dependent sampling.

**Note:** This option is only available to Inertial Explorer users who are exporting a GNSS+INS trajectory. The *Select Epoch Sampling Mode* page is not applicable to GNSS-only trajectories.



## 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*.

### 1.9.3.4 IMU Epoch Settings

#### **Limit Exported Time Range**

The time range to export can be changed here. Multiple time ranges may be entered.

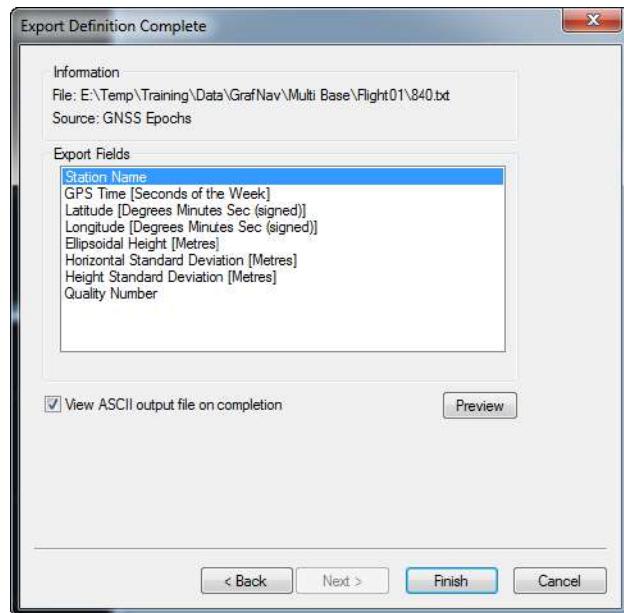
#### **Epoch Interval Options**

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.



### 1.9.4 View Coordinates

This opens the last file generated by the Export Wizard in Inertial Explorer's internal ASCII viewer.

### 1.9.5 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.

### 1.9.6 Export to Google Earth

#### 1.9.6.1 Export and View

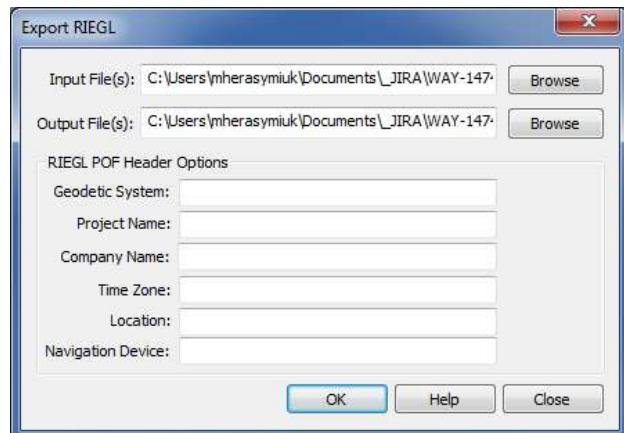
Writes a compressed Google Earth (KMZ) file to the HTML sub-directory and automatically opens it in Google Earth.

#### 1.9.6.2 Export Only

Writes a compressed Google Earth (KMZ) file to disk, but does not launch Google Earth.

### 1.9.7 Export to RIEGL POF/POQ

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.



### 1.9.8 Export to SBET

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.

### 1.9.9 Export to Waypoint Legacy Format

This option converts your Waypoint trajectory files to the binary format defined by version 8.60 of the software. It is useful if you have a workflow catered to the 8.60 SBTC/SBIC data format.

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

### 1.9.10 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.

#### 1.9.10.1 Output File Name

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

#### 1.9.10.2 Output Components and Options

The following options are available:

##### **Stations/Features**

Outputs any stations or features loaded.

##### **Baselines/Static Sessions**

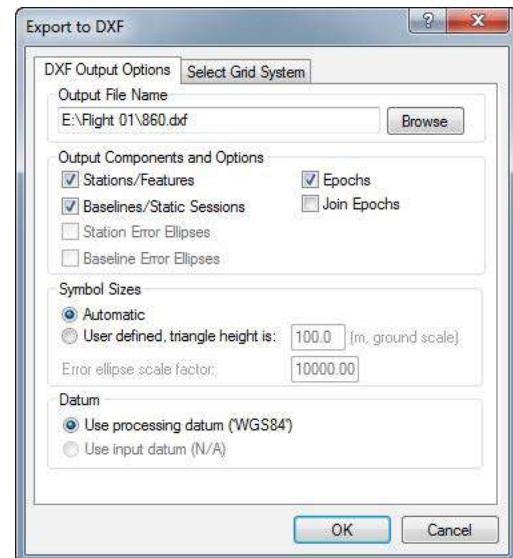
Outputs baselines between all the static sessions. The color of the baselines will be the same as it appears in Inertial Explorer and is determined by the quality factor.

##### **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.



#### 1.9.10.3 Symbol Sizes

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

#### 1.9.10.4 Datum

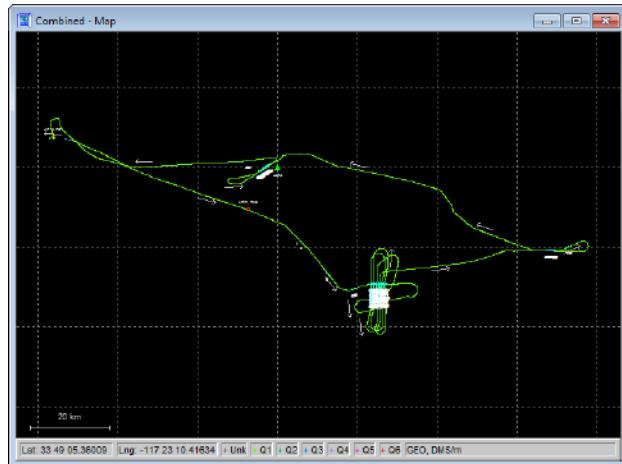
Allows you to choose between the processing datum or the input datum.

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.

#### 1.9.11 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. Inertial Explorer's Q/C plots should be accessed for a more detailed analysis of solution quality. See *Common Plots* on page 80 for descriptions of commonly accessed plots.



The information displayed to the map window is fully customizable from the *Display* tab within *Settings | 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 Inertial Explorer's quality control plots for a more in-depth analysis.

**Table 4: 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

#### 1.9.11.1 Mouse Usage in Map Window

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 95 for additional interactive mapping tools.

## 1.9.12 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 *Output Variables* on page 177 for descriptions of variables which can be monitored during data processing.

The Processing window is updated twice a second.

### 1.9.12.1 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 4: Quality Number Description* on the previous page.

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.

### 1.9.12.2 Progress

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

### 1.9.12.3 View

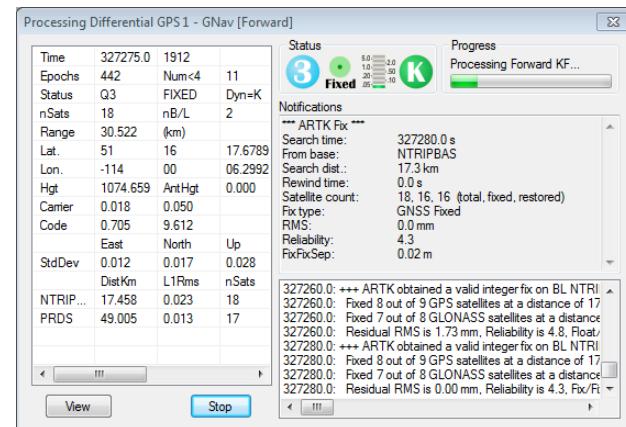
In the left-hand window, various parameters are available for display via the *View* button. The list of available parameters is given in *Table 7: Processing Window Parameters* on page 94.

### 1.9.12.4 Notifications

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

**Table 5: 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.



Message	Description
Rewind time	When ARTK achieves a fix, Inertial Explorer can (data quality permitting) apply the integer carrier phase ambiguities 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 <i>total</i> , <i>fixed</i> and <i>restored</i> numbers are reported. <i>Total</i> represents the number used in the float solution. <i>Fixed</i> indicates the number which achieved fixed integers at the restore time. <i>Restored</i> indicates the number of satellites where Inertial Explorer was able to restore backwards in time (see <i>Rewind time</i> )
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 <i>Combined Separation with Fixed Ambiguity</i> 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 (metre 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 6: 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.
Reliability	See <i>Reliability</i> for ARTK fixes in <i>Table 5: Notifications Windows Messages</i> on the previous page for a definition. The reliability for long fixed static solutions may be reported as <i>N/A</i> , 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 <i>single</i> or <i>dual</i> 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.

Message	Information
Type	<p>Fixed static solution type used.</p> <p><i>Continuous</i> looks for the best continuous block of cycle slip free data to use within the fixed integer solution.</p> <p><i>NewFixed</i> (multi-sat) uses all of the data, although it may reject some sections of data for individual satellites.</p>

**Table 7: Processing Window Parameters**

Parameter	Description
Acceleration Vector	Displays the east, north and height acceleration components in Local Level frame.
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.
Channel (Ambiguity)	Displays the ambiguities, as well as their standard deviation, for each satellite being tracked.
Channel (Az/Elev)	Displays elevation and azimuth for each satellite being tracked, in degrees.
Channel (Flag/Locktime)	Displays the status flag and locktime count for each satellite being tracked.
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 antenna height of the remote.
Local Level Vector	Local Level vector in metres.
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	Solution quality information such as number of satellites, quality factor and ambiguity status.
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.
Velocity Vector	Components of velocity in the Local Level frame.
Channel Data B/L	Allows for selection of baseline for which to display channel information.

## 1.10 Tools Menu

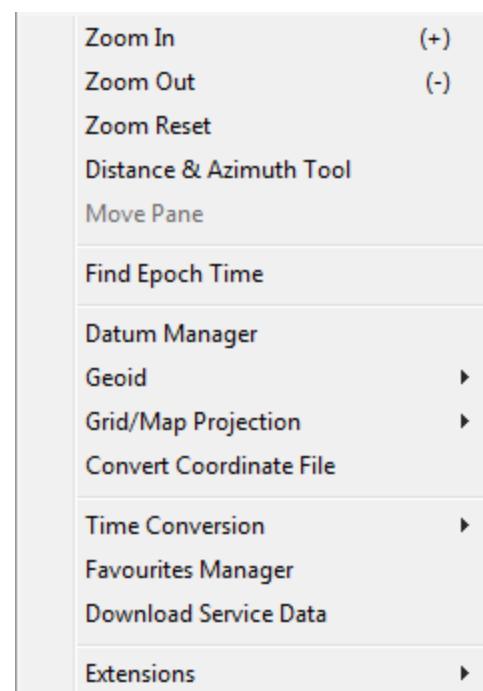
### 1.10.1 Zoom In, Zoom Out & Zoom Reset

The *Zoom In* and *Zoom Out* tools adjust the viewing scope of the map, while the *Zoom Reset* brings the map back into the default view.

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.

### 1.10.2 Distance & Azimuth Tool

The *Distance & Azimuth* tool can be used between epochs, base stations and feature/station marks that are displayed on the Map window. Left click on the feature or epoch that you wish to measure *from* and then right-click on the feature or epoch that you want to measure *to*. The *Distance and Azimuth* window reports the horizontal, surface, grid and spatial distances between the selected points within the project grid (*Settings | Grid*). The default grid is a UTM zone automatically computed from the rover trajectory. The azimuth and scale factor information are also displayed.



### 1.10.3 Move Pane

This tool is only accessible provided you have used the *Zoom In* tool to view a smaller portion of the Map window at greater magnification. This tool allows you to access different areas of the Map window without changing the zoom level.

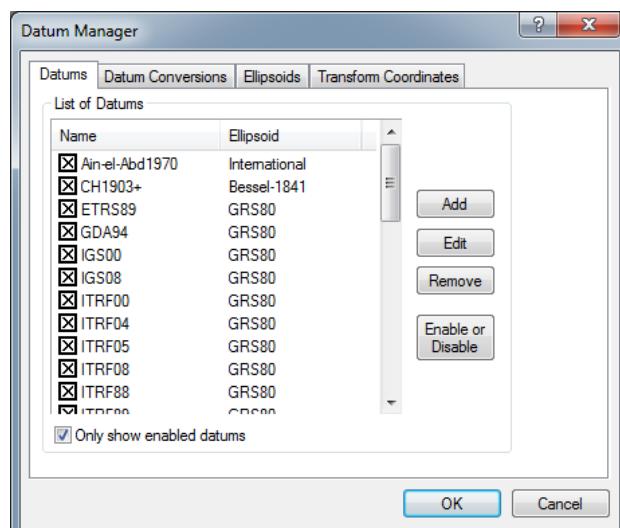
### 1.10.4 Find Epoch Time

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.

### 1.10.5 Datum Manager

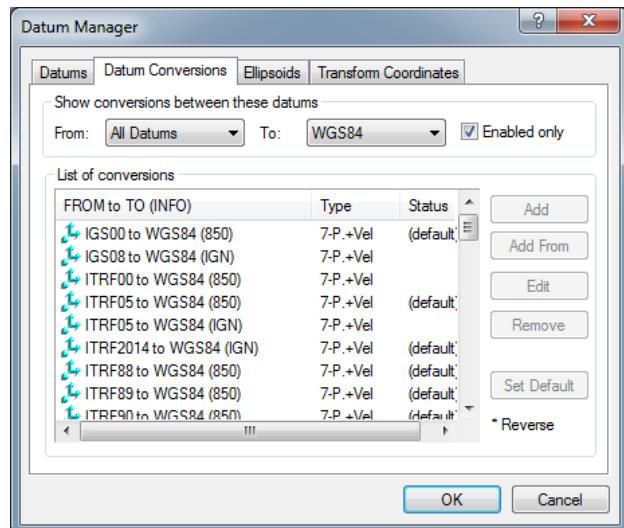
#### 1.10.5.1 Datums

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



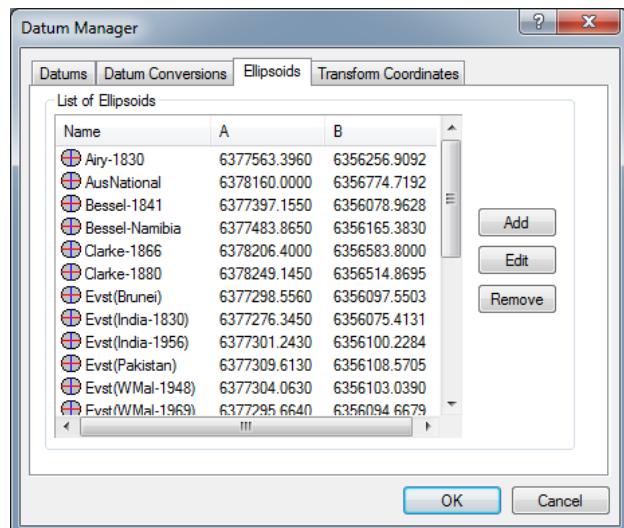
### 1.10.5.2 Datum Conversions

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



### 1.10.5.3 Ellipsoids

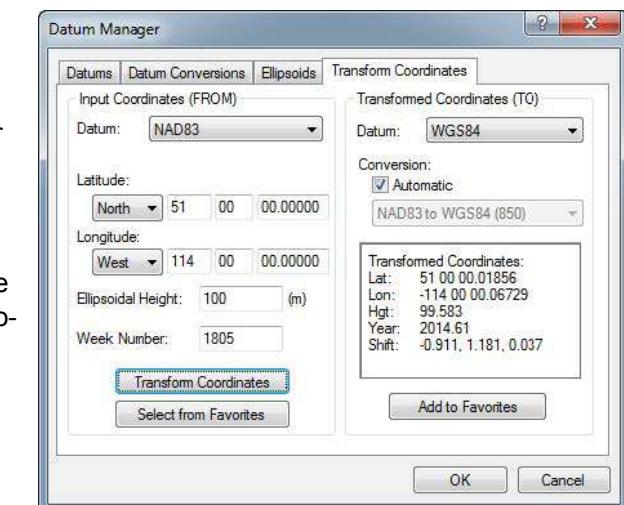
This tab allows you to view the  $a$ ,  $b$  or  $1/f$  values for a particular ellipsoid. You can also add new ellipsoids.



### 1.10.5.4 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.





Specifying the week number of the coordinate effects the final result if using a 14-parameter conversion.

### 1.10.6 Geoid

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, Inertial Explorer subtracts an interpolated geoid height (undulation value) 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/](http://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 Inertial Explorer 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.

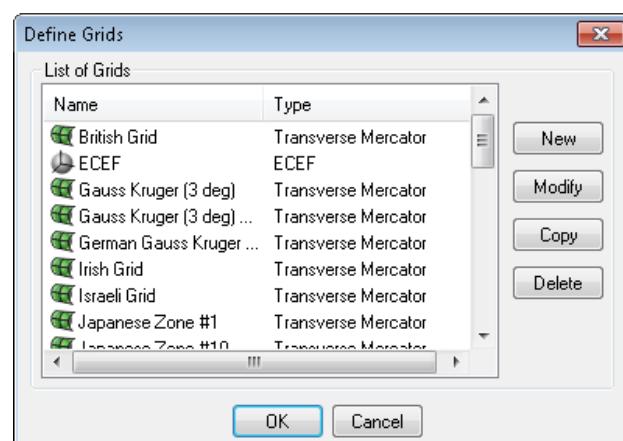
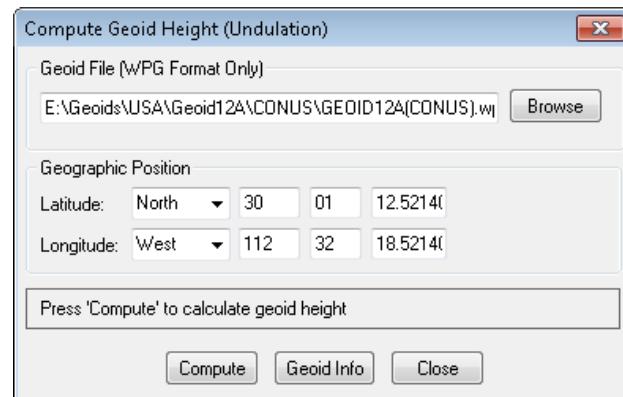
Regardless of how you have entered your base station coordinates (i.e. if you have directly entered an ellipsoidal height or if you have used the *Enter MSL height* feature), the Export Wizard will prompt you for a geoid if your export profile contains MSL heights.

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 vice versa), use the *Convert Coordinate File* on the next page feature. The *Geoid Info* button will access basic properties of the WPG file, including the datum, vertical datums and geographic boundaries.

### 1.10.7 Grid/Map Projection

Inertial Explorer supports grid/map projections in several ways including the following:

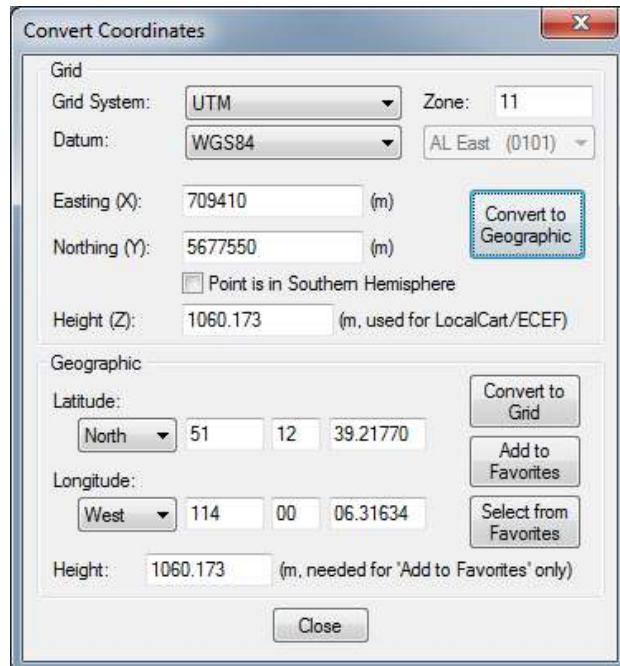
- The *Enter Grid Values* feature within the *Coord Options* pull-down list on the Master Coordinate dialog allows you to enter base station coordinates in any defined grid, including ECEF.
- You can output final coordinates in a map projection of your choice. See *Preferences* on page 73 and *Show Map Window* on page 91 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.

### 1.10.7.1 Transform Coordinates

This tool transforms coordinates for a single point from geographic to grid, or vice versa.



Use the *Add to Favorites* button to save a converted coordinate for easy retrieval in future projects.

### 1.10.8 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.

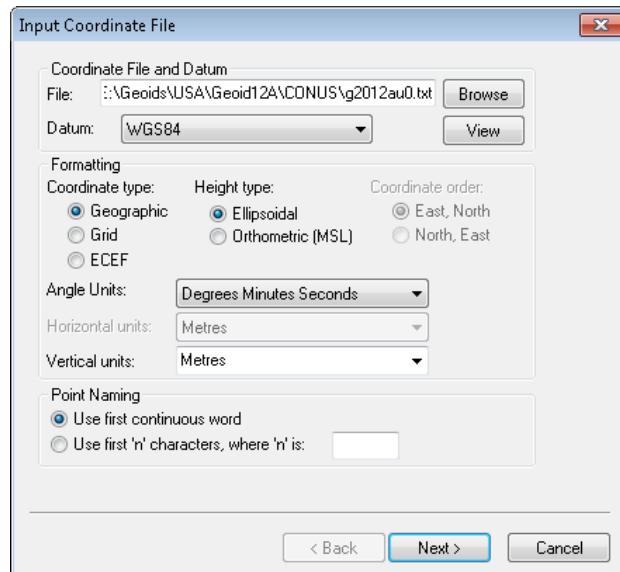
Additional options seen on the screen just before generating the output file include the following:

#### **Include column header**

Conerves 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.

### 1.10.9 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.

### 1.10.10 Favourites Manager

Inertial Explorer's 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.

Inertial Explorer's Favourites Manager comes pre-loaded with coordinates for the CORS, IGS and IGN permanently operating reference networks. The CORS(2011) and the CORS(IGS08) 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(IGS08) group provides access to published IGS08 coordinates at epoch 2005.0 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 Inertial Explorer 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. Inertial Explorer 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.

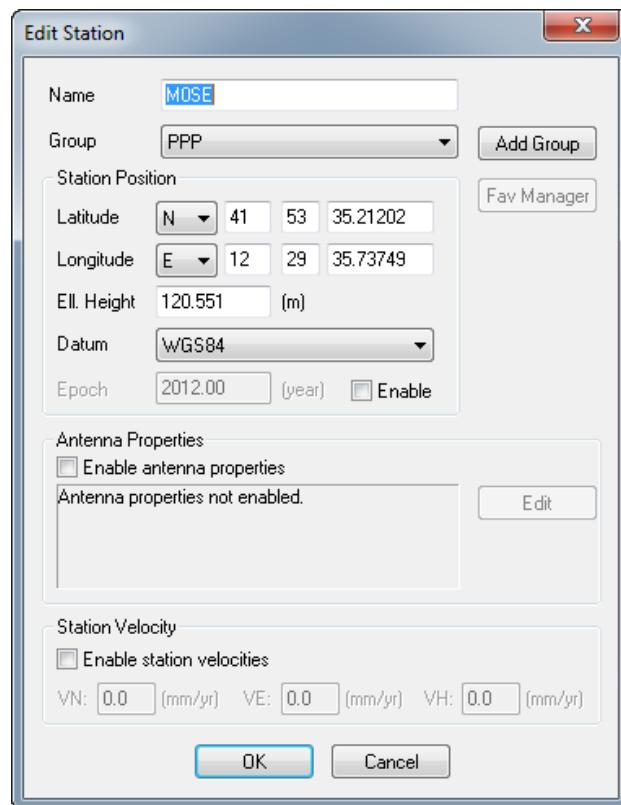
**Add Site**

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.



### 1.10.11 Download Service Data

The Download Service Utility facilitates downloading, converting, and if needed concatenating and resampling of GNSS base station data.

There are currently 18 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.

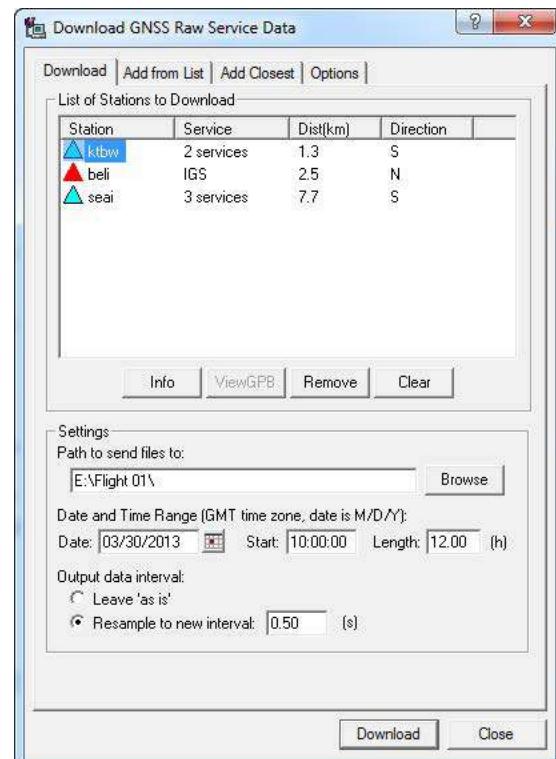
The *Add Closest* tab can be used to search for base station data provided a converted GPB file that you wish to process. This function not only reports a list of the nearest stations, but also automatically scans the date, start/end times, path to download the files to and sampling rate of the GPB file.

The download utility can be used not only to quickly retrieve GNSS base station data, but also to download precise ephemeris and clock files, additional GNSS broadcast ephemeris data and IONEX files (map of the TEQC - only useful for single frequency long distance processing).

#### 1.10.11.1 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 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.

### 1.10.11.2 Add From List

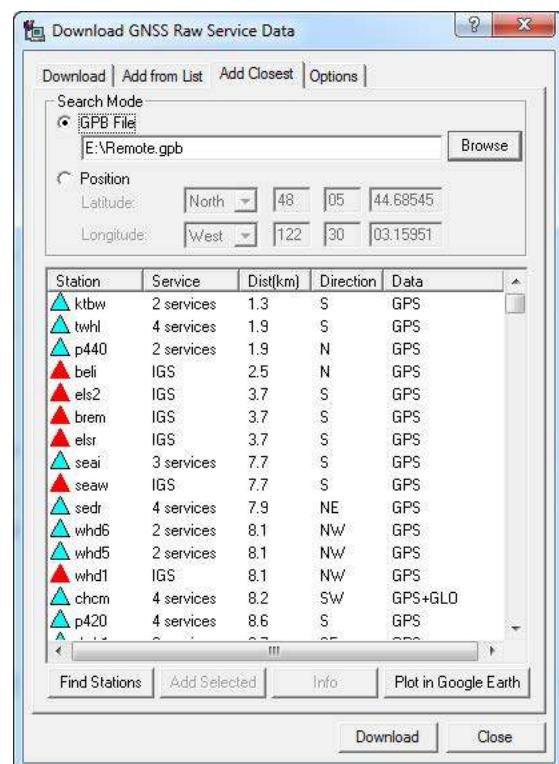
#### List of Stations

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.

### 1.10.11.3 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.



#### 1.10.11.4 Options

##### Precise Files

Precise ephemeris and clock data can be downloaded here for GPS, GLONASS and BeiDou. Sources that provide GLONASS and BeiDou corrections also provide GPS corrections, although quality will vary from source to source.

Precise ephemeris and clock data are required for PPP processing in order to correct for metre level errors. Precise ephemeris data is optional in differential projects as much of the orbital error is cancelled, 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 may benefit from the inclusion of precise ephemerides.

##### Other Files to Download

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.

##### **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.

##### **IONEX File**

Contains information regarding the total electron count (TEC) of the ionosphere. This is useful in single frequency processing to help reduce ionospheric error. IONEX data is not helpful to, and thus not applied, if dual frequency processing is used.

##### **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.

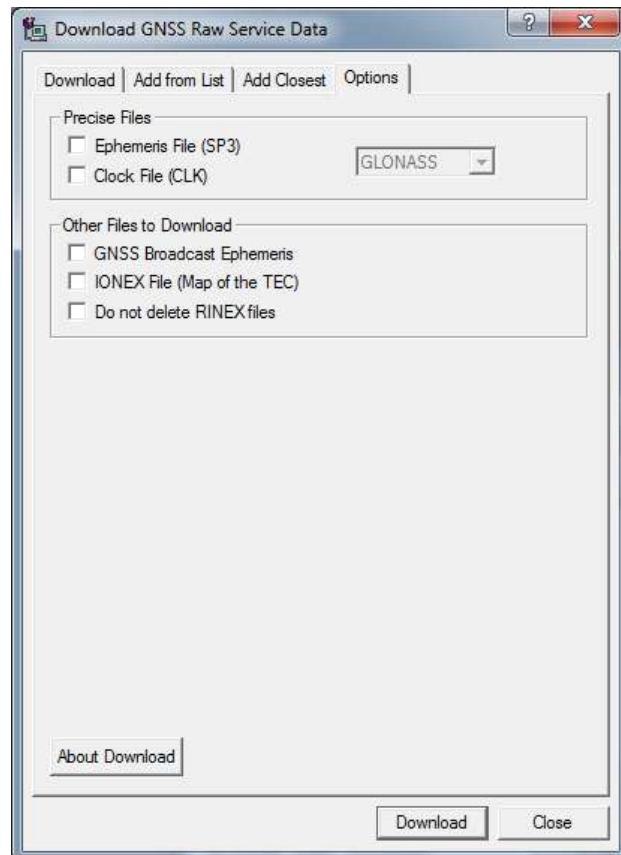
#### 1.10.11.5 Add Stations and Services

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.com](mailto:support@novatel.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 Inertial Explorer users as well.

If you prefer to add your own custom service, create a *user.xml* file within your User directory (C:\NovAtel\WayptGPS870\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 metres.
    <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 or HTTP).
  <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. 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.
  <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 6.
  <hgfile></hgfile>      Generic path to the hourly GLONASS navigation file.
  <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  
[wkm] 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)  
[I] 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

## 1.11 Interactive Windows

See *Show Map Window* on page 91 for information regarding the *Map Window* and the features available within it.

## 1.12 Processing Window

1.9.1.4 *Common Plots* on page 80 contains a list of the parameters available for viewing in Inertial Explorer during processing. Display these values via the *View* button in the *Processing Window*.

The values in *Plot Results* on page 77 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.

## 1.13 Help Menu

### 1.13.1 Help Topics

Opens an HTML version of this manual.

### **1.13.2 Check for update...**

Provided an internet connection, this feature checks the Waypoint server to see if any Inertial Explorer updates are available. If so, they can be directly downloaded and installed.

### **1.13.3 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.

#### **1.13.3.1 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.

### **1.13.4 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.

## **1.14 About Inertial Explorer**

This window displays information about the software version, build dates and copyright information.

# Chapter 2 GrafNet

## 2.1 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.

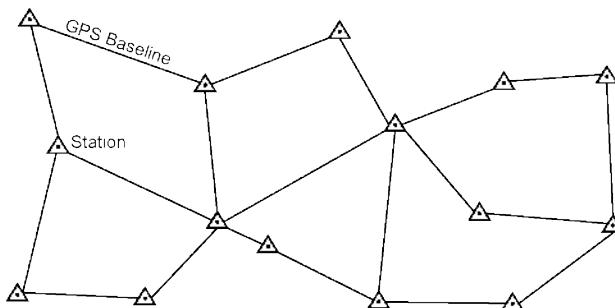
GrafNet is included with both GrafNav and Inertial Explorer, however can also be purchased separately as *GrafNav Static*. This section includes examples of networks that are commonly processed in GrafNet, as well as step-by-step instructions for first time users.

### 2.1.1 Types of Networks

#### 2.1.1.1 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.

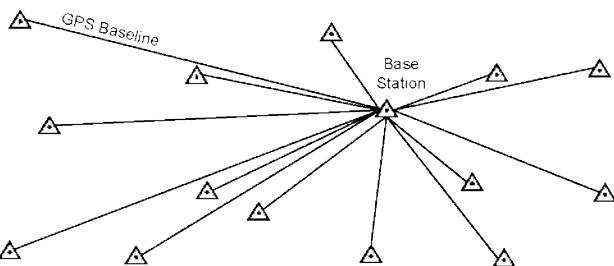
Figure 2: Closed Loop Network



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.

#### 2.1.1.2 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 or more remote GPS receivers are moved from point to point being surveyed.

**Figure 3: Radial Network**

## 2.1.2 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:

### 2.1.2.1 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.

### 2.1.2.2 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.

### 2.1.2.3 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 8: 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
L1-ARTK	Y	N	N	Single frequency fixed solution without ionospheric correction or tropospheric error state

Solution Type	Fixed Integer	Ionospheric Correction	Tropospheric Error State	Description
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

### 2.1.3 Computing Coordinates

Once the processing is complete, there are two methods to produce coordinates for each station.

#### 2.1.3.1 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.

#### 2.1.3.2 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.

## 2.2 Start a Project with GrafNet

### 2.2.1 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 18 for installation instructions.

### 2.2.2 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 139 for information about how to convert raw GNSS data to GPB format.

### 2.2.3 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 139 for more information.
2. Open *GrafNet* from the *Waypoint GPS* program group in your Start menu.
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*.



Entering the name of a project that already exists overwrites the file contents.

#### 2.2.4 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.



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.

#### 2.2.5 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.

### **2.2.6 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 107.

### **2.2.7 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.

### **2.2.8 Verify That All Baselines Have Passed**

Passed baselines are plotted in green, failed baselines in red, purple or blue. Duplicate baselines appear yellow.

### **2.2.9 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.

### **2.2.10 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.

### **2.2.11 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.

## 2.2.12 Fix Bad Baselines

The following sections contain ideas to try when attempting to fix bad (red) baselines in GrafNet.

### 2.2.12.1 Fixed Static Solutions

If a fixed integer solution is not achieved, consider lowering the ARTK quality acceptance criteria to its lowest setting ( $Q_0$ ) 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.

### 2.2.12.2 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.

### 2.2.12.3 Change the Elevation Mask

GrafNet by default uses a  $15^\circ$  elevation mask. This is because tropospheric, ionospheric and multipath errors increase significantly on low elevation satellites. Lowering the mask to  $10^\circ$  allows more satellites into the solution, strengthening the geometry. The improved geometry may more than compensate for increased measurement errors.

### 2.2.12.4 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).

### 2.2.12.5 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.

## 2.3 File Menu

### 2.3.1 New Project

Use this option to create a new GrafNet project, which carries a GNT extension.

### 2.3.2 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.

### 2.3.3 Save Project

This option saves the GrafNet project file (.gnt) to disk, including all observations added to the project.

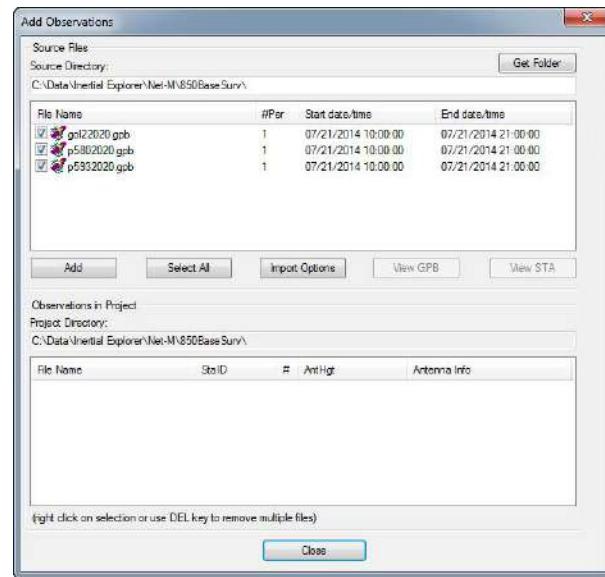
### 2.3.4 Save As

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.

### 2.3.5 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.

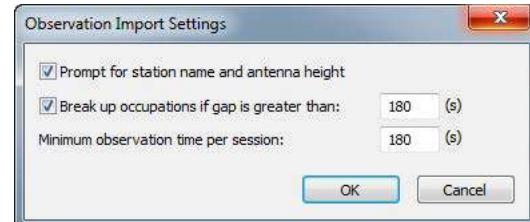


#### 2.3.5.1 Import Options

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:**

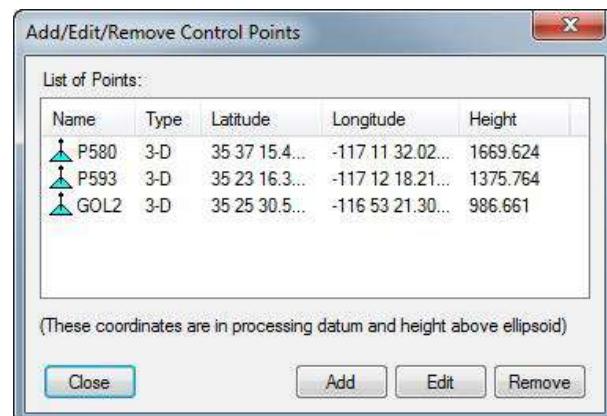
GrafNet will not form sessions between stations that contain less than this adjustable threshold. The default value is 180 seconds. This is a good way of filtering out short and unintentional baselines from being included in your project.

### 2.3.6 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.



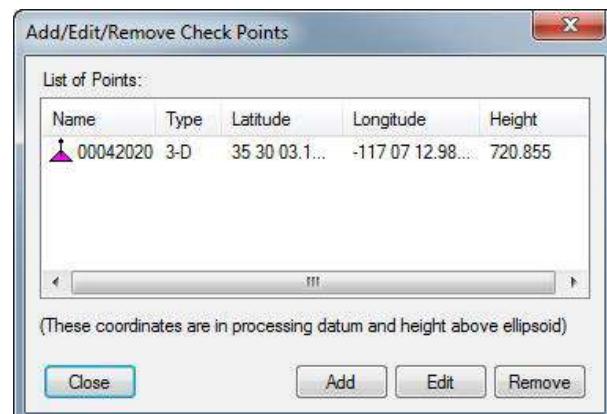
Standard deviations can be entered at this stage. The default values are 5 mm for horizontal and 5 mm for vertical. Standard deviations are only taken into account in the network adjustment. They are useful for combining high and low accuracy control points and will control the extent to which the network adjustment adjusts control point positions.

### 2.3.7 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.

### 2.3.8 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 32 for more information.



### 2.3.9 Import Project Files

This feature imports stations and baselines from another GrafNet project into the current project.

### 2.3.10 View

#### 2.3.10.1 ASCII File

See *ASCII File(s)* on page 41 for information regarding this feature.

#### 2.3.10.2 Raw GNSS Data

See *Raw GNSS Data* on page 42 for information regarding this feature.

### 2.3.11 Convert

#### 2.3.11.1 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 139.

### 2.3.12 GPB Utilities

The GPB Utilities are available for use with GPB files and includes the following:

#### 2.3.12.1 Concatenate, Slice and Resample

See *Concatenate, Slice and Resample Files* on page 138.

#### 2.3.12.2 View Raw GNSS Data

See *GPB Viewer Overview* on page 134.

### 2.3.13 Recent projects

Displays recent projects.

### 2.3.14 Exit

Exits the program.

## 2.4 Process Menu

### 2.4.1 Processing Sessions

This option brings up the *Process Sessions* window, where all processing options are accessed.

#### 2.4.1.1 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.

## 2.4.1.2 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 107 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

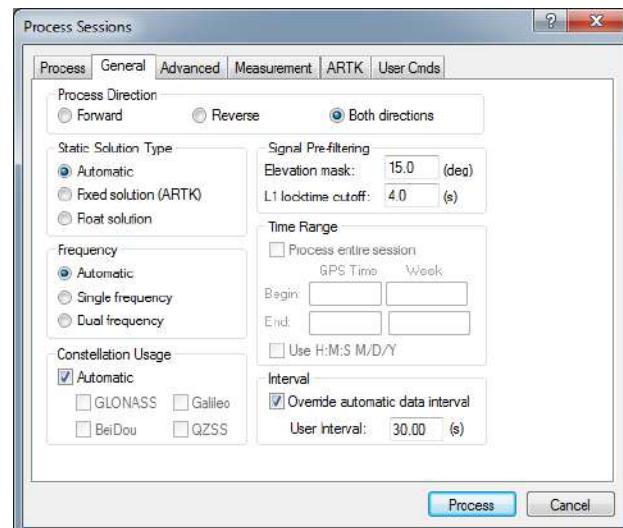
GrafNet supports GPS, GLONASS, BeiDou, Galileo and QZSS. By default, all common data will be processed, however individual constellations (other than GPS) can be disabled here.

### 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.

### 2.4.1.3 Advanced Options

#### Satellite Omissions

See *Satellite / Baseline Omissions in the General (Differential Settings)* on page 44 for more information.

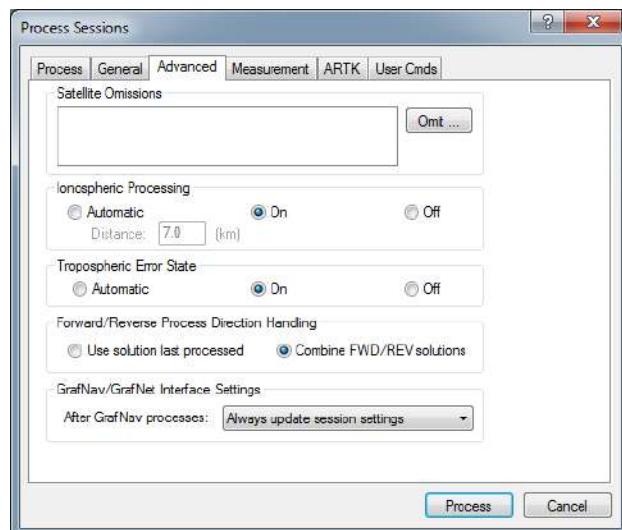
#### Ionospheric Options

See *Ionospheric Processing (Differential processing only)* on page 51 for a description of the Ionospheric options.

#### Tropospheric Error State

See *Tropospheric Error State (Differential processing only)* on page 51 for a description of the Tropospheric 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.

#### GrafNav / GrafNet Interface Settings

If you export baselines to GrafNav for processing, the options below are available to specify how changes made to the processing settings in GrafNav affect those in GrafNet and how the two programs communicate.



If you decide to have the processing settings in GrafNet updated to match those used in GrafNav, they will only be stored for the individual baseline that was exported. The global processing options for the GrafNet project are unaffected.

##### **Always update session settings**

Any changes made to the processing settings in GrafNav will be saved to that baseline's processing settings in GrafNet.

##### **Never update**

Any changes made in GrafNav will not be saved in GrafNet. As such, GrafNet will retain the settings that were used at the time of export.

##### **Prompt user before update**

You will be prompted after every processing run in GrafNav as to whether or not the processing settings used should be saved to GrafNet.

#### 2.4.1.4 Measurement Options

See *Measurement* on page 50 for information regarding the settings on this tab.

#### 2.4.1.5 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**

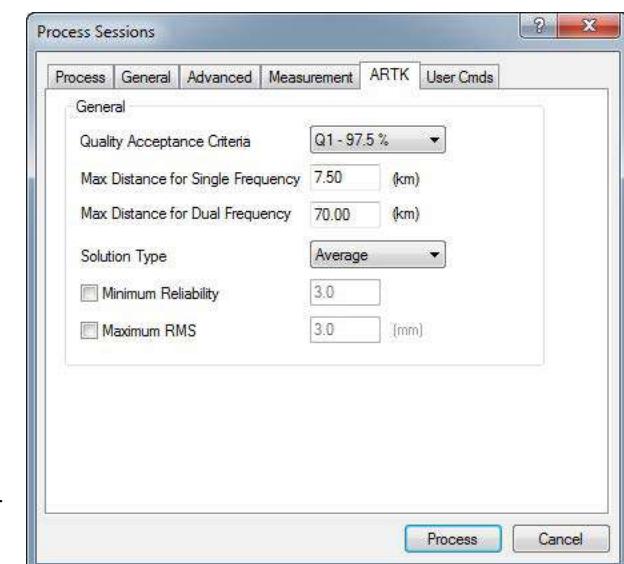
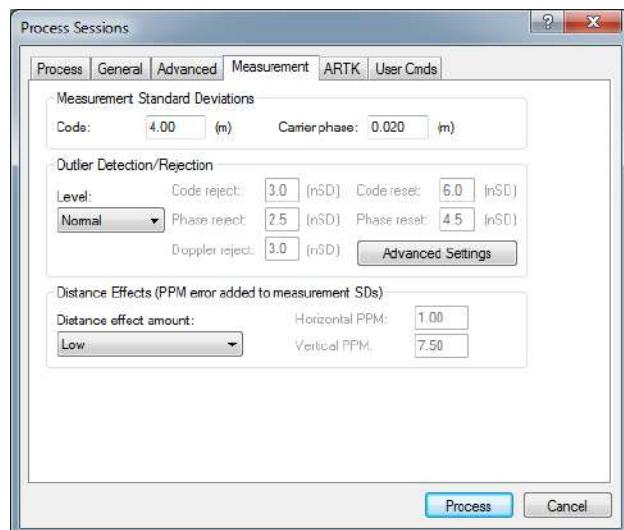
ARTK will not return a successful solution unless the reliability of the ARTK fix meets this threshold. This option is off by default.

##### **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.

#### 2.4.1.6 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.

### 2.4.2 Rescan Solution Files

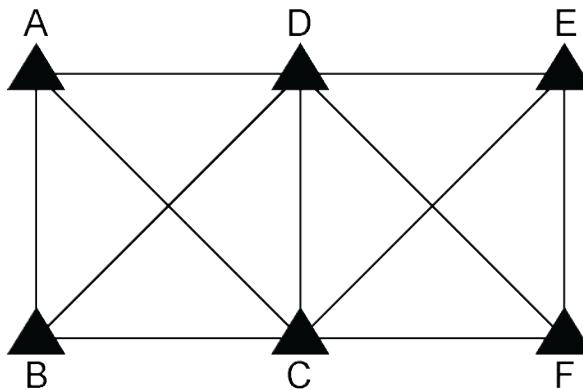
This option rescans the FSS (forward static solution) and RSS (reverse static solution) files. This option will only have an effect if baselines have been processed outside of the GrafNet interface and GrafNet is not recognizing the updated processing results. Normally, this happens automatically but this is controlled through the GrafNav/GrafNet interface settings found in the *Advanced* tab of the GrafNet processing options.

### 2.4.3 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.

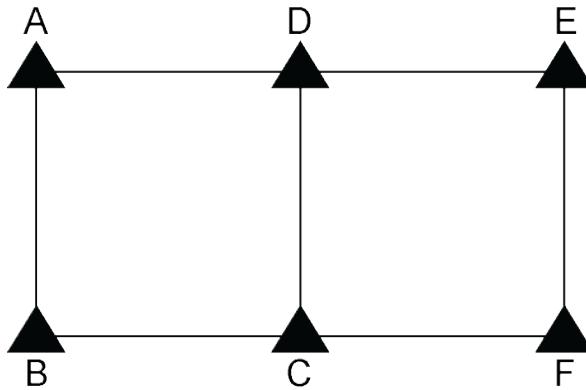
Consider the network in *Figure 4: Trivial Baselines* below. The six stations are surveyed with four receivers during two one-hour sessions. During the first session, stations A, B, C, and D are observed. During the second session, the points C, D, E, and F are observed.

**Figure 4: Trivial Baselines**

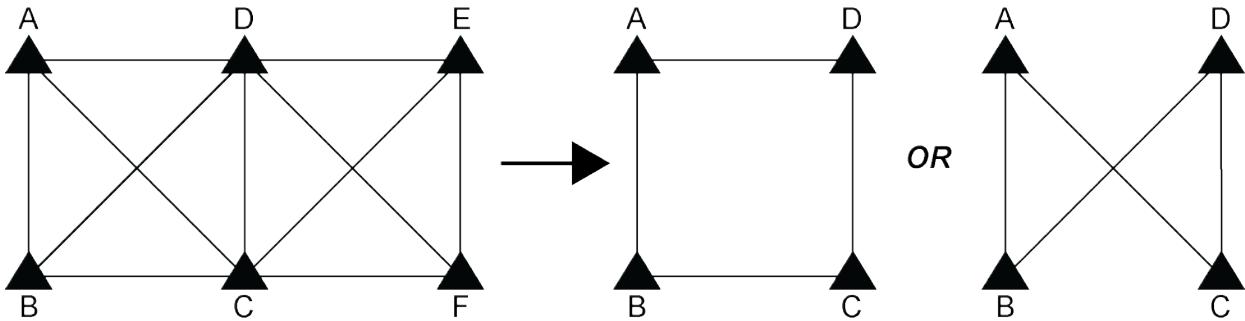


This network can be divided in two sub-networks, formed by the first and second time periods. Before the trivial baseline removal, every baseline in these two sub-networks is dependent on the other baselines. These dependencies cause the loop ties to be low.

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* on the next page 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* below 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 un-ignore 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* above, 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.

#### **2.4.4 Unignore All Sessions**

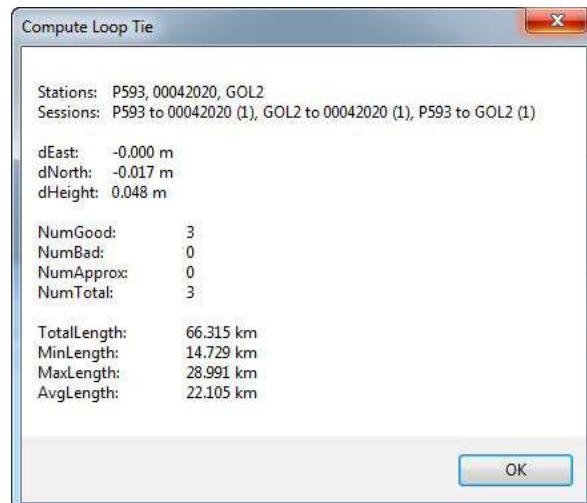
This feature changes the status of all ignored sessions from *Ignore* to the status they had previously.

## 2.4.5 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 113 or *Show Data Manager* on page 127 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.

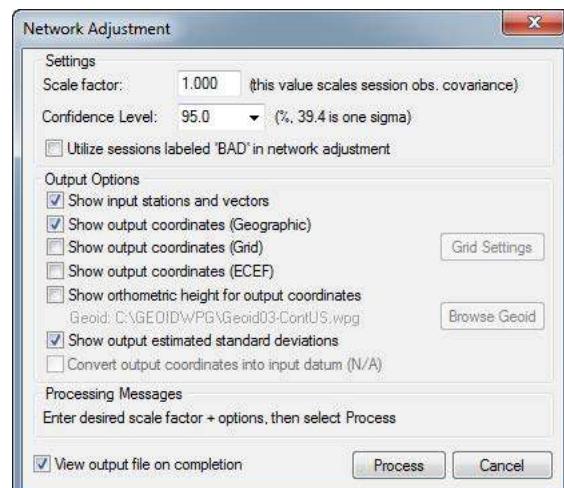
## 2.4.6 Network Adjustment

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.

### 2.4.6.1 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.

#### 2.4.6.2 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.

#### 2.4.6.3 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* (latitude/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.

#### 2.4.6.4 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*.

#### 2.4.6.5 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 the next page 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*.



The network adjustment must be re-run if you have reprocessed sessions or changed the station configuration.

#### 2.4.6.6 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 metres. 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 metres and should ideally be a few centimetres 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 kilometres. 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.

### 2.4.6.7 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.

### 2.4.6.8 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).

## 2.4.7 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.

### 2.4.7.1 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.

The screenshot shows a window titled "C:\Data\Inertial Explorer\Net\NET00000001\Trv.trv" containing the "GRAFNET - GRAPHIC GPS NETWORK PROCESSING SOFTWARE PACKAGE" logo. Below it is the "TRAVERSE SOLUTION:" section with copyright information and version 8.40.2819. The "PROJECT: New.net" is listed. The "DATE: 8/19/2011 (n/e/y)" and "TIME: 13:05:32" are shown. The "DBUFN: WGS84", "GRD: UTM, Zone 1", "UNITS: metres (see Preferences to change)", and "GEOID: (none)" are specified. The "STATIONS (STATUS):" section lists stations B0042028, C012, P580, and P593, all marked as "Control-3D OK". The "STATIONS (COORDINATES):" section provides detailed coordinate data for these stations:

Station	Latitude (° M S)	Longitude (° M S)	Grid-E (m)	Grid-N (m)	Ellipt. (m)	OrthoAlt. (m)
B0042028	35 38 03.14438	-117 07 12.98024	6105431.795	6102473.802	722.181	(-)
C012	35 25 20.64609	-116 53 21.20600	6135446.442	6115621.612	986.661	(-)
P580	35 37 15.49995	-117 11 32.02274	6105498.316	6109025.501	1669.624	(-)
P593	35 23 16.33463	-117 12 18.21678	6110345.973	6082157.891	1375.764	(-)

## 2.4.8 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.

## 2.4.9 View All Sessions

This option will display all sessions in the Data Manager.

## 2.4.10 View All Observations

This option will display all observations in the Data Manager.

## 2.4.11 View All Stations

This option will display all stations in the Data Manager.

## 2.5 Options Menu

The following options are available on the *Options* menu.

### 2.5.1 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*.

## 2.5.2 Sessions Settings (Shown in Data Manager)

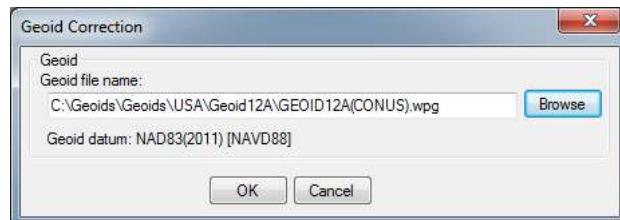
This feature allows you to set the processing options for only the sessions currently appearing in the *Data Manager*. In order to use this feature, the *Sessions* window of the *Data Manager* must be open.

## 2.5.3 Grid Options

See *Grid/Map Projection* on page 97 for information regarding this feature.

## 2.5.4 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.



## 2.5.5 Preferences

### 2.5.5.1 GrafNet Display

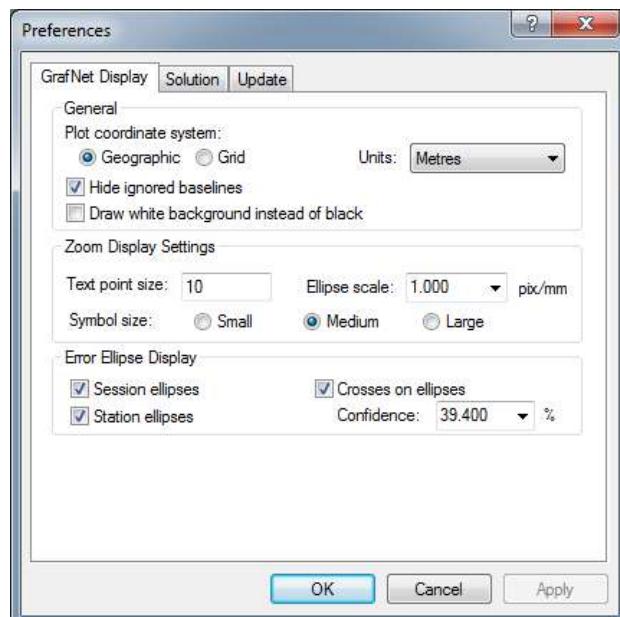
See *Preferences* on page 73 for information regarding any options not described here.

#### **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.



### 2.5.5.2 Solution

Allows the user to choose their default datum and simultaneous forward/reverse processing.

## 2.6 Output Menu

### 2.6.1 Export Wizard

See *Export Wizard* on page 85 for information regarding this feature.

### 2.6.2 Output to Google Earth

See *Export to Google Earth* on page 89 for information regarding this feature.

### 2.6.3 Export to DXF

Only the options specific to GrafNet are discussed here. For descriptions of the other options, see *Export to DXF* on page 90.

#### 2.6.3.1 Station Error Ellipses

Displays the error ellipses around each station and is only available if a network adjustment has been completed.

#### 2.6.3.2 Baseline Error Ellipses

Only the baselines that were processed.

#### 2.6.3.3 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.

### 2.6.4 Export to STAR\*NET

This feature creates an EXP file which is accepted as input to MicroSurvey's STAR\*NET network adjustment software.

### 2.6.5 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.

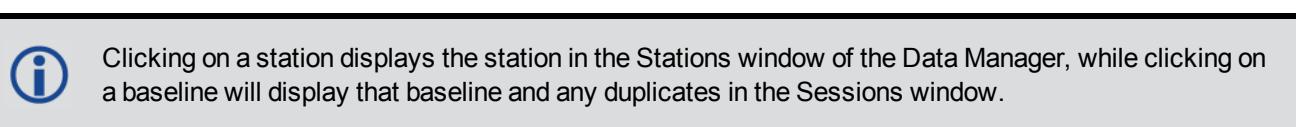
### 2.6.6 Show Map Window

#### 2.6.6.1 Map Window

If you have unintentionally closed the GrafNet Map window, it can be re-opened using this option.

#### 2.6.6.2 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.



## 2.6.7 Show Data Manager

### 2.6.7.1 Data Manager

This interactive window allows for easy display and organization of all project data.

### 2.6.7.2 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 80 for information regarding this plot.

**Plot L1 Satellite Lock**

Launches the *L1 Satellite Lock / Elevation* plot. See *Common Plots* on page 80.

**Plot L2 Satellite Lock**

Launches the *L2 Satellite Lock / Elevation* plot. See *Common Plots* on page 80.

**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.

### 2.6.7.3 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 9: 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 9: Station Color Legend**

Color	Description
Cyan	<b>Control point</b> – A reference station with known coordinates
Dark Purple	<b>Check point</b> – 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	<b>Tie point</b> – Two or more sessions are connected as remotes to this station via the traverse solution. The TRV file will show traverse ties.
Yellow	<b>Traverse point</b> – No tie information can be computed as there is only one avenue for establishing coordinates for this station.

#### 2.6.7.4 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 107 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 107 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 80.

###### **Options**

Allows access to the processing settings so that they can be set individually for this session. See *Process Menu* on page 114 for additional information.

**Override Status**

Manually sets the status of the session. See *Static Solution Types* on page 107 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.

**GrafNav/IE**

Launches the baseline into Inertial Explorer. See *Process Menu* on page 42 for additional information.

**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. See *Distance & Azimuth Tool* on page 95 for help.

**Show To / From Stations**

Displays both stations in the *Stations* window. See *Stations Window* on page 128 for information.

**Show To / From Observations**

Displays both station *Observations* windows. See *Observations Window* on page 127 for information.

Expand the *Sessions* branch in *Data Objects* of the *Data Manager* to display individual sessions in the *Sessions* window.

### 2.6.7.5 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.

**EIIHgt**

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 128 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.

### 2.6.8 Baselines Window

The *Baselines Window* displays information regarding all the sessions in the network. See *Columns in the Sessions Window* on page 130 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 10: Baseline Color Legend**

Color	Description
Blue	<b>Unprocessed</b> – 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 <i>Sessions</i> window of the <i>Data Manager</i> and selecting <i>View Information</i> .
Grey	<b>Ignored</b> – Indicates a session that is to be ignored.
Yellow	<b>Duplicate</b> – 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	<b>Bad / Failed</b> – Represents a baseline where processing failed one or more tests and is thus deemed to be bad. Right-click the baseline in the <i>Sessions</i> window of the <i>Data Manager</i> and select <i>View Information</i> to determine the problem. If you are confident that the solution is okay, the status can be changed from the <i>Sessions</i> window as well. You can control when float solutions pass via the <i>Solution</i> tab under <i>Options   Preferences</i> .
Green	<b>Success</b> – Indicates a session that has passed all tests.

## 2.7 Tools Menu

See *Tools Menu* on page 95 for information regarding the features available through this menu.

## 2.8 Help Menu

See *Help Menu* on page 104 for information about these features.

# Chapter 3 Utilities

## 3.1 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.

### 3.1.1 File Menu

The following options are available on the *File* menu.

#### 3.1.1.1 Open

Any GPB file can be opened with this feature.

#### 3.1.1.2 Close

This feature closes the GPB file without exiting from *GPBViewer*.

#### 3.1.1.3 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.

#### 3.1.1.4 Export to Waypoint Trajectory

This feature saves data from the binary GPB file into a Waypoint trajectory file.

#### 3.1.1.5 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.

Inertial Explorer's *Download Service Data* utility can be used to download and convert GNSS broadcast ephemeris data. See *Download Service Data* on page 100 for more information.

#### 3.1.1.6 Exit

Exits the program.

## 3.1.2 Move Menu

### 3.1.2.1 Forward n and Backward n

Scrolls through *n* epochs in the direction indicated.

### 3.1.2.2 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.

### 3.1.2.3 Search

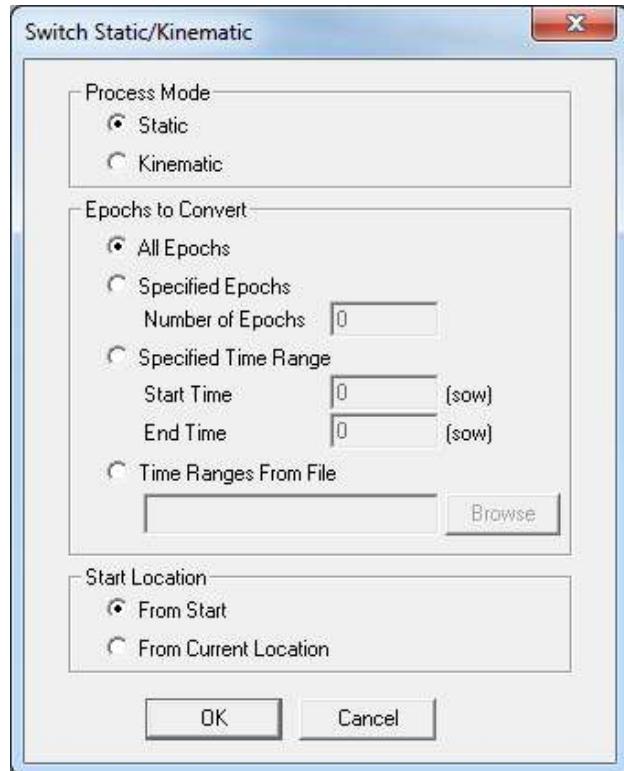
Moves to a specific location in the file. You can specify an epoch number or a time, in either GPS seconds of the week or GMT format.

## 3.1.3 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.

### 3.1.3.1 Switch Static/Kinematic...

Inertial Explorer's 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.

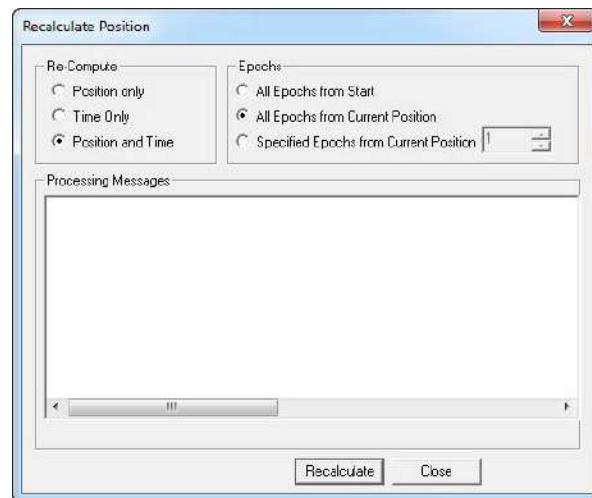
**3.1.3.2 Week Number**

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, Inertial Explorer may not be able to post-process the data. This issue should be addressed with the GNSS receiver manufacturer, but it can also be fixed here.

**3.1.3.3 Recalculate Position and Time**

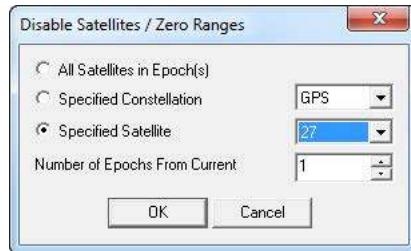
If position records are requested when logging data, Inertial Explorer's Raw GNSS Converter writes them to the GPB file. If no position records are logged, Inertial Explorer's pre-processing functions will compute a single point C/A only solution during data conversion. This is done in order to plot 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 134 for more information.



### 3.1.3.4 Disable Satellite(s)

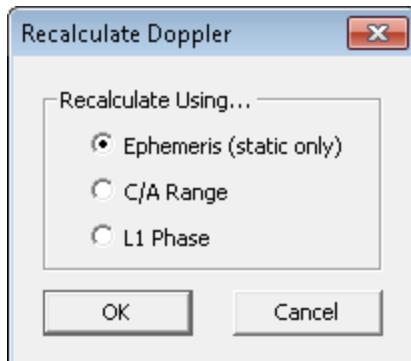
Disabling satellites is normally done within the *Satellite/Baseline Omissions* section of Inertial Explorer's processing options. See *Satellite/Baseline Omissions* on page 45 for more information. This is the recommended method of ignoring satellite data, however in rare cases a bad satellite may be 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.

### 3.1.3.5 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.



### 3.1.3.6 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. Inertial Explorer's 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.

Inertial Explorer's 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.

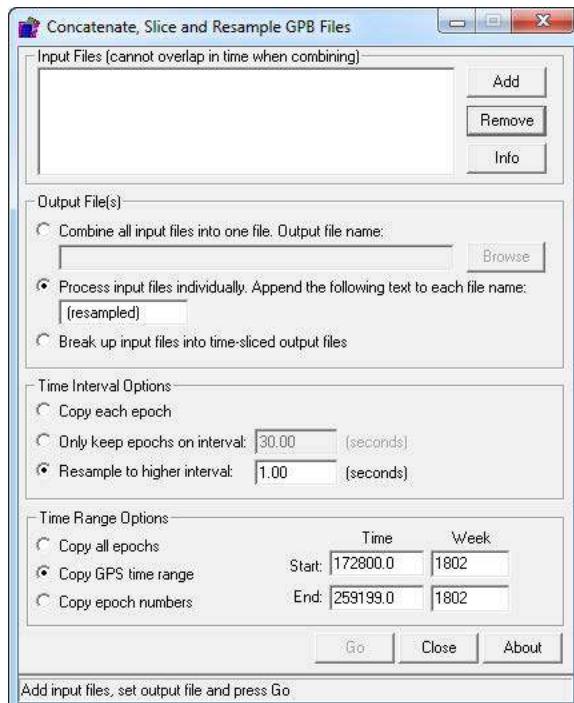
## 3.2 Concatenate, Slice and Resample Files

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).

### 3.2.1 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.



### 3.2.2 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.

### 3.2.3 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.



Resampling can only be performed on static data.

### 3.2.4 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*.

### 3.3 GNSS Data Converter Overview

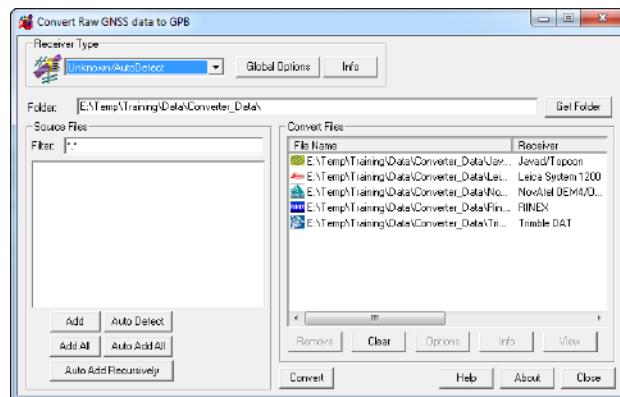
This utility converts raw GNSS data into GPB format. Supported receiver formats are documented in *Supported Data Formats* on page 141.

#### 3.3.1 Convert Raw GNSS data to GPB

##### 3.3.1.1 Receiver Type

Choosing a receiver type prior to conversion applies a file filter commonly associated with the receiver type. This causes only files with these extensions to be listed under *Source Files* within the current folder. You may add or modify the default filter for any receiver type.

After pointing to the folder containing GNSS data to be converted, it is generally recommended to leave the receiver type as *Unknown/AutoDetect* and use either the *Auto Add All* or *Auto Add Recursively* functions.



##### **Global Options**

To view decoding options for individual receiver types, choose the receiver type from the pull down menu and then select *Global Options*. Any changes made to the global 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.

##### 3.3.1.2 Folder

Use the *Get Folder* button to browse to a folder containing raw GNSS data.

##### 3.3.1.3 Source Files

Lists the files in the folder with extensions matching those specified in the *Filter* field.

##### **Add**

When clicking *Add* after selecting an individual file under *Source files*, the converter attempts to auto-detect the receiver type if it has been left as *Unknown/AutoDetect*. If auto-detection succeeds, the file is added under the *Convert Files* section.

##### **Add All**

If a receiver type has been chosen from the pull down menu, all files are added for conversion under this receiver type. If *Unknown/AutoDetect* is selected as the receiver type, an auto-detection is performed on every file in the *Source Files* list.

##### **Auto Detect**

Auto-detects the selected file in the *Source Files* window for conversion.

##### **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.

### 3.3.1.4 Convert Files

This lists all the files to be converted. The icon displayed to the left of the filename indicates the detected receiver type. 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.

**Clear**

Removes all files from the *Convert Files* window.

**Options**

Displays the options associated with the receiver type of the selected file. Any changes are only applied to the selected file and will not be retained.

**Info**

Displays the file path, receiver type and conversion status of the selected file.

**View**

Opens the converted GPB file within the GPB Viewer.

### 3.3.2 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. Inertial Explorer uses this position 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 for Inertial Explorer 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 Inertial Explorer uses Doppler 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 allows Inertial Explorer to automatically load an appropriate processing profile (*GNSS Airborne*, *GNSS Ground Vehicle*, or *GNSS Marine*) the first time the processing dialog is accessed for a project.

### 3.3.3 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.

#### 3.3.3.1 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 the previous page 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.

##### **Decode epochs with bad checksums**

If disabled, epochs containing records with failed checksums will not be decoded. Otherwise, only the affected data is ignored.

##### **Use SAVE marker to store sites to .sta file**

Markers are saved to an STA file.

##### **Verbose messaging mode**

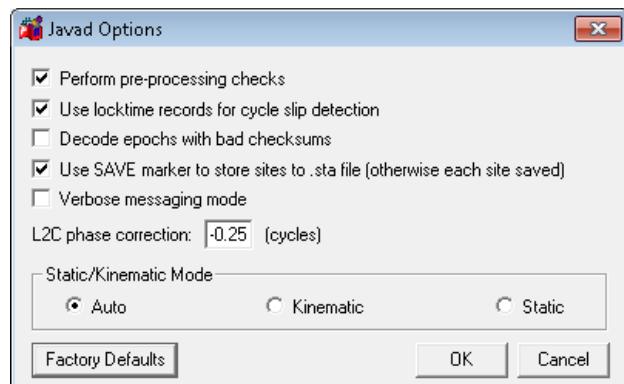
Alerts you of warnings and errors that have occurred.

##### **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 11: Records Supported for Javad and Topcon**

Record	Type	Comment
RC, rc	C/A Code Measurement Block	One of these is required, RC suggested.
1R	L1 P-Code Measurement Block	
3R	L2 C/A Code Measurement Block	
R2, r2, 2R, 2r	L2 P-Code Measurement Block	2R suggested.
PC, pc, CP, cp	L1 Phase Measurement Block	CP suggested.

Record	Type	Comment
P2, p2, 2P, 2p	L2 Phase Measurement Block	2P suggested.
3P, 3p	L2C Phase Measurement Block	
DC	L1 Doppler Measurements	Recommended.
GE	GPS Ephemeris	Required.
NE	GLONASS Ephemeris	Required for GLONASS users.
TO	Clock Offset	
TC	Locktime	
PO	Position	Recommended.
SI	PRN List	Required.
RD	Receiver Date	Required.
--	Receiver Time	Required.

### 3.3.3.2 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 140 for more information.

**Combine multiple (.000,.001...) 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 12: 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.

### 3.3.3.3 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 140 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 13: 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.

### 3.3.3.4 NavCom

The following describes the options available for this converter:

#### **Perform pre-processing checks**

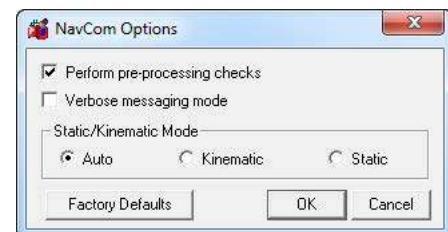
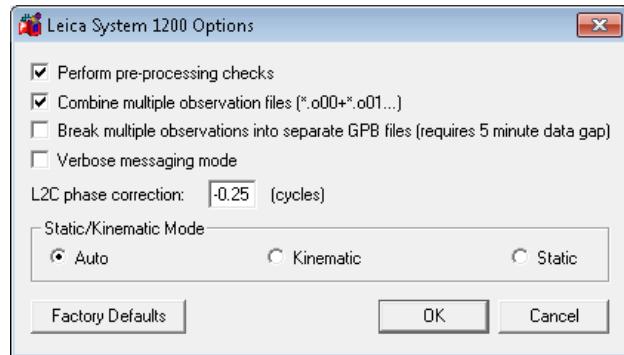
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 140 for more information.

#### **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 14: Records Supported for NavCom**

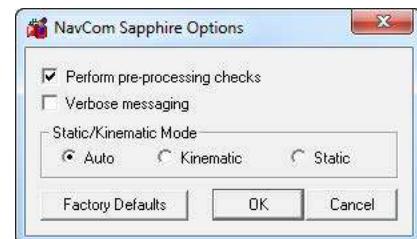
Record	Type	Comment
0xB0	Measurements	Required.
0x81	Ephemeris	Required.
0xB1	Position	Recommended for GrafNet users.
0xB4	Event Marker	Written to STA file.

### 3.3.3.5 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 140 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 15: 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.

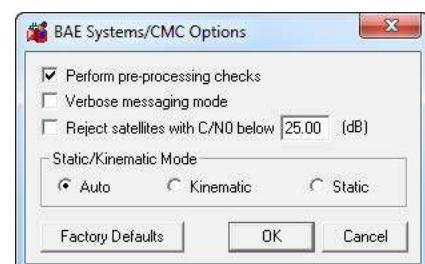
### 3.3.3.6 BAE Systems / NovAtel CMC

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 140 for more information.



#### **Verbose messaging mode**

Displays additional warning messages.

#### **Reject satellites with low C/NO**

Satellites with C/N0 values below the specified threshold will not be decoded.

#### **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 16: Records Supported for BAE Systems / NovAtel CMC**

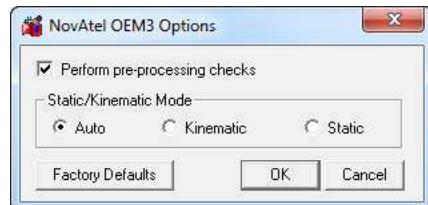
Record	Type	Comment
ID #23	Measurements	One of these records is required, but ID #23 is strongly recommended over the others.
ID #13	Measurements (old style)	
ID #14	Measurements (old style)	
ID #15	Measurements (old style)	
ID #16	Measurements (old style)	
ID #20	Position	Recommended for GrafNet users; should be requested last.
ID #22	Ephemeris	Required.

### 3.3.3.7 NovAtel OEM3

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 140 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.

**Table 17: Records and Files Supported for NovAtel OEM3**

Record/File	Type	Comment
RGEB (ID #32)	Measurements (expanded)	One of these records is required, but RGED is recommended.
RGEC (ID #33)	Measurements (compressed)	
RGED (ID #65)	Measurements (compressed)	
REPB (ID #14)	Ephemeris	Required.
POSB (ID# 01)	Position	Recommended for GrafNet users.
MKTB (ID# 04)	Event Mark (time only)	Written to STA file.
MKPB (ID # 05)	Event Mark (time and position)	Written to STA file.
CLKB (ID# 02)	Clock Information	See <b>Notes</b> .

#### **Notes**

1. If using receivers with standard correlators, you should either request the CLKB record, or else re-calculate the position and clock information. The clock correction (offset) is needed for processing. This record is also suggested for users logging data right from power-up. Request the CLKB record before the measurement record.
2. Ensure that the baud rate is set high enough to properly handle 12 channels worth of measurement records, as well any additional records.

3. The GPS/GLONASS Millennium receiver has 24 channels.
4. Log MKTB or MKPB, but not both.

### 3.3.3.8 NovAtel OEM / SPAN

The following describes the options available for this converter:

#### **Perform pre-processing checks**

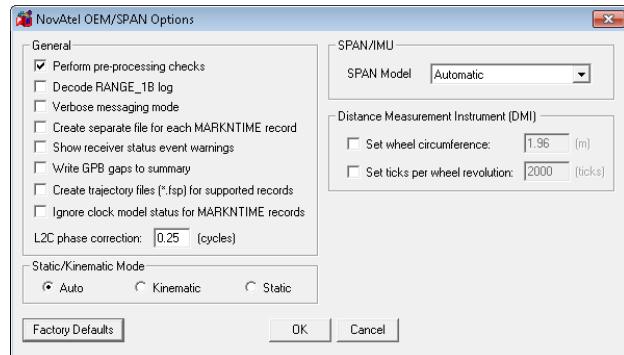
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 140 for more information.

#### **Decode RANGE\_1B log**

This is applicable only to SAASM receivers.

#### **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.

#### **Create trajectory file (\*.fsp) from following record**

This option generates a separate FSP file for each supported position record that is logged. The files can be 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 little GNSS.

#### **L2C phase correction**

This correction value is inserted into the GPB header and can be used by the post-processing engine. OEMV firmware versions 3.0 and 3.1 use a correction of 0.50, while firmware versions 3.2 and later will use either -0.25 or 0.00. Generally, this value should occur on the  $\frac{1}{4}$  cycle.

#### **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 [www.novatel.com/assets/Documents/Bulletins/APN-076-SPANLoggingEI8.7.pdf](http://www.novatel.com/assets/Documents/Bulletins/APN-076-SPANLoggingEI8.7.pdf)) for detailed instructions and examples for data logging.

*Table 18: Records Supported for NovAtel OEM/SPAN* on the next page 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 18: 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)	
RAWEPEHMB (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)	Galileo Ephemeris	Required if logging Galileo data
QZSSEPHEMERISB (ID# 1336)	QZSS Ephemeris	Required if logging QZSS data
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
MARKnTIMEB (ID #1130, 616, 1075, 1076)	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.

Record	Type	Comment
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.
BESTLEVERARM2B (#1256)	IMU to secondary lever arm	Lever arms must be set first through the SETIMUTOANTOFFSET and SETIMUTOANTOFFSET2 commands.
IMUTOANTOFFSETSB (ID #1270)	Primary and secondary lever arms	
BESTGPSPSOB (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.
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
MARKnPVAB (ID #1067, 1068, 1118, 1119)	Event Mark Time	Written to STA file
HEADINGB (ID #971)	Heading from dual antenna	Written to HMR file
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.

### 3.3.3.9 RINEX

Receiver Independent Exchange (RINEX) data is a standard, manufacturer independent ASCII format for raw GNSS data. All GNSS manufacturers should provide tools to convert their native data to RINEX format. If your receiver type is not directly supported by Inertial Explorer, first convert the data to RINEX using a utility supplied by the manufacturer and then import the RINEX data to Inertial Explorer.

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 140 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.

##### **Shift time to user interval**

The decoder will attempt to determine the data interval by reading the header or scanning the observation file. If this fails, enable this option to force an interval.

#### Doppler Source

These options allow you to choose a method of obtaining Doppler measurements.

##### **Automatic/use D1 value**

Uses the D1 value, if present, from the RINEX file for Doppler. Otherwise, it uses *Calculate from CA code* for data intervals of 10 seconds or less, and *Use ephemeris (static)* for anything else.

##### **Calculate from L1 phase**

Select this option if the Doppler signal is missing or unstable.

##### **Calculate from CA code**

If the Doppler signal is missing or unstable, using the CA code will create fewer problems than using L1 phase, but velocity accuracies may be worse.

##### **Use ephemeris (static)**

Assumes static data and computes Doppler from satellite velocities.

#### 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.

**Use alternative ephemeris file**

You may define a path to the navigation file manually. This will override the previous option.

**Table 19: Files Supported for RINEX**

File	Type	Comment
*.yyo, *.obs, *.rxo	Measurements	One of these files is required.
*.yyd	Measurements (compressed)	
*.ynn, *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.

**3.3.3.10 RTCM Version 3.0**

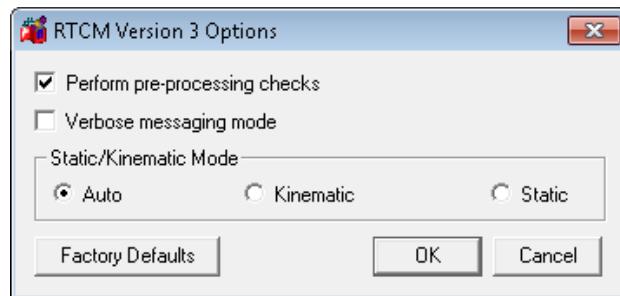
The following describes the options available for this converter:

**Perform pre-processing checks**

If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 140 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 20: 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 MSM5 and MSM7 messages, which can be used for multi-constellation operation. See *Table 21: Supported MSM Messages* on the next page.



MSM7 messages are more precise than MSM5 messages, but are also larger.

**Table 21: Supported MSM Messages**

Record	Type	Comment
1075	MSM5 GPS L1 only measurements	One of these is required for GPS users.
1077	MSM7 GPS L1/L2 measurements	
1085	MSM5 GLONASS L1 only measurements	One of these is required for GLONASS users.
1087	MSM7 GLONASS L1/L2 measurements	
1095	MSM5 Galileo L1 only measurements	One of these is required for Galileo users.
1097	MSM7 Galileo L1/L2 measurements	
1115	MSM5 QZSS L1 only measurements	One of these is required for QZSS users.
1117	MSM7 QZSS L1/L2 measurements	
1125	MSM5 BeiDou L1 only measurements	One of these is required for BeiDou users.
1127	MSM7 BeiDou L1/L2 measurements	
1013	System Parameters	Required to extract the week number.
1019	GPS Ephemeris	Recommended for GPS users.
1020	GLONASS Ephemeris	Recommended for GLONASS users.
1042	BeiDou Ephemeris	Recommended for BeiDou users.
1044	QZSS Ephemeris	Recommended for QZSS users.
1045	Galileo F/Nav Ephemeris	Recommended for Galileo users.
1046	Galileo I/Nav Ephemeris	

### 3.3.3.11 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 140 for more information.

#### **Verbose messaging mode**

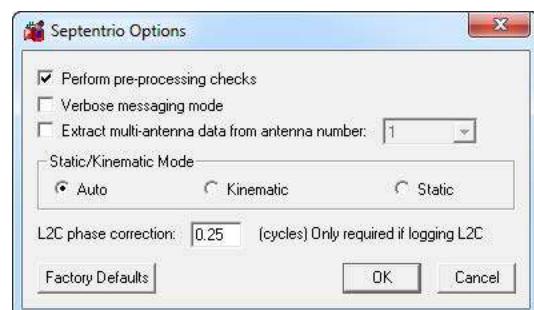
Allows you to see additional warning messages.

#### **Extract multi-antenna data**

For multi-antenna applications only.

#### **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 Septentrio SBF**

Record	Type	Comment
5889	Measurements	One of these records is required
5890	Measurements (compressed)	
5891	Ephemeris	Required
5904	Position	Recommended for GrafNet users
5924	Event	Written to STA file

### 3.3.3.12 Thales/Ashtech/Magellan B-File

The following describes the options available for this converter:

#### Thales (Ashtech) Receiver Type

Selects the receiver used to collect the data. If auto-detect does not work, 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 page 140 for more information.

##### **Detect static/kinematic from site name**

Looks in B-file for data tagged as static or kinematic, using ??? site ID.

##### **Ignore questionable L2 phase**

Allows for processing of highest quality L2 data only. Should be enabled if ARTK is having difficulties.

##### **Verbose messaging mode**

Allows you to see 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 Thales 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.

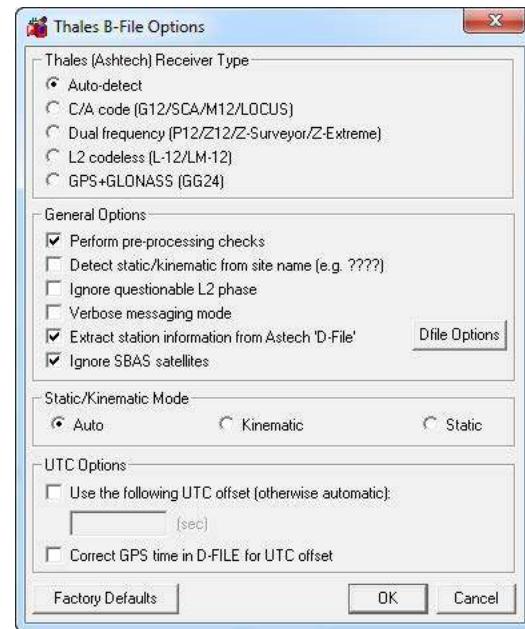
#### Static/Kinematic Mode

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 23: Files Supported for Thales B-File**

File	Type	Comment
BssssAyy.jjj	Measurements	Required.
EssssAyy.jjj	Ephemeris	Required.
SssssAyy.jjj	Static Station Information	Written to STA file.
DssssAyy.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.

### 3.3.3.13 Thales/Ashtech/Magellan 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**

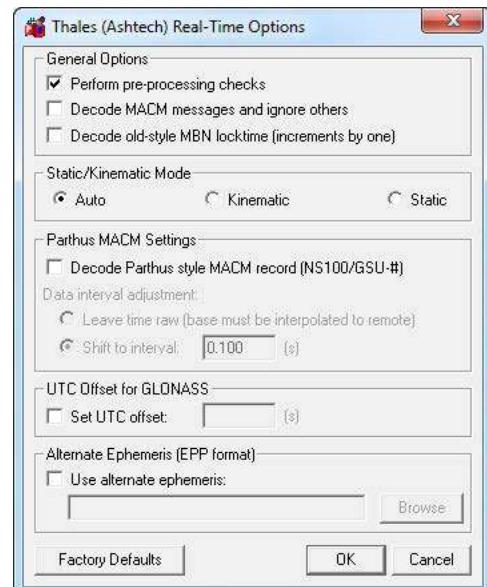
If enabled, data is scanned after conversion to correct potential issues. See *Pre-processing Checks* on page 140 for more information.

##### **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 138 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 24: Records Supported for Thales 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, 10Hz or 20Hz, 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.

### 3.3.3.14 U-Blox

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 140 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.

#### **Verbose messaging mode**

Displays additional warning messages.

**Table 25: Records Supported for U-Blox**

Record	Type	Comment
ID #10	Measurement	ANTARIS format
ID #15	Measurement	M8 format
ID #31	Ephemeris	ANTARIS format
ID #13	Ephemeris	M8 format
ID #02	Position	Recommended
ID #22	Clock	Recommended.
ID #3	Mark	If collecting time stamped events

## 3.4 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)*.

### 3.4.1 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 26: 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

### 3.4.2 Waypoint IMU Data Conversion

#### 3.4.2.1 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.

##### **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**

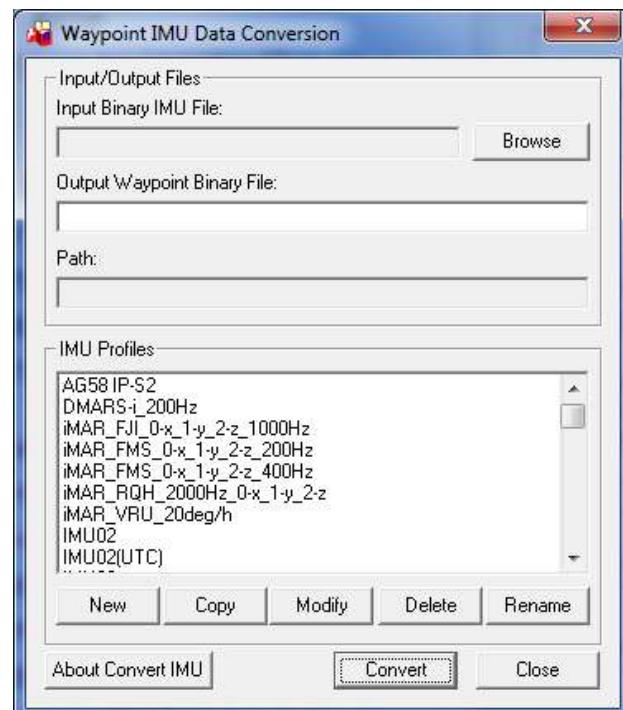
Deletes an existing profile.

##### **Rename**

Renames an existing profile.

#### 3.4.2.2 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.



### 3.4.3 Creating / Modifying a Conversion Profile

#### 3.4.3.1 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.

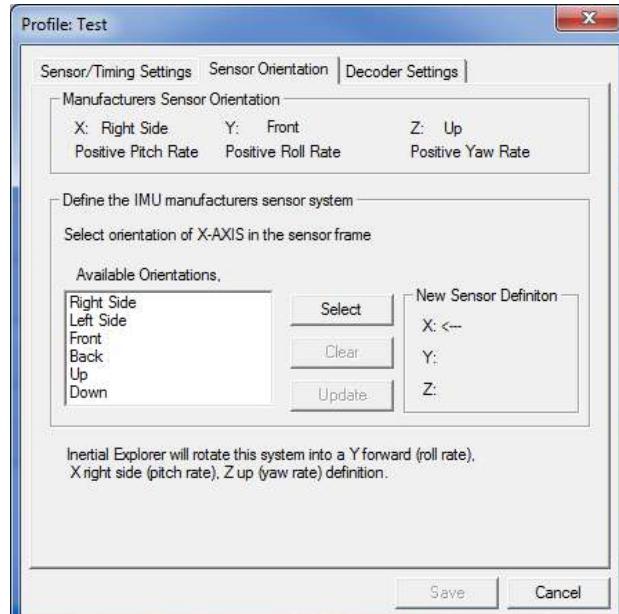
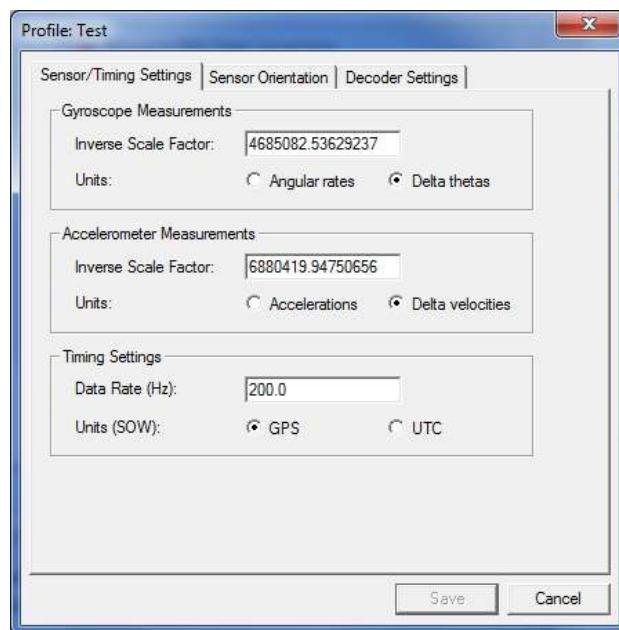
#### 3.4.3.2 Sensor Orientation Settings

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.



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.



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.

#### 3.4.3.3 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.



For SPAN, the IMU decoding is handled through the GNSS decoder.

# Chapter 4 File Format Overview

This section describes the format of the files used by Waypoint software.

- *CFG File* below
- *GNSS Data Files* below
- *Output Files* on page 162
- *Inertial Explorer Data Formats* on page 156
- *Inertial Explorer File Formats* on page 166
- *Inertial Explorer Output Files* on page 175

## 4.1 CFG File

A CFG file is a Inertial Explorer project file. This file is written by Inertial Explorer when creating a new project and contains all processing options used in the project. The name of the CFG file defines the name of all ASCII and binary files written by Inertial Explorer when processing.

## 4.2 GNSS Data Files

The following files are produced by Inertial Explorer's raw GNSS data conversion utility.

### 4.2.1 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 and time information and other information.

GPB files can be opened within Inertial Explorer's *GPB Viewer*, which allows you to view the raw measurements collected and perform basic editing functions if needed. Requests for the GPB file format should be made to [support@novatel.com](mailto:support@novatel.com).

### 4.2.2 STA File

A station file contains any decoded camera marks, antenna heights and station names. It is read automatically by Inertial Explorer 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 metres
  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 metres, azimuth in degrees, height
                                   difference in metres)

  OffL: DE DN DH                 Offset in local level frame, in metres
  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 metres
Vel:	VE VN VH	Velocity, in m/s
Att:	roll pitch heading	Altitude, 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.

### 4.2.3 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.com](mailto:support@novatel.com).

## 4.3 Output Files

This section discusses some of the output files created when processing with Waypoint software.

### 4.3.1 FML, RML, FSL and RSL Files

The Forward Message Log and Reverse Message Log files (FML and RML) contain all of the messages generated by the differential processing engine. FSL and RSL files contain all of the messages generated by the Precise Point Positioning engine. Some common messages are described here:

#### Reading ephemeris files...

**Processing ephemeris file 'C:\GPSSData\rover\_.epp'**

**Detected 40 GpsEph, 0 GlonassEph, 0 GpsLono and 0 GpsAlmanac records**

This message is generated just prior to processing. Inertial Explorer combines all ephemeris measurements at the base and rover before processing.

**Best base on BL1 is PRN 17 with 4 points and elevation of 62.1 degrees**

**Second best on BL1 is PRN 16 with 2 points and elevation of 51.7 degrees**

This message indicates the base satellite (and its elevation) selected after a base change or at outset. The second best base is also shown. Base satellite selection is based on a point system that includes a number of factors such as elevation above the horizon and whether it is rising or falling.

**Detected bad Phase measurement @ 9.1 sigma. Rms is 0.336 m (Worst Prn is 14 on B/L BL1 with residual of 0.465)**

This can be caused by undetected cycle slips or noisy measurements due to a challenging GNSS signal environment. Inertial Explorer's outlier detection routines will attempt to fix the problem by rejecting individual measurements and recomputing the residual.

**+++ ARTK obtained a valid integer fix on BL BL1**

**Fixed 8 out of 8 satellites at a distance of 8.3 km**

**Residual RMS is 2.47 mm, Reliability is 3.8, Float-fix-sep. is 0.243 m**

**ARTK not engaged--rewind ignored**

**ARTK success!**

Message displayed for a successful ARTK fix

**Epoch rejected due to poor satellite geometry--DD\_DOP of 918.0 too large**

This message warns that an epoch has been rejected because of poor satellite geometry.

**Doppler L1 cycle slip on PRN 24 of 1575419.57 cycles on baseline BL1**

Indicates that a large change in carrier phase has been detected which is interpolated as a cycle slip.

**Locktime cycle slip on PRN 4 of -5.92 cycles on baseline BL1**

Cycle slip has been reported by base or remote receiver.

**Inserted L1 cycle slip due to locktime reset for PRN 4 on baseline BL1**

Receiver cycle slip counter reset at some time in the past but was not caught. Therefore, slip inserted now.

**Less than four satellites at startup--Will try next epoch(s)**

Software needs at least 4 satellites and good measurement quality at startup.

**Warning: Epoch with less than 4 good satellites (Cycle slips)**

This message warns about an epoch with less than 4 satellites.

**Locktime cycle slip on PRN 26 of -41.31 cycles on baseline BL1**

**Small L2 cycle slip on PRN 26 of 0.65 cycles on baseline BL1**

Both messages warn of cycle slips on L2. The DPH is an indicator of the size of the cycle slip. It shows the difference in phase. If the data contains many L2 cycle slips, it will make for a bad ionospheric-free solution. If there are many L2 cycle slips, try using the relative ionospheric solution.

**Prn 15 is below mask angle of 10.0 degrees**

This message indicates that a satellite has gone below the elevation mask.

**Satellite 7 is rising or re-appearing**

This message is usually caused from a satellite on the horizon.

**Prn 27 disappeared for 33.0 seconds on baseline BL1**

Indicates that as the satellite dropped out and is reappearing, a new ambiguity will be solved.

**Calculating fixed solution**

**Calculating RMS values**

**Continuous fixed solution reliability: 7.43 (PASSED), RMS: 0.0372 m (PASSED), STD:**

**0.0014 m**

**Continuous fixed solution position is: 39 01 23.54716, -84 36 21.25817, 259.7909 m**

**Computing New Fixed solution**

This message shows the results from the multi-satellite fixed solution. The reliability is the ratio between the second best RMS and the best RMS. The minimum reliability for a pass is 1.35. The RMS is the RMS fit of the fixed solution. This number is in metres and the maximum value to pass is 0.025 m + 1PPM for dual frequency and 0.015 + 1PPM for single frequency.

**Warning: No precise ephemeris available for prn 21**

Message warns that a precise ephemeris is missing for a satellite. The user may want to try another SP3 file to better the results.

**\$\$\$ GPS data errors detected--will try and reject measurements, baselines or satellites**

Error messages starting with \$\$\$ indicate bad carrier or code measurements encountered. The above message should be following another message indicating what residuals are out-of-range and which satellite has the largest value. The indicated satellite may not be the actual problem one because the Kalman filter distributes the errors around. A number of tests will be performed to isolate the problem data and satellite. Therefore, this message is followed by the messages shown below.

**On code, worst PRN is 20, RMS is 1.46 m (PASS), reliability is 1.84 (FAIL)**

A further test on the combined code-carrier solution to ensure that the code is OK.

**On phase, worst PRN is 28, RMS is 0.0949 m (PASS), reliability is 1.19 (FAIL)**

This test will generally indicate if a missed cycle slip to other carrier phase problem was fixed by removing a particular satellite. The above message indicates that the problem could not be fixed, and will generally be followed by a filter reset message. See below. The reliability must be greater than 4.0 to be signaled as a pass. The user should investigate the clock offset information at this epoch via **GPBView** to see if the problematic epoch is due to an incorrectly computed clock shift.

**\$\$\$ Engaging filter reset--Accuracy is severely reduced**

This is printed when the filter reset is being engaged. It should be preceded by a message indicating why the filter reset was issued. A filter reset is when a cycle slip is issued to all satellites and the position is reset to startup values.

**(+) ARTK engaged due to occurrence of filter reset**

Following any filter reset, ARTK is re-engaged

**Locktime and doppler cycle slip on PRN 30 of -307.64 cycles on baseline BL1**

Indicates that a cycle slip has occurred and it has been detected by both the locktime and a large change in the carrier phase.

**%%% PRN 18 was omitted for time range 488400.0-488500.0 s on ALL baselines**

**%%% ALL satellites were omitted for time range 8000.0-8100.0 s on baseline mast**

'%%%' followed by a message indicates when and how long a baseline and/or PRN was omitted from processing.

### 4.3.2 FSS & RSS Files

Reported in the solution summary files is a summary of each ARTK fix and static session.

---

---

---

Configuration and processing settings

---

---

Project settings:

Master 1	:	Name	GRN04-0107a	ENABLED
	:	Antenna	SIMPLE_VERT	0.000 m
	:	File	\waypoint01\c\GPSData\Manual_	
Data\GRN04.gpb	:	Position	43 45 49.97515 -87 50 51.75271	
198.262	:			
Remote	:	Name	Remote	ENABLED
	:	Antenna	SIMPLE_VERT	0.000 m
	:	File	\waypoint01\c\GPSData\Manual_	
Data\air_rover.gpb	:	0 static sessions		
Direction	:	FORWARD		
Process Mode	:	Dual frequency carrier phase		
Static Initial.	:	Float		
Use AR	:	Yes		
Use Glonass	:	Yes		

The file may look different depending on whether static or kinematic processing was performed. When static processing, the output includes the final coordinates and various statistics associated with those coordinates. In kinematic processing, the ARTK summary record is the only output if ARTK resolved carrier phase ambiguities.

Following are the final coordinates that are output in a static solution. The difference between the fixed and float output is the fixed will have an RMS and reliability. The RMS represents the fit of the carrier phase measurements in the solution. The reliability is the ratio between the second best RMS and the best RMS.

```
-----  
-----  
Final FIXED static position for Station STATIC, Base BL1  
-----  
-----
```

```
Static {  
    ToSta:          "STATIC"  
    FromSta:        "BL1"  
    IsBest:         Yes  
    AntHgt:         0.486 m  
  
    StartTime:      6240.00 1318 01:44:00.0 04/10/2005  
    EndTime:        6375.00 1318 01:46:15.0 04/10/2005  
    TimeLen:        2 minutes, 15 seconds  
  
    Latitude:       -39 00 33.18453  
    Longitude:      174 10 46.74393  
    EllHeight:      63.8096  
    SolType:        L1L2-ARTK  
    IsFixed:        Yes  
    RMS:            0.0040 PASS ; m  
    Reliability:   10.3 PASS ; RMS ratio  
  
    StdDev:         0.0063 0.0068 0.0147 ; m (e,n,h)  
    EcefVec:        45.4059 -48.5693 -63.9423 ; m  
    EcefCov1:       2.02423923e-004  
    EcefCov2:       -5.94309046e-005 4.99990537e-005  
    EcefCov3:       6.87795183e-005 -1.87233603e-005 5.03819486e-005  
    AvgDDDop:       3.35  
    AvgPDop:        2.12  
    AvgNumSats:    7.0  
    Quality:        1  
  
    SlopeDist:     92.246 ; m  
    HorizDist:     92.235 ; m  
    SurfaceDist:   92.235 ; m  
    Azimuth12:     151 42 36.21749  
    Azimuth21:     331 42 35.07388  
}
```

The only output from kinematic processing is the ARTK summary record as shown below. Note that if kinematic processing is used without ARTK, no output will be shown in the FSS/RSS files.

```
; ----- ARTK Results -----  
Kar {  
    ARTK: 1  
    EngageTime: 130770.00 1802 12:19:30.0 07/21/2014  
    RestoreTime: 153780.00 1802 18:43:00.0 07/21/2014  
    SearchTime: 153780.00 1802 18:43:00.0 07/21/2014  
    TimeSkipped: 23010.0 s  
    TimeUsed:    5280.0 s    PASS  
    RMS:         0.5      mm  PASS
```

```
Reliability: 1.9          PASS
FixFixSep: 0.01   m    PASS
SearchDist: 14.73  km   "GPS Fixed"
AvgDist:    14.73  km
AvgSats:    9.0
SearchSats: 10           "G07G07G07 G01 G04 G08 G11 G15 G17 G26 G28
G30"
RestoreSats: 10           "G07G07G07 G01 G04 G08 G11 G15 G17 G26 G28
G30"
RestoreDop:  1.5
RestorePos: 35 30 03.14304 -117 07 12.98110 722.151
}
```

### 4.3.3 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.

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 binary structure definitions that define these files contact [support@novatel.com](mailto:support@novatel.com). The legacy ASCII files can be output using the *Output | Export to Waypoint Legacy Format* option.

### 4.3.4 FBV & RBV Files

*Binary Value* files contain individual satellite residuals and multi-base data which is not written to the standard output files. These files contain:

**For each baseline:**

- i. Code, carrier and Doppler RMS values
- ii. Code, carrier and Doppler SD values
- iii. Code and carrier phase separation values
- iv. DOP values
- v. Ambiguity drift
- vi. Effective weighting

**For each satellite:**

- i. PRN
- ii. Baseline
- iii. Rejection + base satellite flags
- iv. Code, carrier and Doppler residual values
- v. Code, carrier and Doppler SD values

## 4.4 Inertial Explorer File Formats

### 4.4.1 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 156 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 27: IMR Header Struct Definition**

Word	Size	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. 8.70)
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 <i>dDataRateHz</i> 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 <i>dDataRateHz</i> to get m/s <sup>2</sup> )
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 <i>bDeltaTheta</i> == 0 multiply the gyro measurements by this to get degrees/second If <i>bDeltaTheta</i> == 1 multiply the gyro measurements by this to get degrees, then use <i>dDataRateHz</i> to get degrees/second
dAccelScaleFactor	8	double	If <i>bDeltaVelocity</i> == 0 multiply the accel measurements by this to get m/s <sup>2</sup> If <i>bDeltaVelocity</i> == 1 multiply the accel measurements by this to get m/s, then use <i>dDataRateHz</i> to get m/s <sup>2</sup>
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

Word	Size	Type	Description
szProgramName	32	char[32]	Name of calling program
tCreate	12	time_type	Creation time of file
bLeverArmValid	1	bool	True if lever arms from IMU to primary GNSS antenna are stored in this header
IXoffset	4	int32_t	X value of the lever arm, in millimeters
IYoffset	4	int32_t	Y value of the lever arm, in millimeters
IZoffset	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 28: 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.

#### 4.4.2 DMR File



All odometer data must be written into Waypoint's generic format (DMR) before it can be used within Inertial Explorer.

**Table 29: 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 <i>dmi_lrec_type</i> or <i>dmi_drec_type</i> ) 12 + 8*sDim if <i>sValueType</i> = DMI_VALUE_DOUBLE 12 + 4*sDim if <i>sValueType</i> = DMI_VALUE_LONG Where <i>sDim</i> is number of DMI sensors
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. Max is 3, but only 1 can be used in Inertial Explorer
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 <i>sMeasType</i> == 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 <i>sMeasType</i> == 2 1 = logging velocity in metres/second 2 = logging velocity in ticks/second
dScale	8	double	DMI scale factor in metres/count or metres/second/count. Must be set if <i>sValueType</i> == 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 metres. 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 30: DMR Long Record Struct Definition**

Word	Size	Type	Definition
sSync	2	int16_t	Sync byte, 0xFFEE

Word	Size	Type	Definition
sWeek	2	int16_t	GPS week number, set to -1 if unknown
dTime	8	double	GPS seconds into week
lValue	12	uint32_t[3]	Values for each DMI sensor as integers. Only use lValue[0] for Inertial Explorer

**Table 31: 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	24	double[3]	Values for each DMI sensor as double precision. Only use dValue[0] for Inertial Explorer

#### 4.4.3 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 32: 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 33: HMR Record Struct Definition**

Word	Size	Type	Definition
dGpsTime	8	double	GPS seconds of week
sGpsWeek	2	int16_t	GPS week
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

Word	Size	Type	Definition
fPitch	4	float	Pitch between the two antennas in decimal degrees. Only use if <i>ucType == 2</i>
fPitchStdDev	4	float	Standard deviation of the pitch in decimal degrees, 0.0 if not known

#### 4.4.4 MMR File

Gyro-stabilized mount data must be written to Waypoint's MMR format before it can be applied within Inertial Explorer.

Table 34: 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 35: 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

#### 4.4.5 PVA File

Both PVA input and output data share the same binary file format. The PVA format has the following three records defined:

- **pva\_hdr\_type**

Contains header information including coordinate frames/systems, version information, datum and position/orientation offsets.

- **pva\_inprec\_type**

Contains the input data including precise time (TOW + week number), position & velocity in ECEF or Geographic of IMU, GNSS antenna or external sensor (where offsets are required). In addition, attitude can be specified in RPH. WPK is defined but not currently implemented. Using the *uUpdate* flag, each record may contain any combination of position, velocity and attitude. In addition to PVA values, standard deviation (SD) values are also specified while cross-correlation terms are also handled if they are available.

- **pva\_outrec\_type**

Contains the processed results and is only present in the output from Inertial Explorer. It contains pre- and post-filter residuals, solution SDs and measurement SDs. Position and velocity output is currently always ECEF, which is how the Kalman filter handles them, while attitude is RPY.

An input [.PVA] file will have the following records:

- [pva\_hdr\_type]
- [pva\_inprec\_type]
- [pva\_inprec\_type]
- :

An output [.DTPVA] file (where D=(f)orward or (r)everse, and T=(t)ightly coupled, (l)oosely coupled), while PPP-TC is currently not implemented or defined). Each output file contains the following records:

- [pva\_hdr\_type]
- [pva\_inprec\_type]
- [pva\_outrec\_type]
- [pva\_inprec\_type]
- [pva\_outrec\_type]
- :

For each input, there will be one input + one output record. Note that an output file cannot be used for input, and *pva\_outrec\_type* structure is not described here.

#### 4.4.5.1 PVA Binary Records

This section describes the binary structures used by PVA input.

**Table 36: Binary Header Structure (pva\_hdr\_type)**

Variable Name	Type	Description
szHdr[12]	char	Must be "\$PVABIN\r\n\0"
usFileVersion	uint16_t	Currently 1
usHdrSize	uint16_t	Size of this header (bytes), normally 2048 bytes
usFileType	uint16_t	File type, input, output, see <i>pva_fileio_t</i> , INPUT=1, OUTPUT=10
usVersion[3]	uint16_t	Version numbers of creating program [major, minor, build]
szProgramName[32]	char	Name of program that created file
ulNumRec	uint32_t	Number of records (0 if not known, i.e. scan)
usRecSize	uint16_t	Size of each record in bytes
usReserved1	uint16_t	Reserved
Data info (must be filled in and passed to create)		

Variable Name	Type	Description
ulDefaultUpdType	uint32_t	Unless otherwise specified, updates will include the following: see PVA_UPDATE_???, see <i>Table 37: List of UPDATE Bit Definitions</i> on the next page.
usPosSys	uint16_t	Position coordinate system, see enum <i>pva_possys_t</i> , ECEF=1 GEOGRAPHIC=0 ENU=2* BODY=3*
usPosLoc	uint16_t	Position reference location, see enum <i>pva_posloc_t</i> , IMU=0, GNSSANT=1, SENSOR1=10
usAttSys	uint16_t	Coordinate system for attitude data, see enum <i>pva_attsys_t</i> , RPH=0, WPK=1, BTE=2. <b>Note:</b> Only RPH is currently supported.
usAttAlign	uint16_t	Axes alignment for attitude, see <i>pva_attalign_t</i> , IMU=0, SENS1=10, Currently not used, use PVA_BS_??? commands for sensor orientated data.
usOffsetAvail	uint16_t	1-offset available
usReserved2[5]	uint16_t	Reserved
Data info, datum (optional)		
szDatum[32]	char	Name of datum used. Blank OR "NONE" if not known. Currently, no datum transformation is applied in the software, meaning this parameter is ignored.
szConversion[128]	char	Name of datum conversion, Blank or "AUTO" for auto selection. <b>Note:</b> datum conversion is ignored inFileVersion 1
Offset information (40 bytes each, currently on only 1 block)		

Variable Name	Type	Description
fLevBodyX	float	Lever arms values (IMU body axis, m)
fLevBodyY		See also <i>PVA_LEVER</i> command for applying offsets during processing
fLevBodyZ		
usReserved[2]	uint16_t	Reserved
dBSAtt[3]	double	Boresight attitudes, must match attitude input, currently not used, use <i>PVA_BS_INIT</i> command.
usReserved3[1780]	uint16_t	Reserved

\* Only used in conjunction with relative updates

**Table 37: List of UPDATE Bit Definitions**

Name	Hex Value	Description
PVA_UPDATE_NONE	0	No update
PVA_UPDATE_POS	1	Position update to be used and/or available
PVA_UPDATE_VEL	2	Velocity update to be used and/or available
PVA_UPDATE_ATT	4	Attitude update to be used and/or available
PVA_UPDATE_RELATIVE	8	Relative update*
PVA_UPDATE_IGNORE	100	Skip this record
PVA_UPDATE_REJPRE	200	Rejected by pre-filter test
PVA_UPDATE_REJPST	400	Rejected by post-filter test
PVA_UPDATE_TEST	800	Residuals computed (Not used in filter)
PVA_UPDATE_BSVALID	1000	Boresight values are valid in output
PVA_UPDATE_USECMD	10000000	Override record value with passed value
PVA_UPDATE_USEHDR	20000000	Use value from file header
PVA_UPDATE_USEREC	40000000	Use value from each record
PVA_UPDATE_INVALID	80000000	Invalid input or update value (error code)

**Table 38: Input data record (pva\_inp\_type)**

Name	Type	Description
dUpdateTime	double	TOW of end of update (s)
dRelStartTime	double	Relative updates only, TOW of start (s), used in rel. only *
usUpdateWeek	uint16_t	GPS week number of UpdateTime
usRelStartWeek	uint16_t	Week number (start, relative only) *
uUpdate	uint32_t	Update flags type, see <i>Table 37: List of UPDATE Bit Definitions</i> above

Name	Type	Description
szID[16]	char	Optional event 'ID', 15 characters maximum, NULL terminated string
usCheck	uint16_t	Must be 0xC0DE, used as internal check for file validity
usReserved2[3]	uint16_t	Reserved
dPos[3]	double	GEO or ECEF value (lat,lon,hgt or x,y,z) [deg/m]
dAtt[3]	double	Attitude angles RPH, WPK, ECF [deg]. <b>Note:</b> Heading and not Yaw, converted to Yaw internally. Currently, only RPH is supported
fVel[3]	float	Velocity (LL or ECF), (e,n,h) or (x,y,z) [m/s]
fPosSD[3]	float	SD values for position, geo(e,n,u)/ecef(x,y,z) (m), as defined by usPosSys in header
fAttSD[3]	float	SD values for attitude, (r,p,h), (w,p,k), or (tx,ty,tz) (deg), as defined by usAttSys in header
fVelSD[3]	float	SD values velocity (e,n,u) for LL or (x,y,z) for ECEF, as defined by usPosSys in header
Off-diagonal correlation coefficients. These are correlation coefficients, defined as: $cc = cov[i][j] / (sd_i * sd_j)$ scale to a signed 16-bit integer using the scale factor 65536.0. $cc\_int = (int) cc\_float * 65536.0$		
sCCUpperDiag[36]	int16_t	[pxpy pxpz pxvx pxvy pxvz pxax pxay pxaz] (-1 to 1 after scaling) [pypyz pyvx pyvy pyvz pyax pyay pyaz] [pzvx pzvy pzvz pzax pzay pzaz]
ucReserved3[16]	unsigned char	32 bytes reserved

## 4.5 Inertial Explorer Output Files

This section discusses the different output files that are created when processing with Inertial Explorer.

### 4.5.1 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.

### 4.5.2 FL(S)/RL(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 binary struct definitions that define these files please contact

[support@novatel.com](mailto:support@novatel.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 90 for more details.

## APPENDIX A Output Variables

**Table 39: 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 $\diamond$ 2)	Angle between true north and the baseline made between FROM and TO stations
Azimuth (2 $\diamond$ 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
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 <sup>2</sup>
East, North, Height Fwd/Rev Separations	Separations between the forward and reverse solution in the east, north and height axes

Variable	Description
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.
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

Variable	Description
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
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.

Variable	Description
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, Rellono, CaOnly, SingPoint. In GrafNet, FixedSoln, FloatSoln.
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.

Variable	Description
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.
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.

# Glossary

## B

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### 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

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### 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

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### 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

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### 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

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### 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

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### **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.