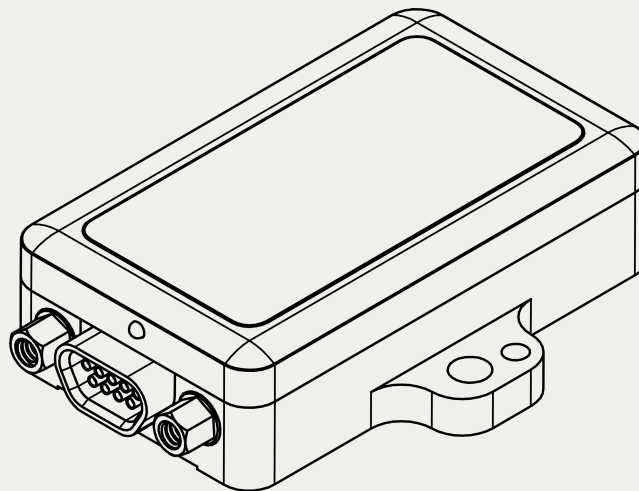


Inertial Sensor Utils Software 1.0

Inertial Sensor Data Processing and Analysis Tools





MicroStrain® Sensing Systems
459 Hurricane Lane
Suite 102
Williston, VT 05495
United States of America

Phone: 802-862-6629

www.microstrain.com
sensing_support@LORD.com
sensing_sales@LORD.com

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1. Overview

1.1 Objectives of Inertial Sensor Utils Software:

1. Parse binary log files from either LORD Sensing MIP inertial sensors or Novatel devices into csv files and/or upload to the LORD Sensing SensorCloud™ software platform.
2. Load such csv files or other csv files* that have GPS Week/Time-of-Week (TOW) columns, or download sensor data from SensorCloud™, and create:
 - Overlay plot of column(s) of data as a function of TOW/Relative Time/UNIX Timestamp** from a single csv file or sensor, or
 - Overlay plot of a column of data as a function of TOW/Relative Time/UNIX Timestamp** from two or more csv files or sensors
 - A “diff plot” of differences between a specific column in 2 csv files or sensors, or
 - A list of LORD EKF flags from (0x82, 0x10) message that turned on at least once during the run (this applies only when csv files are loaded)
 - Overlay plot of LORD EKF flags from (0x82, 0x10) message on a specific column of data (this is available only when csv files are loaded)
 - Lat-lon plots:
 - either stand-alone from a single csv file/sensor, or
 - overlay plot of lat-lon from 2 or more csv files or sensors, or
 - “diff plot” between lat-lon (in meters) as a function of TOW/Relative Time/UNIX Timestamp**
3. Upload csv files (obtained by parsing earlier, or “other csv files”*) to SensorCloud™
4. Compare 2 sensors even if one of them does not have a GPS Timestamp but contains only time from start of log as “TOW” (such as: 3DM-GX5-25 with no GPS)

5. Perform following actions on SensorCloud™:
 - Add new sensor with channel data, or
 - Add new channel data to an existing sensor, or
 - Append to existing channel data of existing sensor or
 - Delete existing sensor(s) on SensorCloud™
6. Upload up to 5 binary and/or csv files as a batch to SensorCloud™
7. Export plots to Word or PowerPoint

1.2 Notes

The utility automatically converts LORD Sensing device values to appropriate units when plotting. For example, all radian values are converted to degrees. For this, it uses the LORD Sensing MIP™ Data Communications Protocol to determine which columns are in radians. Similarly, values in 'g' are converted to m/s^2 .

* Rules for "other csv files":

1. Must have a column with text "tow" or "time" (case-insensitive) which will be considered as "GPS TOW". This column can contain GPS TOW or just time from start of recording. If uploading to SensorCloud™ or doing overlay/diff plot with Relative Time unchecked, must also have a column with text "week" (case-insensitive), which will be considered as "GPS Week".
2. Each row in the csv must have a value in these 2 columns. Other columns can have empty cells.
3. The csv files can have any number of comment lines in the beginning, but must have a line that has the text "DATA_START" (all by itself on that row) immediately preceding the line that has the column headers.
4. The column headers must all appear in a single row in the csv and cannot spread over 2 or more lines.

5. The values of columns in these “other csv files” will not be converted automatically because they can contain any text in the column headers. So the user is responsible for supplying data in the converted units that the LORD Sensing device data would be (such as degrees for Pitch/Roll/Yaw).
6. If the device does not have GPS, the GPS Week column could be 0 and GPS TOW could contain time from start of logging. The user cannot upload such csv files to SensorCloud™, but can still load those csv files and create overlay and diff plots. So the plotting feature of the utility can be used for any time-based csv file, not necessarily an inertial sensor.

**** UNIX Timestamp**

This option is available only when downloading sensor data from SensorCloud™ and not when loading plain csv files.

This User Manual assumes familiarity with LORD Sensing inertial sensors, the DCP (Data Communication Protocols) that go with them and use of MIP™ Monitor software to collect binary log files.

No Warranty

THIS PROGRAM IS DISTRIBUTED "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND PERFORMANCE OF THE PROGRAM IS WITH THE USER. SHOULD THE PROGRAM PROVE DEFECTIVE, THE USER IS RESPONSIBLE FOR THE COST OF ALL NECESSARY SERVICING, REPAIR OR CORRECTION.

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2. Installation

1. Save the InertialSensorUtils_GUI_exe.zip into a folder of your choice.
2. Extract all files from the zip file.
3. Double-click the QInertialSensorUtils_GUI.exe to launch the program.
4. Proceed to the User Manual for step-by-step instructions.

2.1 Settings File

MIP™ Monitor software allows the user to export the inertial sensor's settings into a Settings File. This file captures the configuration of a LORD Sensing inertial sensor that was used when collecting a specific log file. It is therefore required by LORD Sensing support to perform analysis of data set(s) sent by the customer.

2.2 Time Stamp

- When parsing MIP™ binary files, the user must select the “GPS Timestamp” message in each category of inertial data inside MIP Monitor, i.e., Estimation Filter, GNSS, and IMU-AHRS. Otherwise the utility will display an error stating: “GPS Timestamp required in each message format” and the binary file will not be parsed.
- In addition, the output frequency of the GPS Timestamp message must be the highest amongst all messages in that category. In other words, the other messages in each category can have same output frequency as the GPS Timestamp message but not more.
- If a LORD Sensing device does not have GPS (such as: 3DM®-GX5-15, 3DM®-GX5-25), the GPS Week will be zero inside the GPS Timestamp message; that is acceptable and will be parsed as such. However even for such devices, the user must still select the GPS Timestamp message in each category of the MIP™ Monitor Message Format.
- If a csv file is being loaded for plotting, it must have a column header with the text “tow” or “time” (case-insensitive). This will be mapped to “GPS Time of Week (TOW)”. This requirement is automatically met if the csv file is obtained by parsing the binary log file from this utility. The column can contain real GPS Time-of-Week, or just time from start of logging. The “GPS Week” column is optional if using the Relative Time checkbox with the “Self” radio-button, or “1 plot (tab) per column” button or “Flags Overlay Subplot” button. If the user desires the GPS Week column, then the column header must contain the text “week” (case-insensitive) and that column will then be considered as the “GPS Week” column.

2.3 Help/User Manual

The User Manual can either be accessed using the User Manual link inside the device spec on the web-site, or via the '?' Icon in the Main tab of this utility.

2.4 Use of data-loggers instead of MIP™ Monitor

The Inertial Sensor Utils Software can parse binary log files recorded from LORD Sensing inertial sensors using either MIP™ Monitor software or a third-party data-logger. The binary file format is simply the serial stream from the device written directly into a .bin file.

2.5 CSV logging in MIP™ Monitor vs Parsing Binary log in Inertial Sensor Utils

Currently one can record output of LORD Sensing inertial sensors in either binary or csv format using MIP™ Monitor. The csv files obtained from MIP™ Monitor have some issues that still need to be resolved. At this time, it is recommended that the user get the binary log file from MIP™ Monitor and parse into csv using Inertial Sensor Utils.

2.6 System Requirements

The software requires a 64-bit Windows machine [may or may not have Python or PyQt already installed].

Note that no new modules are “installed” nor are any existing software modules touched or modified when the user unzips the distribution zip file. So Python 2.7.6 is included as part of that zip, but isn't really “installed” on the user's PC in a technical sense. Same thing with PyQt4. Whatever files are required by the software are included in sub-folders that go with the zip. Because of that, the target PC may or may not have Python or PyQt4 installed on it, or may have a later or older version of Python/PyQt4 installed, and the software would still use the required files from sub-folders included in the zip.

3. Logging In (with SensorCloud option unchecked -- default)

When the user double-clicks on QInertialSensorUtils_GUI.exe, it opens a window that looks like this:

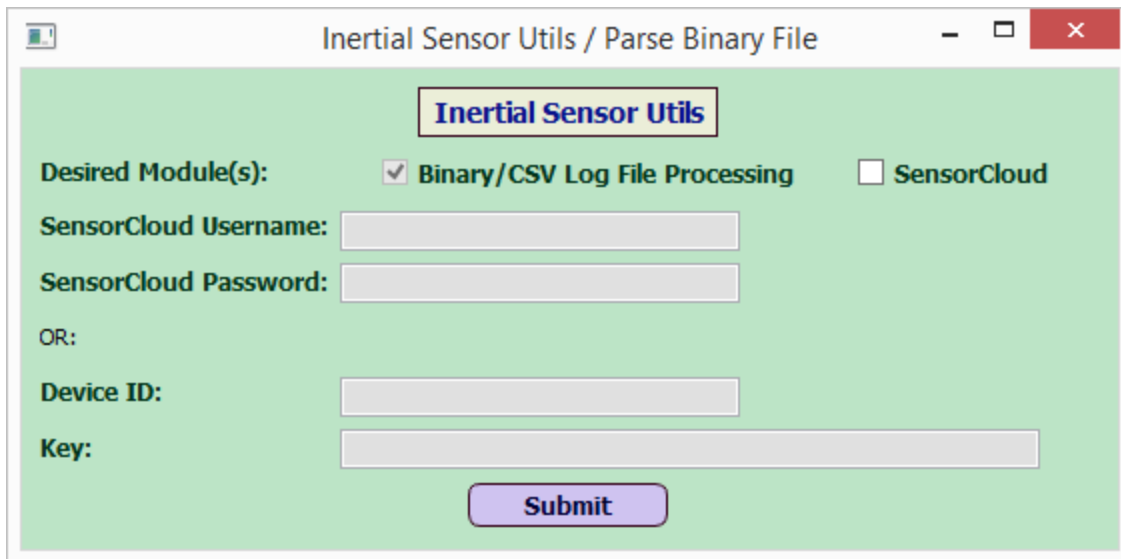


Figure 1 -Log In Window Without SensorCloud™

By default, the 'SensorCloud' box is unchecked. However the Binary/CSV Log File Processing check-box is always checked. If the 'SensorCloud' box is unchecked and the user clicks the Submit button, it would open a window that looks like this:

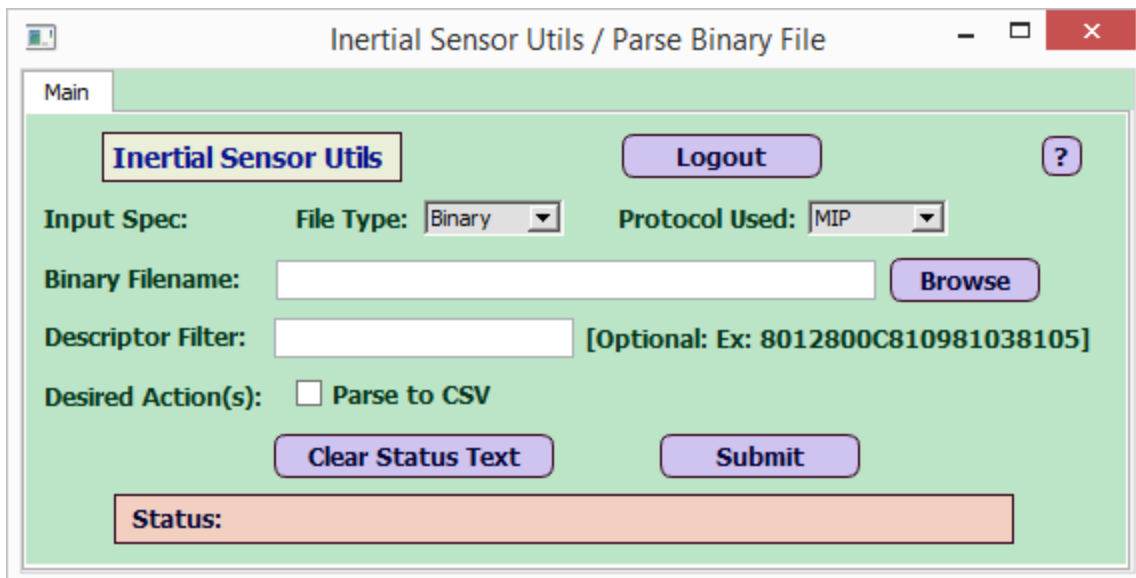


Figure 2 -View After Selecting Submit

Note that this shows only a single tab called 'Main'. The 'File Type' drop-down shows two options: Binary and CSV. With 'File Type' of Binary, the Desired Action(s) field shows a single option that says 'Parse to CSV'. The 'Protocol Used' drop-down has two options: MIP™ (default for all LORD Sensing devices), or Novatel. The Descriptor Filter field is optional; the user can enter a string of field descriptors (example: '810981038105' to select a subset of fields to parse from the binary file.

4. Parsing Binary Log Files

If File Type is Binary, the user can check the box that says 'Parse to CSV'. The Protocol Used could be either MIP™ (for LORD Sensing devices) or Novatel. This would parse the binary log file based on the appropriate DCP (MIP™ or Novatel) and place the parsed csv files in the same folder as the binary file. The csv files would have the same name as the binary file name, with the file extension replaced with .csv.

4.1 Parsing MIP Binary Files

For MIP™ binary files, it creates three csv files from one binary:

- IMU
- GPS
- EKF

Notes:

1. Each of the 3 categories above (IMU, GPS and EKF) must have a GPS Timestamp for the parsing to work. If not, it returns an error message stating that "GPS Timestamp required in each message format".
2. Messages within each category can have different output rates (Hz). In that case, the parsed csv file would have empty cells for columns that don't have a value for a given timestamp.

4.2 Parsing Novatel Binary Files

For Novatel, it creates five csv files from one binary:

- INS
- RAWIMU
- EKF
- GPS
- Veh2BodyRotation

The messages included (currently supported by this tool) in each of these five categories are listed below. Note that Novatel can include either a 'Short Header' or a 'Long Header' for each message, with different message id for the Short Header vs the Long Header version.

Category	Message	Long/Short Header Message ID
INS	INSATT	263/319
	INSPOS	265/321
	INSSPD	266/323
	INSVEL	267/324
	INSPVA	507/508
RAWIMU	RAWIMU	268/325
EKF	BESTPOS	42
	BESTVEL	99
	BESTXYZ	241
GPS	TIME	101
Veh2BodyRotation	VEHICLEBODYROTATION	642

4.3 Descriptor Filter String

One can specify a “descriptor filter string” (such as: “810981038105”) when parsing MIP™ binary files. By doing so, only the fields specified in that string would be retrieved into the csv. This is useful when the user wants to focus on a subset of columns instead of getting every column from the binary file. The field is optional; if left empty, all columns from the binary are retrieved.

4.4 Different Hz for Individual Messages

The parsing feature can also handle the situation where individual messages are logged at different Hz within each category (for either MIP™ or Novatel). For messages that are output slower, the csv would contain empty cells when no message is available for a given timestamp.

4.5 Split Packets

Each MIP™ packet has a payload that consists of one or more field descriptor(s) along with field data. When the payload size exceeds 255 bytes, the device splits the packet into 2 or more separate “split” packets. Each split packet can handle up to 255 bytes of payload size. Note that at the current time, only the EKF category can exceed 255 bytes in size, so split packets can occur only within the EKF category.

When the user combines this feature with the ‘different Hz’ feature in EKF category (section 4.4), one could alternate between split and non-split packets, or alternate between 2 split packets and 3 split packets, during the run. This would happen if the user selects different data rates within the EKF category, such that number of the slower output messages is much more than the number of faster output messages, then the packets are not initially split but are split further down when the slower

messages start appearing. The binary file parser in this tool pieces the split packets together to show up as one row in the csv.

4.6 The 'SV Info' [x810C] MIP Message

The MIP™ GPS 'SV Info' [x810C] message is somewhat special and behaves a little differently than other MIP™ messages. x810C comes as a separate MIP packet with no timestamp, and can be either one or two x810C packets, depending on the number of visible SV's™. If that number is 18 or less, we have a single x810C packet, otherwise we have two contiguous x810C packets that can either follow the 'main' GPS packet or precede it (depending on the order of selecting messages in MIP™ Monitor). Since the visible SV's can change during the run, it is possible to have one x810C for certain time periods, followed by two x810C packets at other times, or even alternating between one and two x810C packets. It should work even if the GPS signal is lost and x810C packets stop coming, and then later reappear when the GPS signal is restored. The parsing feature can handle all of these cases, and would combine data from the main GPS packet and the one or two x810C packets, into a single row in the csv.

4.7 EKF Filter Status [x8210] MIP Message

If the binary file being parsed contains the EKF Filter Status [x8210] message, the tool determines 17 different flags from the individual bits of EKF x8210 message based on the DCP. The 17 flags that get parsed into the csv file, and display on the 'CSV Data' tab and how they map to the ones in the DCP is shown in the table below:

Bit Position	Hex Value	DCP Flag Description	Parsed CSV Column Header/ 'CSV Data' tab Flag Display
0	0x0001	IMU unavailable	Flag_IMU_Unavailable [x8210]
1	0x0002	GNSS unavailable	Flag_GPS_Unavailable [x8210]
3	0x0008	Matrix singularity in calculation	Flag_Matrix_Singularity [x8210]
4	0x0010	Position covariance high warning	Flag_Pos_Cov_High [x8210]
5	0x0020	Velocity covariance high warning	Flag_Vel_Cov_High [x8210]
6	0x0040	Attitude covariance high warning	Flag_Att_Cov_High [x8210]
7	0x0080	NAN in solution	Flag_NaN_in_Soln [x8210]
8	0x0100	Gyro bias estimate high warning	Flag_Gyro_Bias_Est_High [x8210]
9	0x0200	Accel bias estimate high warning	Flag_Accel_Bias_Est_High [x8210]
10	0x0400	Gyro scale factor estimate high warning	Flag_Gyro_SF_Est_High [x8210]
11	0x0800	Accel scale factor estimate high warning	Flag_Accel_SF_Est_High [x8210]
12	0x1000 [Filter State: Initialization]	Attitude not initialized	Flag_Att_Uninitialized [x8210]
13	0x2000 [Filter State: Initialization]	Position & Velocity not initialized	Flag_Pos_Vel_Uninitialized [x8210]
12	0x1000 [Filter State: Running]	Mag bias estimate high warning	Flag_Mag_Bias_Est_High [x8210]
13	0x2000 [Filter State: Running]	GNSS antenna offset correction estimate high warning	Flag_GPS_Ant_Off_Corr_Est_High [x8210]
14	0x4000	Hard Iron offset estimate high warning	Flag_Mag_Hard_Iron_Est_High [x8210]
15	0x8000	Soft iron correction estimate high warning	Flag_Mag_Soft_Iron_Est_High [x8210]

5. Loading and Plotting CSV Files

5.1 CSV Object Name

When the user changes the 'File Type' drop-down to 'csv', the descriptor filter string label automatically changes to 'CSV Object Name'. This name is used to identify an "object" that shows up in the 'CSV Data' tab when a csv file is loaded. So one "CSV Object Name" would represent one .csv file that is loaded. The field is optional; if it is left blank, the csv file name is used to identify the content when plotting.

With 'File Type' of 'csv', the Desired Action(s) field shows a different set of options:

- a. Load CSV
- b. Create KML/GPX
- c. IMR

The screenshot shows a software window titled "Inertial Sensor Utils / Parse Binary File". Inside, there's a "Main" tab. At the top left is a logo "Inertial Sensor Utils" and a "Logout" button. Below these are input fields: "Input Spec:" (empty), "File Type:" (dropdown menu showing "CSV"), and "Protocol Used:" (dropdown menu showing "MIP"). Below these are "CSV Filename:" (text input) and "CSV Object Name:" (text input) with a "Browse" button next to the filename field. A note next to the object name field says "[Optional: Defaults to CSV File name]". Below these are checkboxes for "Desired Action(s)": "Load CSV", "Create KML/GPX", and "IMR". There are also three small input boxes for "LLH Cols:". At the bottom are "Clear Status Text" and "Submit" buttons. A "Status:" label is at the bottom left of a large orange box.

Figure 3 -CSV File Options

5.2 "KML/GPX" File Generating Feature

If File Type is csv, the user can check a box that says 'Create KML/GPX', and it enables 3 more fields, for specifying the LLH columns in the csv file (default to 4,5,6 respectively). The user can change the numbers in those 3 fields, to specify the exact column numbers for Lat, Lon and Height that apply for the csv file being loaded. Checking this box would create a ".kml" and a ".gpx" file in the same folder as the input csv file, with a file name same as the csv file name (with the .csv extension replaced with .kml and .gpx for the 2 new files generated per csv).

5.3 'IMR' Check-box

The 'IMR' check-box creates a .imr file from a MIP™ IMU csv file that has deltaTheta, deltaV columns, for use in Novatel's Inertial Explorer post-processing software. Note that the deltaTheta/ deltaV values in the .imr are in LORD IMU frame in units of arcsec and micrometer/s respectively. The user is expected to use this file in Inertial Explorer's File -> Convert -> Raw IMU Data to Waypoint Generic (IMR) menu option, while also creating a new IMU Profile that specifies the Gyro/Accel Scale Factors [360000 arcsec/deg and 1000000 micrometer/m respectively] and exact orientation of LORD IMU frame axes [X-Forward, Y-Right, Z-Down]. The user would then use the converted Waypoint IMR file as IMU input to the Inertial Explorer project. The user would also require a new LORD INS profile with LORD IMU error model created using its Settings -> Manage Profiles menu option. Finally the user would specify the Novatel Vehicle (Body) Frame to LORD IMU Rotation in the Process TC Menu option to get a blended solution.

5.4 Plotting

The user can plot from either the 'CSV Data' tab or the 'View Sensors' tab.

5.4.1 'CSV Data' Tab

When the user loads a csv file, a new tab labeled 'CSV Data' is created that displays the CSV object name with an arrow icon and a check box on its left. If the user clicks on the arrow icon, it expands the csv object to show individual columns for that object, with check-boxes on the left of each column. When the user loads a second csv file, it adds another CSV object in the 'CSV Data' tab. The user can repeat this process to keep adding several CSV objects in that tab.

Once the desired CSV objects are created, the user can generate various types of plots as follows:

A. '1 plot (tab) per column' button

This plots one column of a given CSV object vs TOW. User must select a TOW column; otherwise shows an error. Lat-lon plots are an exception to the rule: here, the user selects only Lat and Lon columns (no need for TOW or Week), then clicks the '1 plot (tab) per column' button to get a plot of lat vs lon. If multiple dependent columns are selected and the user clicks on this button, it creates 1 tab per plot (column), in other words, as many new tabs as the columns selected.

B. 'Multi-CSV Files on 1 plot' button

The user can overlay the same column from up to 5 different CSV objects using this button.

C. 'Diff plot' button

The diff plot would display a specific column's difference between 2 sensors or CSV objects.

The user must select exactly 2 sensors/CSV objects in this case, otherwise it displays an error.

Also the user cannot select more than 1 column in this case. For a diff plot, the user must select the TOW and Week columns along with the column being plotted (except when the user checks the Relative Time check-box and also selects the “Self” radio-button, described in Sec 5.4.2). This applies to lat-lon diff plots as well; the user must select TOW and Week, along with lat-lon, for each CSV object.

Note that the sensors / CSV object names are sorted alphabetically (case-sensitive), so the selected sensor or CSV object that appears above the other selected sensor or CSV object would be considered the “first” sensor (or CSV object) [“Sensor 1”], and the one that appears further down would be the “second” sensor (or CSV object) [“Sensor 2”].

The “diff” in a diff plot is defined as:

$$\text{diff} = (\text{Sensor 2 Column} - \text{Sensor 1 Column})$$

where: Sensor 2 values are interpolated at Sensor 1 TOW and the “diff” is plotted as a function of Sensor 1 TOW.

The following snap-shot shows two sensors being diff’ed. An extra character “A” was added in front of the “Novatel INS” sensor, to name it as “A Novatel INS”, to force it to become Sensor 1, since it is alphabetically ahead of the other sensor named “GX5-45 59120 EKF” which now becomes Sensor 2:

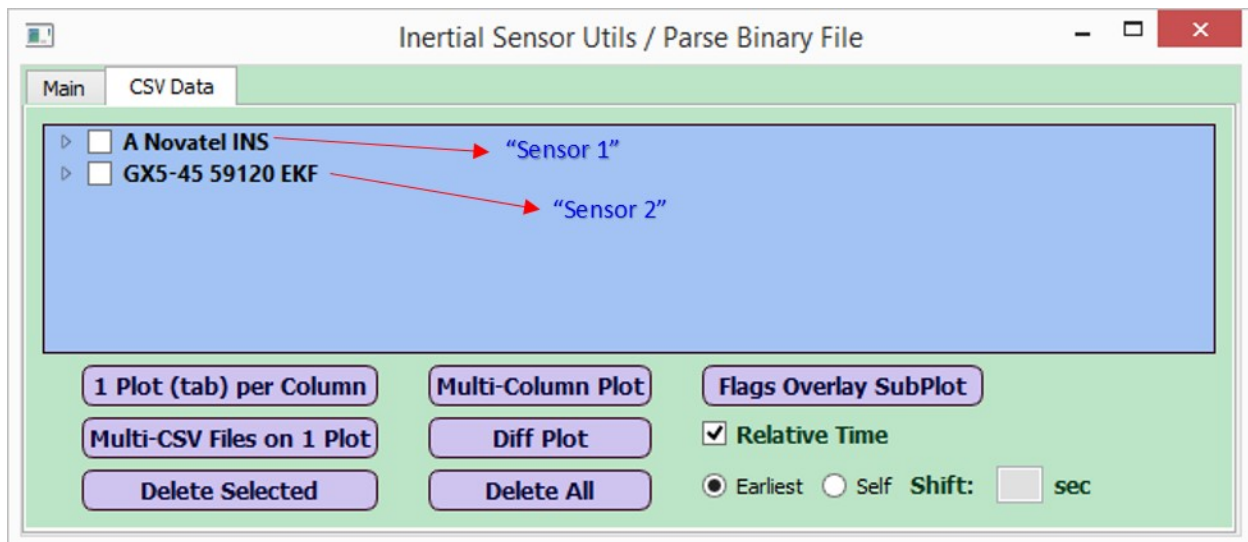


Figure 4 -Sensor Sequence for Diff Plot

The following snap-shot shows a diff plot between these two sensors for the “Pitch” column.

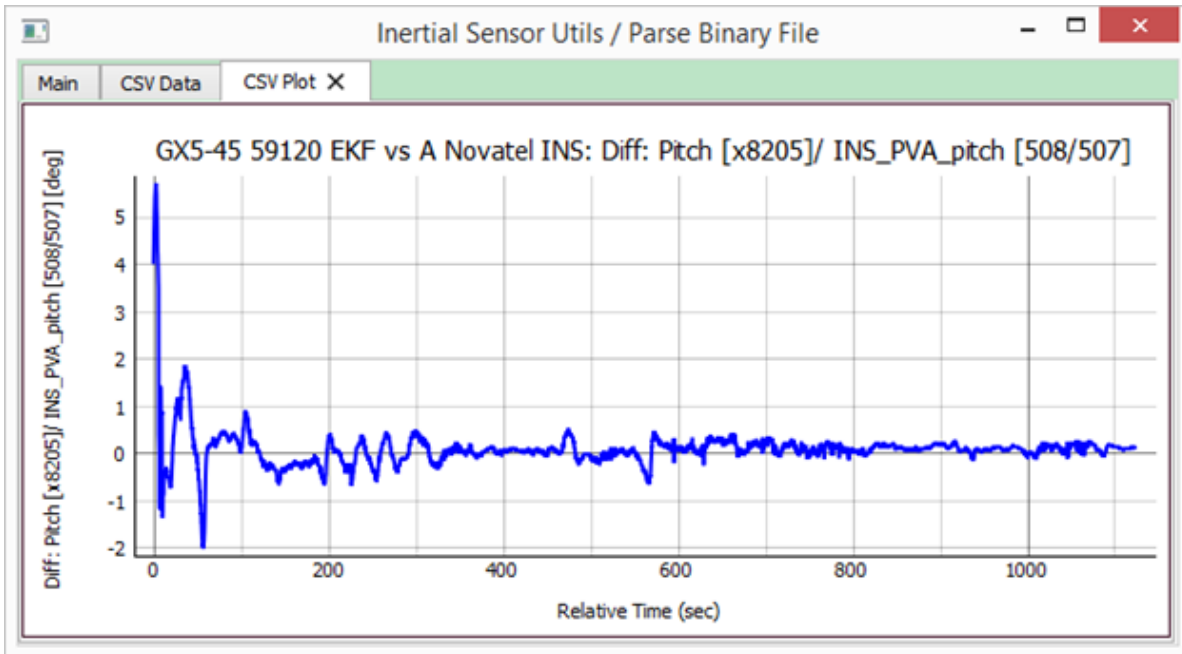


Figure 5 -Diff Plot Graph for Pitch

If the initial TOW of Sensor 2 is after the initial TOW of Sensor 1, and/or if the last TOW of Sensor 2 is before the last TOW of Sensor 1, then the tool takes only the portion of exact overlapping TOW between the 2 sensors when doing the diff plot. This is shown in the figure below:

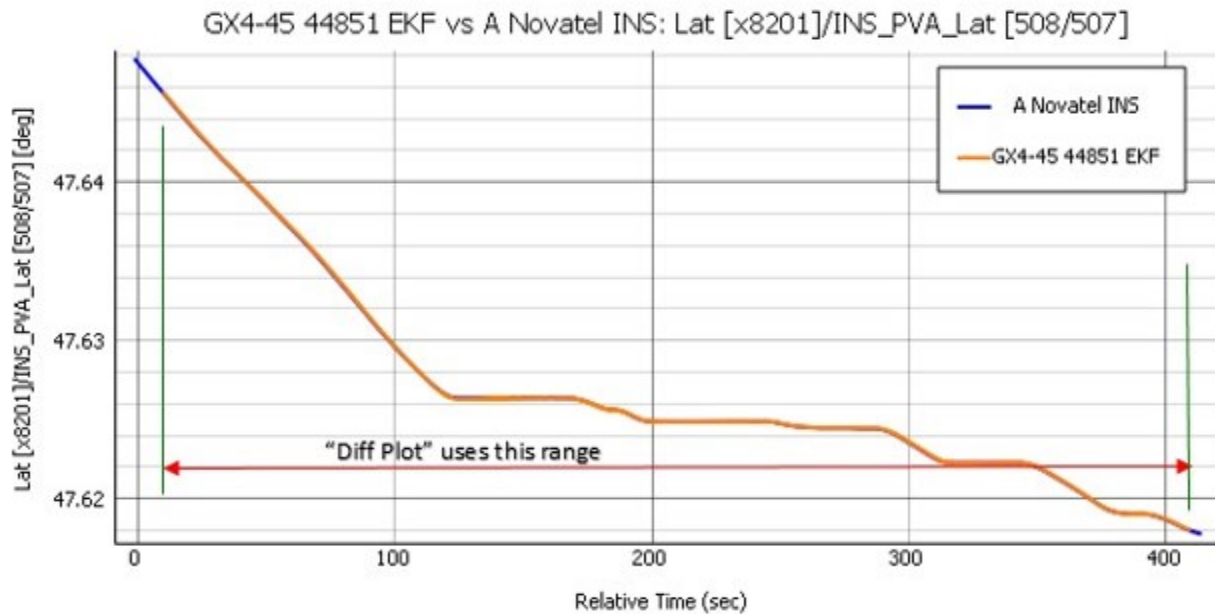


Figure 6 -Overlapping TOW Range Used in Diff Plot

If the user chooses the 'Relative Time' check-box in this situation, the relative time is computed from the first point on the overlapped TOW region.

D. 'Multi-column plot' button

Up to 5 columns from a given CSV file can be overlaid in the same plot using this button.

E. 'Flags overlay subplot' button

One can use this button to overlay up to 3 flags from the EKF x8210 "Filter Status" message, onto 1 dependent column. This includes a total of 17 flags from that field (IMU Unavailable, GPS Unavailable, Accel Bias Est High, etc.) based on the Filter Status (0x82, 0x10) field described in the DCP for the device.

The 3 flags show up as 3 sub-plots, each flag using a different color. If 2 flags are selected, it shows 2 sub-plots, and if only 1 flag is selected, it shows a single plot.

For CSV files that get loaded, the tool displays only flag(s) that turned on at least once during the run, and these show up in red color. In other words, the set of flags that show up may be different from one sensor to the other. The user then picks up to 3 flag(s) to overlay on the main column being plotted. Note that the sensors loaded from SensorCloud™ show all 17 flags, and no red color, because the data is loaded from cloud only when the user selects the flag column to plot. A sample screen with these flags showing in red color is shown below:

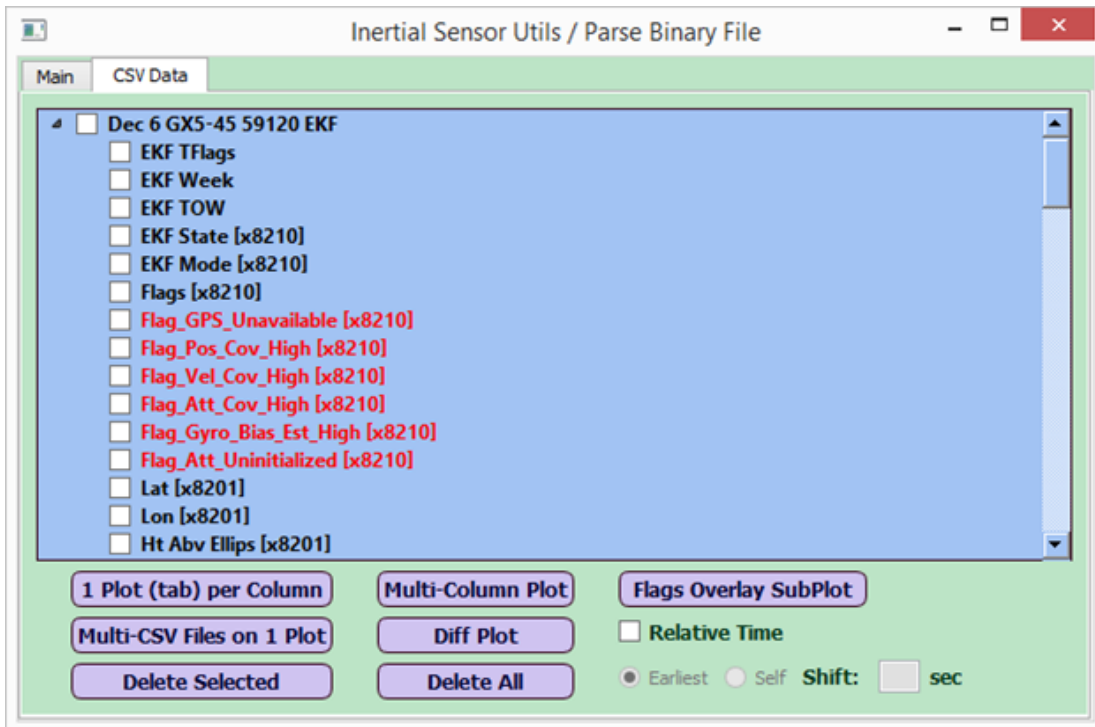


Figure 7 -EKF Status Flags that Turned ON Show in Red

A sample 'Flag overlay subplot' from this may look like this:

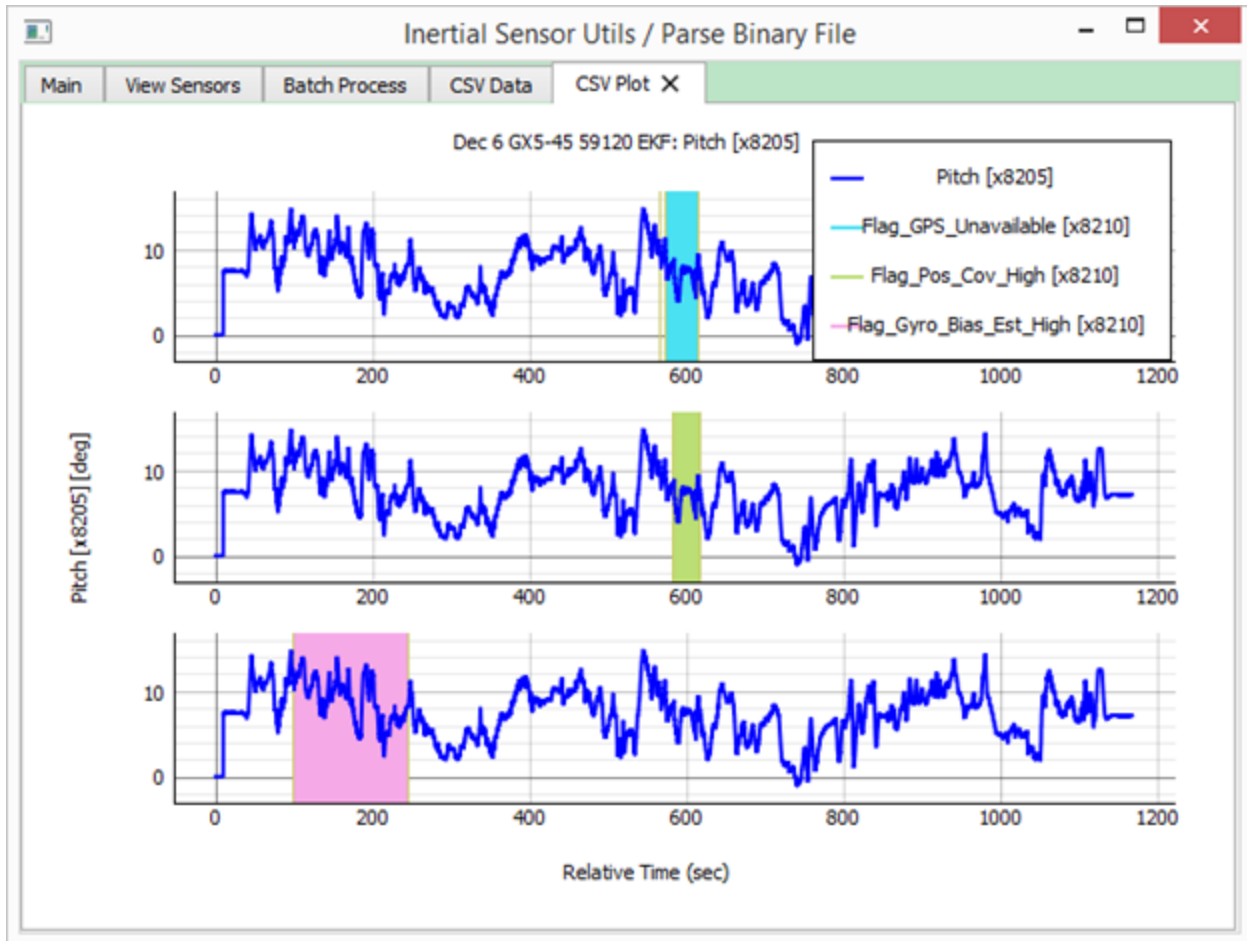


Figure 8 -Flag Overlay Subplot

5.4.2 Relative Time Check-box

It has a check-box for “Relative Time” plots; selecting that would plot in relative time from time $t = 0$ sec, by deducting the initial GPS Time of Week from all GPS TOW values on the X-axis.

This works even for a diff plot or multi-sensor plot, with some differences. In this case, the user can use an extra set of radio buttons with labels: “Earliest” (default) or “Self”:

- The “Earliest” option would use the earlier of all sensors as time = 0, so the sensors other than the one with the earliest start time would have their relative start time as a non-zero value.
- The “Self” option would deduct each sensor’s initial TOW from all TOW of that sensor. So at the end of this, each sensors’ data would start at time = 0 sec. As the user selects the “Self” radio button, it enables one more field called “Shift”, where the user can specify the number of seconds to shift the second (and subsequent) plot data, with respect to the first.

The following snap-shot shows a window with two sensor objects loaded using csv files, with the Relative Time check-box checked:

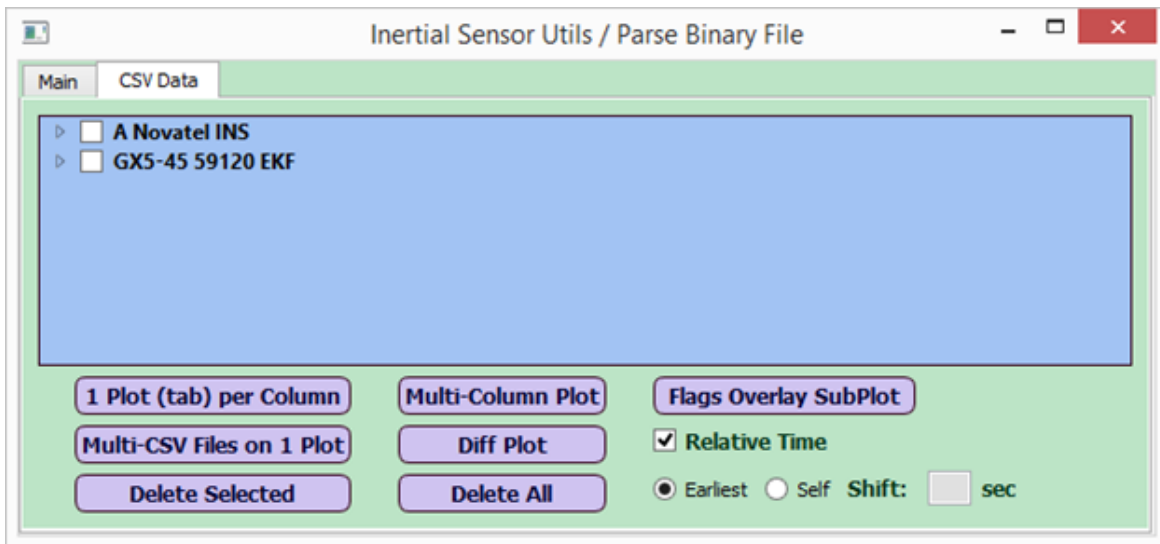


Figure 9 -Using Relative Time Option

When the “Relative Time” check-box is checked, the radio button defaults to “Earliest”. In this case, when two or more sensors (or CSV objects) are being overlaid or differenced, the earliest start TOW of the sensors (or CSV objects) is deducted from the TOW of all sensors (or CSV objects). In other words, after such deduction, the relative time of the sensor with the earliest start TOW would start from time = 0 sec, but all other sensors would have a relative start time greater than or equal to zero.

Note that when the ‘Relative Time’ check-box is checked, and the “Self” radio-button is selected, the ‘GPS Week’ column automatically becomes optional.

When the user specifies the shift value and clicks the “Multi-Sensor” (or “Multi-CSV Files in 1 Plot”) or “Diff Plot” button, it moves all values of the second and other sensors by that amount, either to the right or left, for positive and negative shift respectively. In addition, the plot now shows a new label which displays the shift value specified for that plot, so there is no ambiguity when looking at plots with different shift values.

The shift value defaults to 0.0 sec. The user can specify a positive or negative shift value with up to 2 decimal places. Note that a “Self” radio-button selection with shift of 0.0 sec is not the same as the “Earliest” option. In the former, all sensors would begin at a relative time of 0 sec, whereas in the latter, sensors other than the “Earliest” would begin at a non-zero relative time.

The “Self” radio button and the shift value combination would typically be used in situations where one or more sensors being compared uses its own clock that may be out of sync with the other sensor’s clock(s), or the other sensor(s) may be using the GPS timestamp.

The following describes an example of the “Self” radio button usage, when comparing GX5-25 device which does not have GPS and so it’s TOW (Time of week) column only represents relative time from start of recording and a Novatel sensor which does have real GPS TOW.

Select the TOW and Pitch columns from the first sensor:

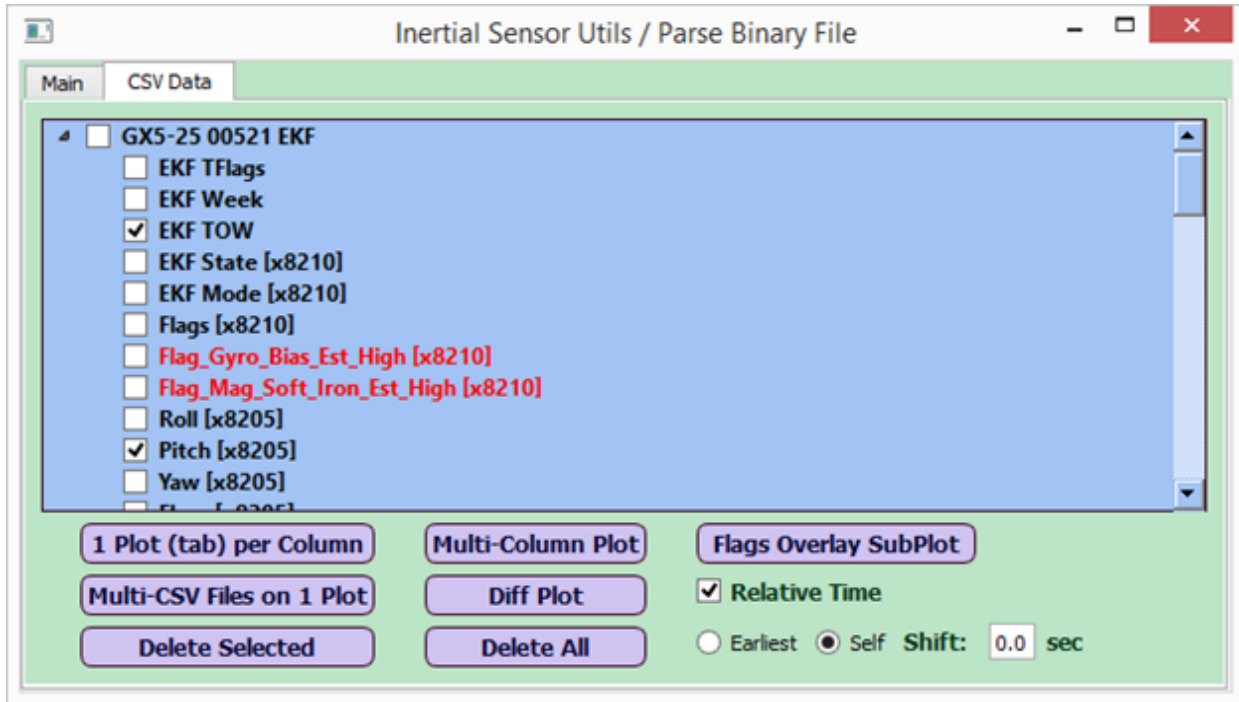


Figure 10 -Check EKF TOW and Pitch - Sensor 1

Next, select the TOW and Pitch from the second sensor:

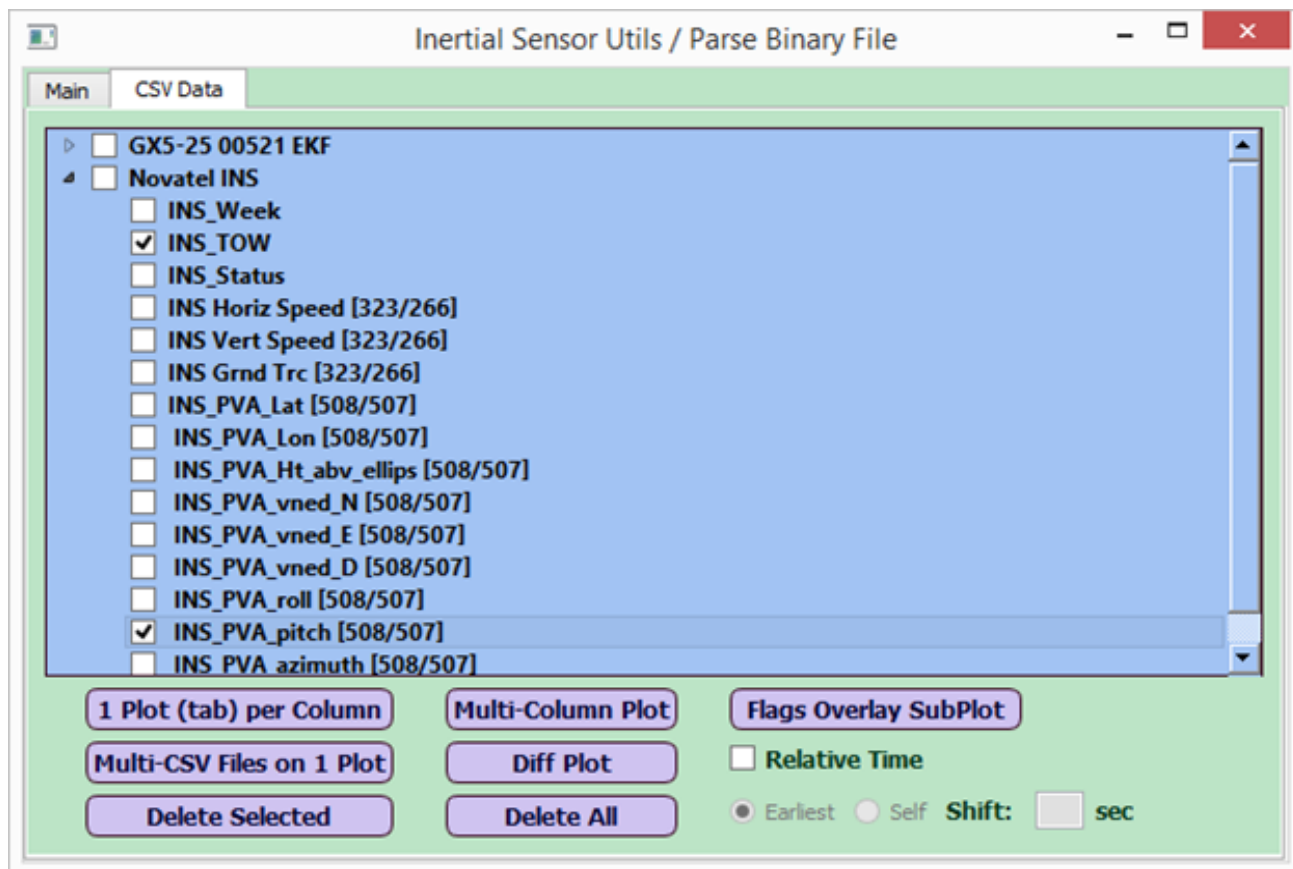


Figure 11 -Check EKF TOW and Pitch - Sensor 2

Finally, select the “Relative Time” check-box, the “Self” radio button with shift of 0.0 sec, and then “Multi-CSV Files on 1 Plot” button:

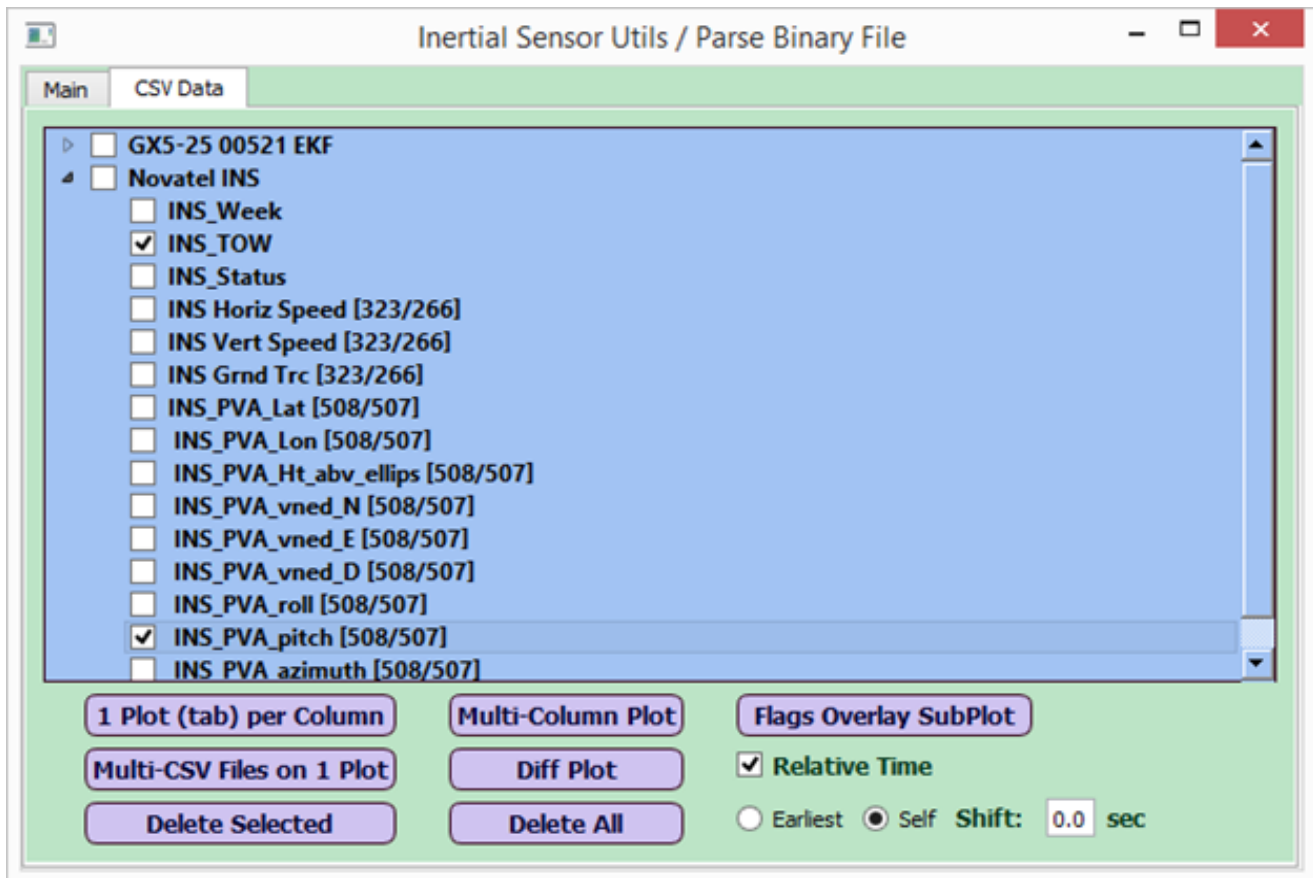


Figure 12 -Submit Self Radio Option with 0.0 Sec Shift

The plot looks like this:

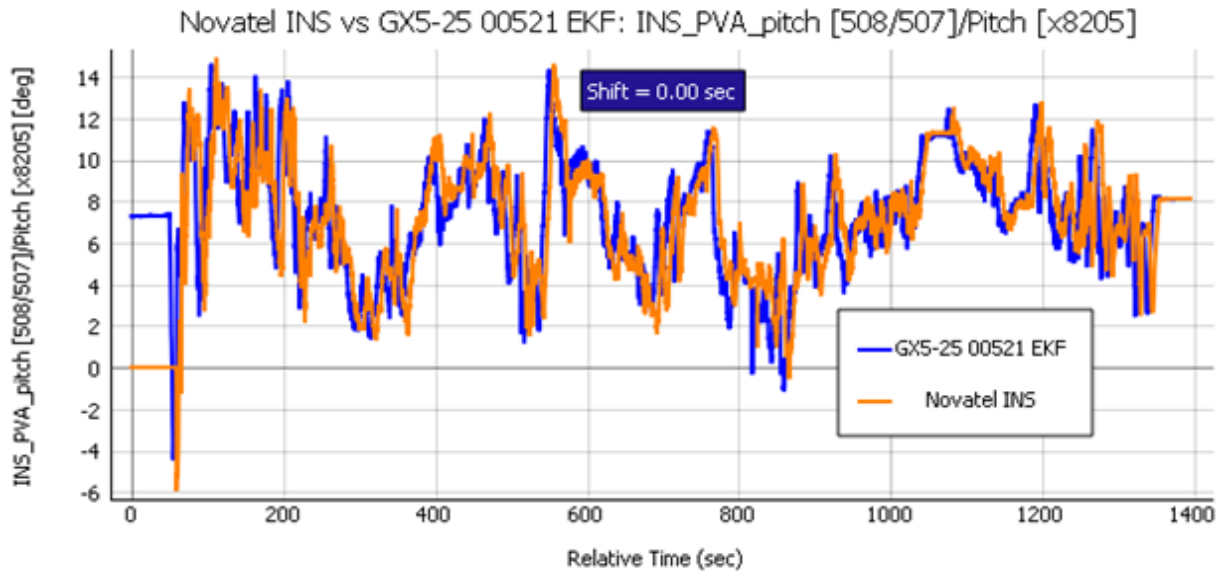


Figure 13 -Overlay Plot with 'Self' Radio and 0.0 Sec. Shift

Now the user goes back, re-selects the columns in the 2 sensors, and chooses a shift of -6.6 sec:

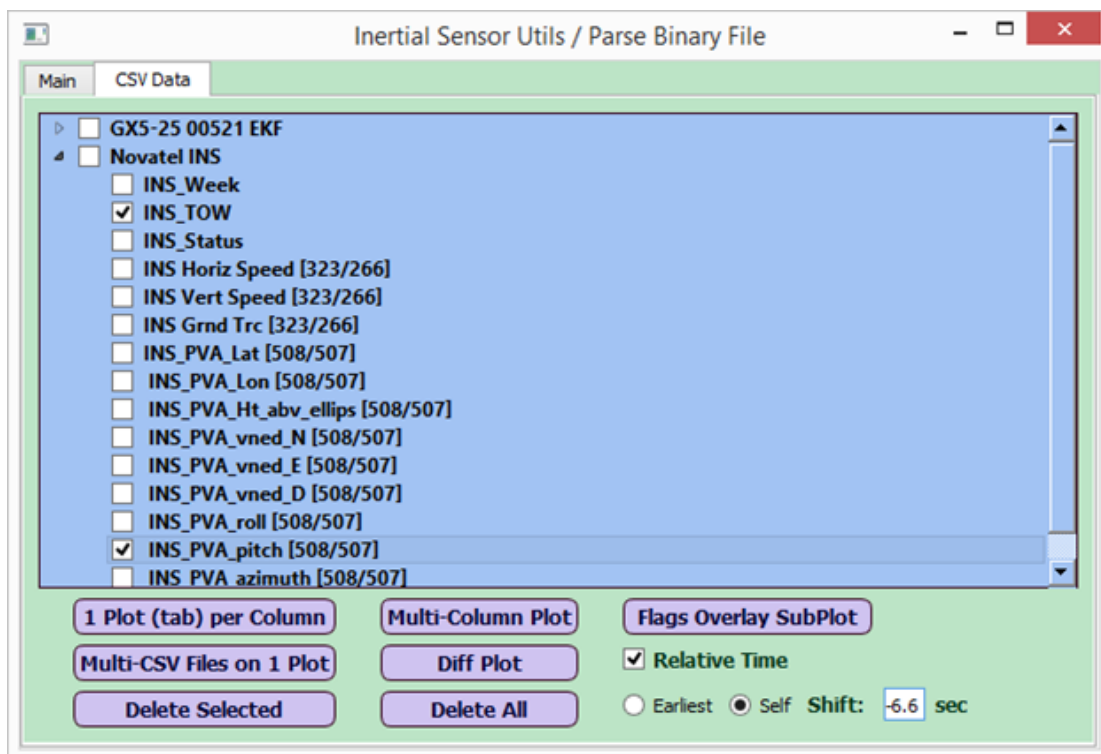


Figure 14 -Submit Self Radio Option with -6.6 Sec Shift

The plot now looks like this (note that the match is much better than before):

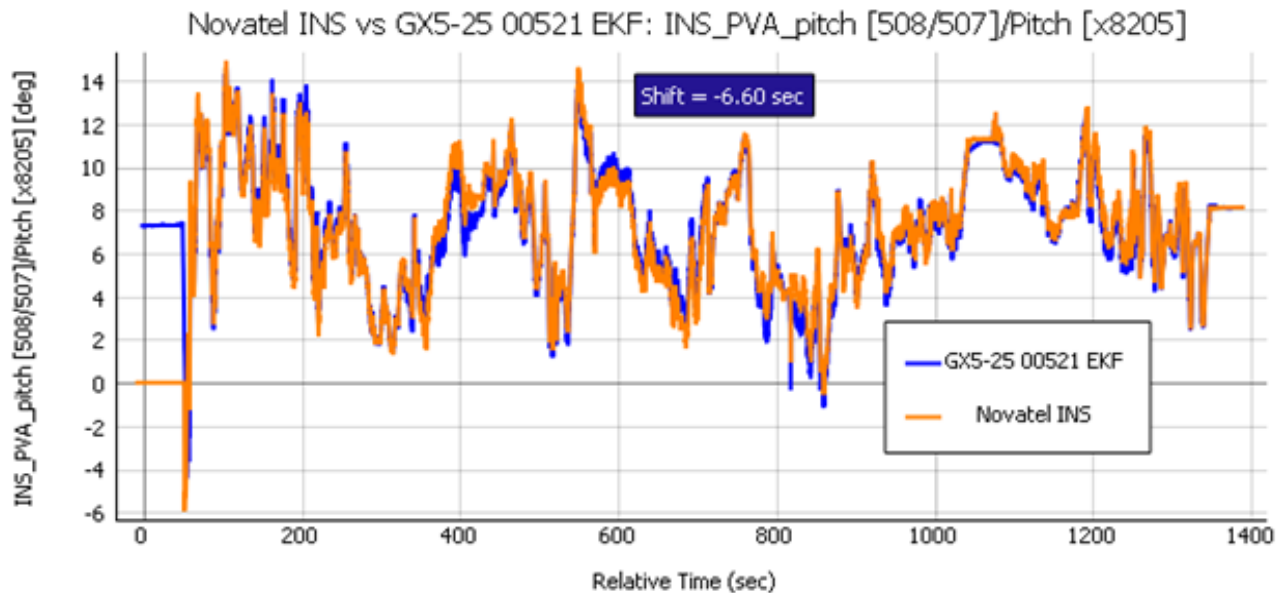


Figure 15 -Overlay Plot with 'Self' Radio and -6.6 Sec. Shift

The user is expected to zoom in on the first overlay plot to determine the approximate shift value to use for best match between the two sensors (or CSV objects) in this case.

- Note that the “Earliest” and “Self” radio buttons and the shift field value would be ignored if the user chooses a plot other than a multi-sensor or a diff plot.

5.4.3 Zooming In/Out On Plots

The tool has an option to switch between a 3-button mouse zoom (the default) or a 1-button mouse zoom. With a 3-button mouse mode, the mouse scroll wheel is used to zoom in or out of a plot. With a 1-button mouse mode, a rectangular area of the plot may be zoomed in by dragging the left mouse button. To change from 3-button to 1-button mouse mode, right-click on the plot area, choose Mouse Mode > 1 button.

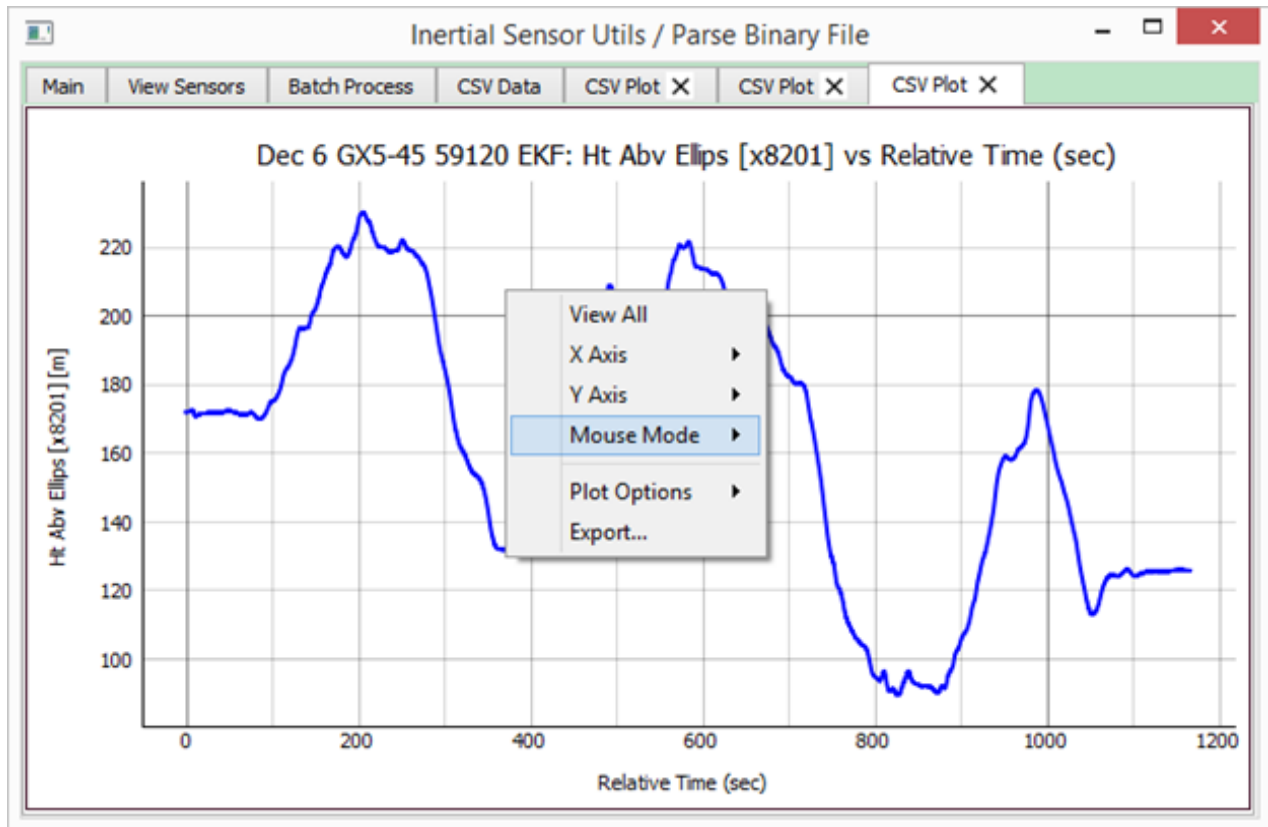


Figure 16 -Mouse Mode Options

A 1-button mouse mode zooming action is shown below:

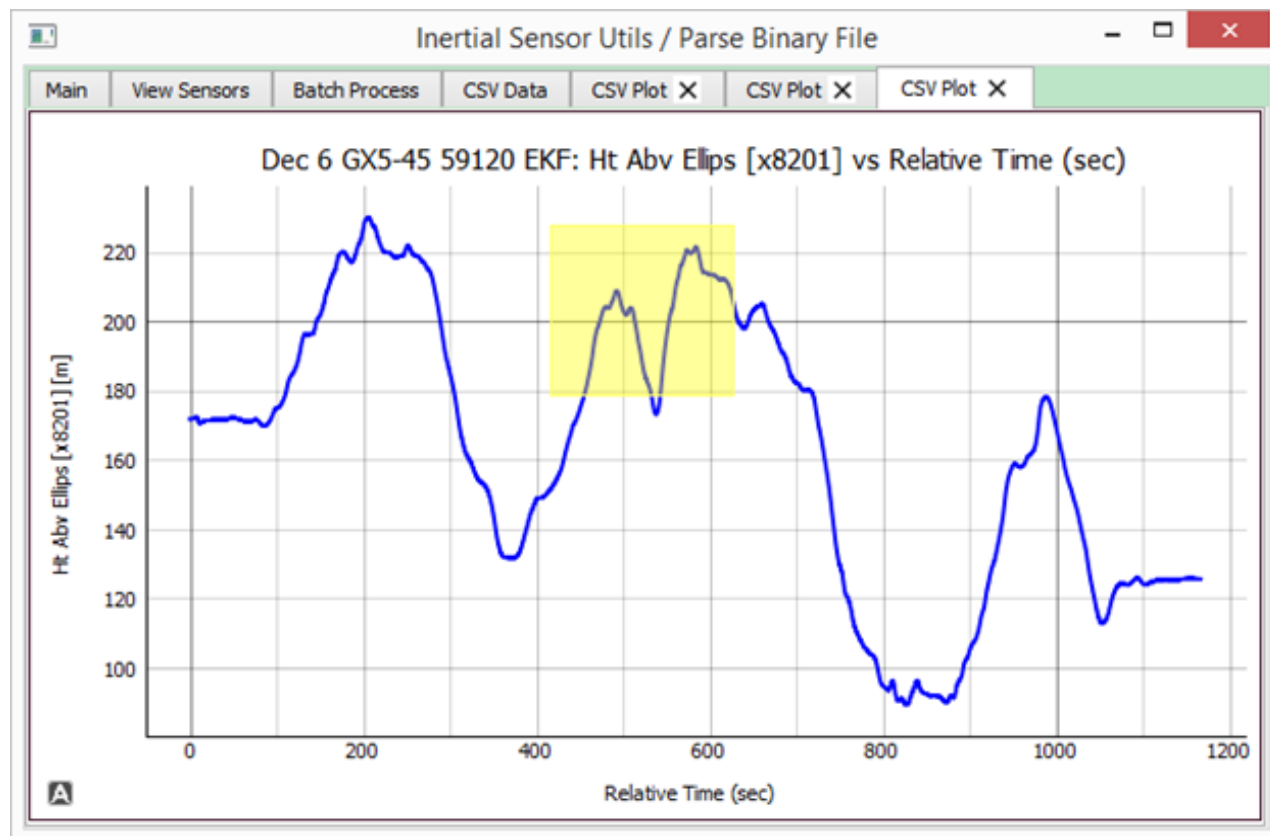


Figure 17 -1-Button Mouse Zoom

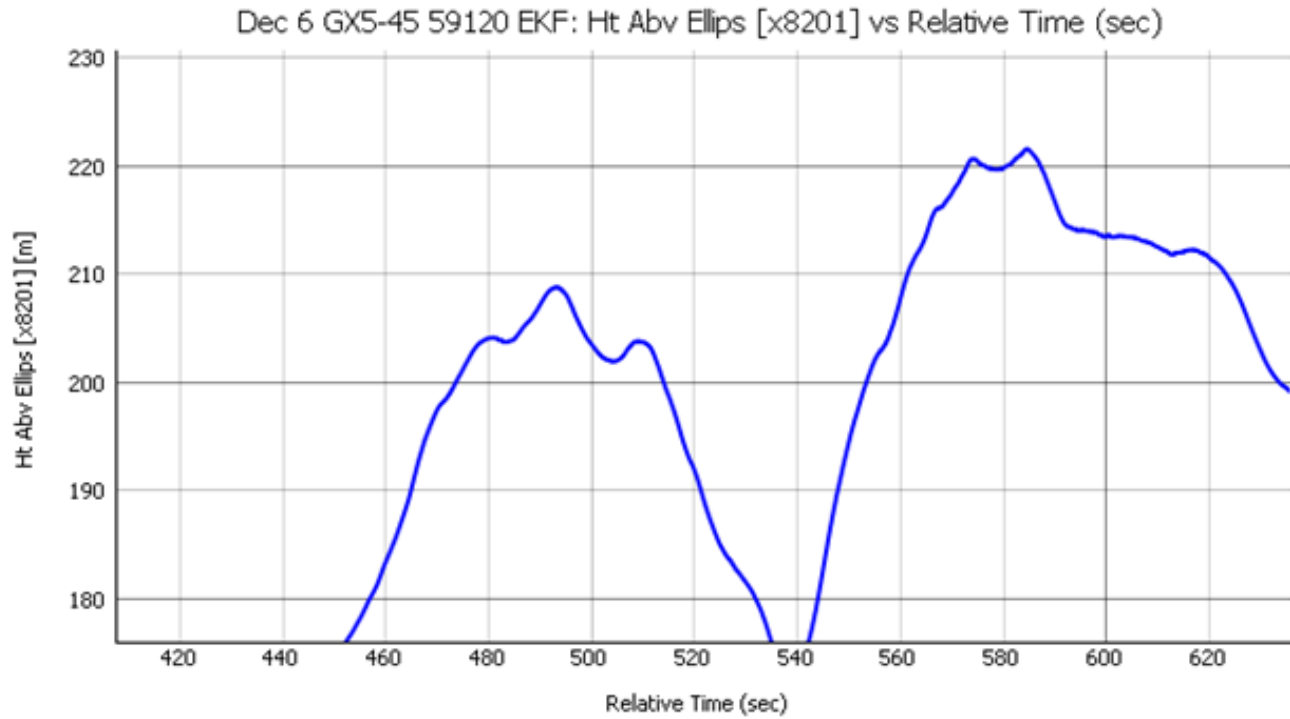


Figure 18 -Zoomed-In Plot View

Selecting 'View All' from the right-click brings back the entire plot in view.

5.4.4 Exporting Plots As Image To Word or Powerpoint , or as CSV

To export a plot as an image that can be copied into Word or Powerpoint, the user needs to right-click on the plot area, choose 'Export', then 'Entire Scene', finally click on the 'Copy' button at the bottom.

The pop-up for making these selections looks like this:

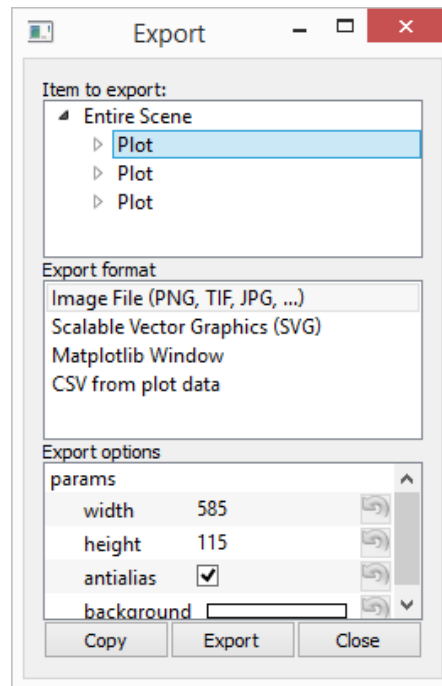


Figure 19 -Export Plots Menu

The 'Export Format' would be 'Image File' in this case. If the user wants to export the plot data as a csv file instead, he/she needs to select 'CSV from plot data' under 'Export format' section of the pop-up, then click on 'Export' button at the bottom.

5.4.5 Plot Units

- (a) It automatically converts all radians type columns to degrees, then plots (regular or diff plot).
- (b) For each column being plotted, it displays the exact units on the Y axis label in square brackets.

5.4.6 Lat-Lon Plots

It can plot lat vs lon, in different formats: regular 1 plot per tab, 2 sensors on 1 plot, or diff plot. As with other diff plots and 2 sensor plots, the lat-lon diff plots and 2 sensor plots can use TOW, Unix Timestamp or Relative Time.

(A) A “Lat-lon plot” for a single sensor or CSV Object does not require the TOW or Week to be selected. It would plot Lat vs Lon, both in degrees, as shown below.

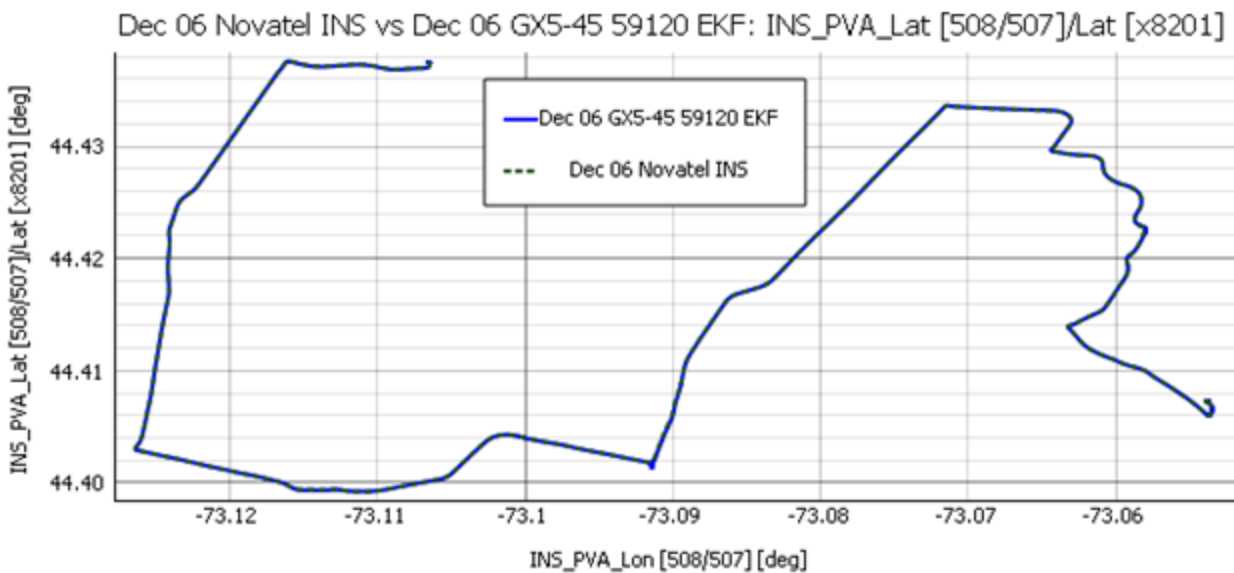


Figure 20 -Lat-Lon Plot

(B) The “lat diff plot” shows the difference in meters instead of degrees (uses earth mean radius = 6371 km for the conversion). Same with lon diff plot. That way it’s easier to visualize the exact difference over the ground in meters. Note that lat, lon and lat-lon plots always show in degrees; it’s only their ‘diff plots’ that convert to meters.

(C) The “lat-lon diff plot” shows the RMS difference of lat-lon (in meters) as a function of TOW, Unix Time or Relative Time. A sample “lat-lon diff plot” is shown below.

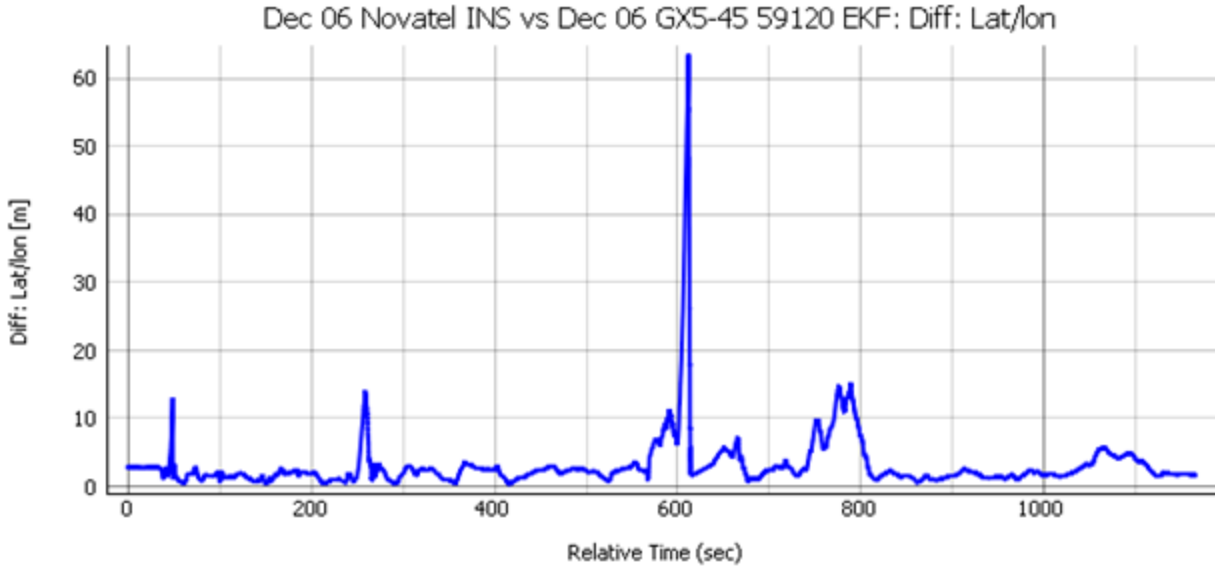


Figure 21 -Lat-Lon Diff Plot

5.4.7 Processing CSV Data For Plotting

When loading a MIP IMU or Novatel RAWIMU csv file that has DeltaTheta and DeltaV, the tool does the following to facilitate overlay and diff plots for deltaTheta and deltaV:

- (a) For Novatel RAWIMU file, it converts DeltaTheta_Y and DeltaTheta_Z to degrees, and then to the MIP Y and Z axes by multiplying by -1 (to be comparable with MIP device values). Note that these are in deg units, because it applies the Gyro Scale Factor to raw values and converts to deg.
- (b) For Novatel RAWIMU file, it converts DeltaV_Y and DeltaV_Z to MIP Y and Z axes by multiplying by -1 (to be comparable with MIP device values). Note that these are in m/s units, because it applies the Accel Scale Factor to raw values.
- (c) For MIP IMU file, it converts DeltaV values to m/s by multiplying the raw values by g, and deltaTheta values to deg.

Note that changes (a), (b) and (c) above are only when plotting; the original parsed csv file remains same as before, which will have units and orientation as in the LORD DCP or Novatel's Firmware Ref Manual (except Novatel's VNED_D column, which will point down and not up).

5.4.8 'Grnd Trace' Derived Column

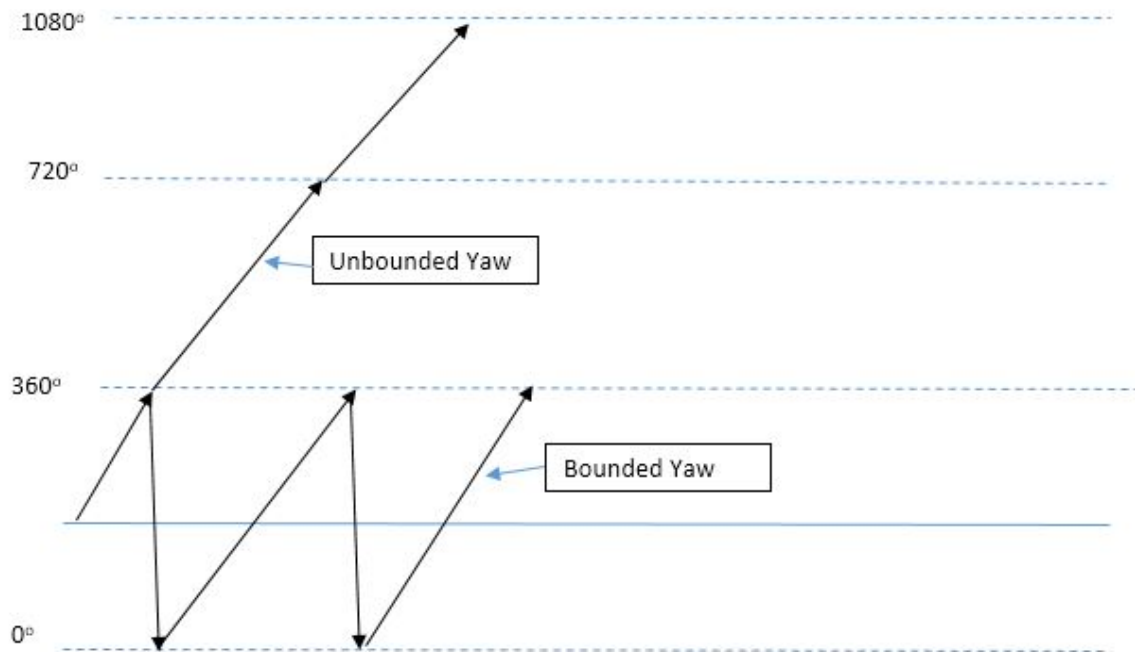
A computed column called 'Grnd Trace [x8202]' and 'Grnd Trace [x8105]' (unbounded... see Section 5.4.9 below) is included when loading an EKF and GPS csv file respectively; these get inserted after the VNED_D column in the csv tree widget for plotting. Note that this does not affect the parsed csv which remains unchanged.

5.4.9 Unbounded Yaw and Ground Trace

When loading an EKF csv file (for plotting), the tool converts the EKF Euler Yaw [x8205] from the default 0 - +/- 180 deg range into 0 - 360 deg range. Note that Novatel's PVA Azimuth [508/507] is already in 0 - 360 deg range (by default). Next, the tool converts both the EKF Euler Yaw and Novatel Azimuth into unbounded values (+/- infinity). This is done to avoid sudden jumps when crossing the 360 deg value from either direction, and to facilitate computing the standard deviation of the differences between LORD Euler Yaw and Novatel Azimuth. Note that this does not affect the parsed csv which still has the 0 - +/- 180 deg range for EKF Euler Yaw (as parsed).

The following figure illustrates how the 0 - 360 deg bounded yaw is converted to an unbounded yaw:

CASE (A):



CASE (B):

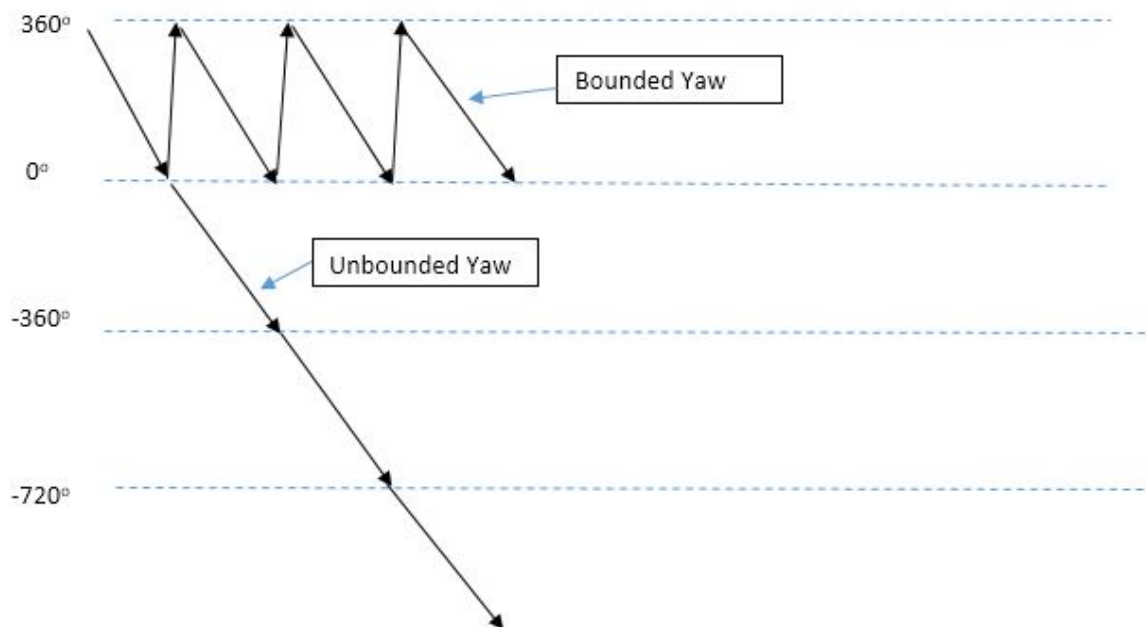


Figure 22 -Unbounded Yaw

5.4.10 Novatel 'Up' vs 'Down' Velocity

The Novatel parsed csv file had a couple of headers: “Vel D [324/267]” and “INS_PVA_vned_D [508/507]”. The actual velocity parsed is “up” velocity and not “down” velocity, so the tool multiplies the parsed value by -1 to make it a “down” velocity. That way it matches with the headers of those 2 columns, which can be used to compare with the VNED_D velocity of LORD devices.

- Note that the “vertical speed” fields in messages 99 and 323 remain unchanged, and reflects the speed going up as positive. In other words, the down velocity in “Vel D [324/267]” and “INS_PVA_vned_D [508/507]” columns would be negative of the ones in the “EKF Vert Speed [99]” and “INS Vert Speed [323/266]” columns.

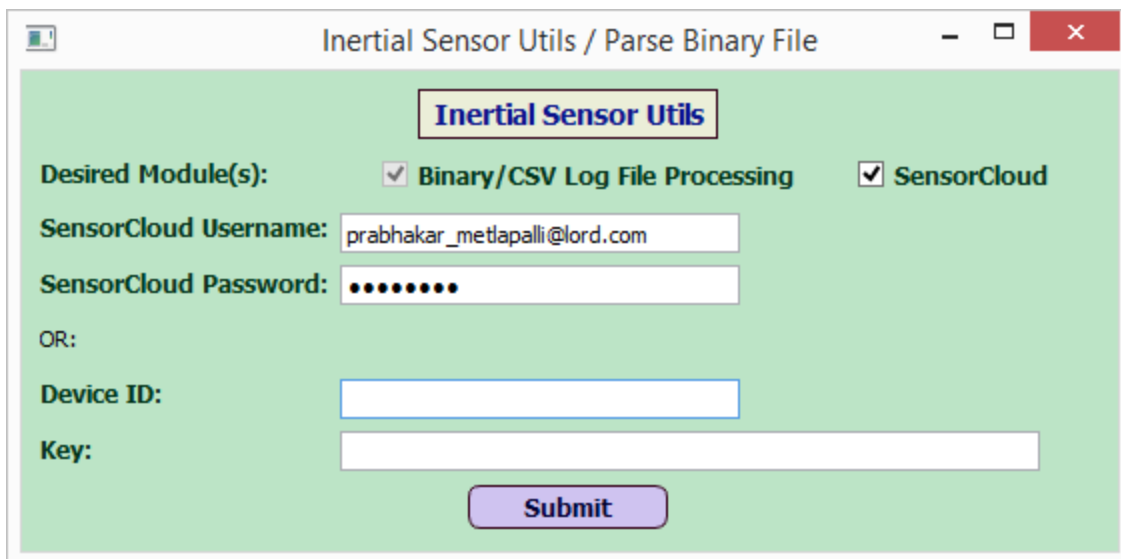
5.4.11 Miscellaneous Notes

If a column contains one or more empty cells in the csv, it picks only the rows with non-empty cells in that column and its matching TOW in the plot.

6. Logging In With SensorCloud Option Checked

The 'SensorCloud' box must be checked to view sensor data already uploaded to SensorCloud™ (<http://www.sensorcloud.com/>), and/or uploading new sensor data to it. When the 'SensorCloud' box is checked, it enables the SensorCloud™ Username/Password and Device ID/Key fields on that window. The user can either enter the SensorCloud™ Username/Password OR the Device ID and Key.

When the user enters the Username/Password combination before hitting Submit, it looks like this:



The screenshot shows a window titled "Inertial Sensor Utils / Parse Binary File". Inside, there is a section titled "Inertial Sensor Utils". Under "Desired Module(s):", there are two checked checkboxes: "Binary/CSV Log File Processing" and "SensorCloud". Below these, there are two input fields: "SensorCloud Username:" with the value "prabhakar_metlapalli@lord.com" and "SensorCloud Password:" with masked characters "••••••••". Below these fields is the text "OR:". Further down, there are two more input fields: "Device ID:" and "Key:". At the bottom center is a purple "Submit" button.

Figure 23 -Log In Window With SensorCloud™

Once the user hits Submit, it figures out the Device ID assigned to that user on SensorCloud™. Typically each user on SensorCloud™ gets a single Device ID. Multiple sensors can be added under that single Device ID.

When the user hits Submit on the log on window, it opens a new window with the Device ID field at the bottom, as shown below:

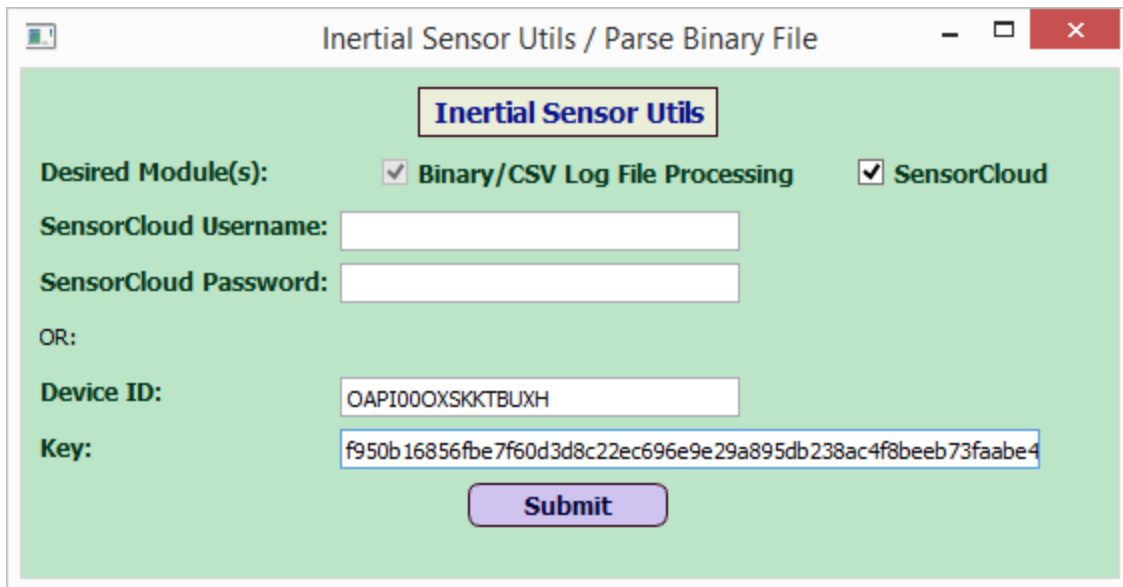
The screenshot shows a window titled "Inertial Sensor Utils / Parse Binary File". It has three tabs: "Main", "View Sensors", and "Batch Process". The "Main" tab is active. The window contains the following elements:

- Inertial Sensor Utils** (text label)
- Logout** (button)
- ?** (help icon)
- Input Spec:** (text label)
- File Type:** (dropdown menu showing "Binary")
- Protocol Used:** (dropdown menu showing "MIP")
- Binary Filename:** (text input field)
- Browse** (button)
- Descriptor Filter:** (text input field)
- [Optional: Ex: 8012800C810981038105]** (text label)
- Desired Action(s):** (text label)
- ☐ **Parse to CSV** (checkbox and text label)
- ☐ **Upload to SensorCloud** (checkbox and text label)
- Sensor Name:** (dropdown menu)
- Device ID:** (text input field containing "OAPI000XSKKTBUXH")
- Clear Status Text** (button)
- Submit** (button)
- Status:** (text label)

Figure 24 -View After Selecting Submit

Instead of Username/Password, a user can also enter a Device ID directly on the log on window. However in that case, the app expects the user to enter a Key value as well. This is to prevent inadvertent use of the Device ID by users other than its owner. The Key is specific to a device and can be obtained by registering at <http://www.sensorcloud.com/>. The key expires after about 12 hours (max 24 hours) and the user needs to log in at <http://www.sensorcloud.com/> and generate a new key.

The following snap-shot shows the user entering the Device ID/Key combination before hitting Submit:



The screenshot shows a window titled "Inertial Sensor Utils / Parse Binary File". Inside the window, there is a section titled "Inertial Sensor Utils". Below this title, there are two checked checkboxes: "Binary/CSV Log File Processing" and "SensorCloud". Below these checkboxes, there are two input fields: "SensorCloud Username:" and "SensorCloud Password:". Below these fields, there is a label "OR:". Below "OR:", there are two more input fields: "Device ID:" and "Key:". The "Device ID:" field contains the text "OAPI000XSKKTBUXH". The "Key:" field contains a long alphanumeric string: "f950b16856fbe7f60d3d8c22ec696e9e29a895db238ac4f8beeb73faabe4". Below the "Key:" field, there is a "Submit" button.

Figure 25 -Log In Using Device ID/Key

After the user hits Submit, the window opens as before, but this time there is a new Key field below the Device ID field as shown below:

The screenshot shows the 'Inertial Sensor Utils / Parse Binary File' window. The 'Main' tab is active. The interface includes a 'Logout' button and a help icon. The 'Input Spec' section has 'File Type' set to 'Binary' and 'Protocol Used' set to 'MIP'. The 'Binary Filename' field is empty, with a 'Browse' button next to it. The 'Descriptor Filter' field is empty, with an example '[Optional: Ex: 8012800C810981038105]' provided. The 'Desired Action(s)' section has two checkboxes: 'Parse to CSV' (unchecked) and 'Upload to SensorCloud' (unchecked). The 'Sensor Name' field is empty. The 'Device ID' field contains 'OAPI00OXSKTBUXH'. The 'Key' field contains 'f950b16856fbe7f60d3d8c22ec696e9e29a895db238ac4f8beeb73faabe433fe'. There are 'Clear Status Text' and 'Submit' buttons. At the bottom, there is a 'Status:' label and an empty text box.

Figure 26 -View After Selecting Submit

- Note that with 'SensorCloud' checked, there are two extra tabs called 'View Sensors' and 'Batch Process' that show up after the 'Main' tab. These two tabs did not show up when the 'SensorCloud' check-box was unchecked.
- Also note that with 'SensorCloud' checked, if the user chooses 'CSV' as the File Type, then the window shows an extra check-box labeled 'Upload to SensorCloud' as shown below:

Figure 27 -Upload A CSV File To SensorCloud™

So by checking that box, the user can upload a csv file directly to SensorCloud™, provided the csv file contains a non-zero GPS Week column and a GPS Time-of-Week column as well.

6.1 View Sensors Tab

When the user clicks on the 'View Sensors' tab, it loads and displays all sensors for the user's device id on SensorCloud™. Currently it assumes that each user has only one device on SensorCloud™, with one or more sensors associated to that device.

On the bottom of this tab, it shows the same 7 buttons for plotting data as on the CSV data tab described in section 5.4.1, which work in a similar way, with the following differences:

- (a) Replace the 'CSV object name' with 'Sensor'
- (b) The user can (optionally) select a TOW column as the X-axis. In this case, the plot would look the same as on the CSV Data tab. If the user does not select a TOW column on this tab, it uses the Unix Timestamp for that column as the X-axis. Note that the TOW column was required in the CSV Data tab, but is optional in the View Sensors tab because it has a default option of using the Unix Timestamp as the X-axis.

Also note that with SensorCloud™ enabled, if the channels have different data rates (Hz), then the slower message columns cannot be plotted vs TOW on the View Sensors tab. The user must select only the slower message column and unselect TOW, so that it plots the column as a function of Unix Timestamp (the default). This is because on SensorCloud™, the Unix Timestamps are associated to each individual value of the column (or channel), so in theory one could have different Unix timestamps

for each column on a given row of a csv. If the user chooses to plot such column vs TOW, it would show an error message stating that the TOW must have the same length as the column to plot.

A sample screen with the 'View Sensors' tab is shown below:

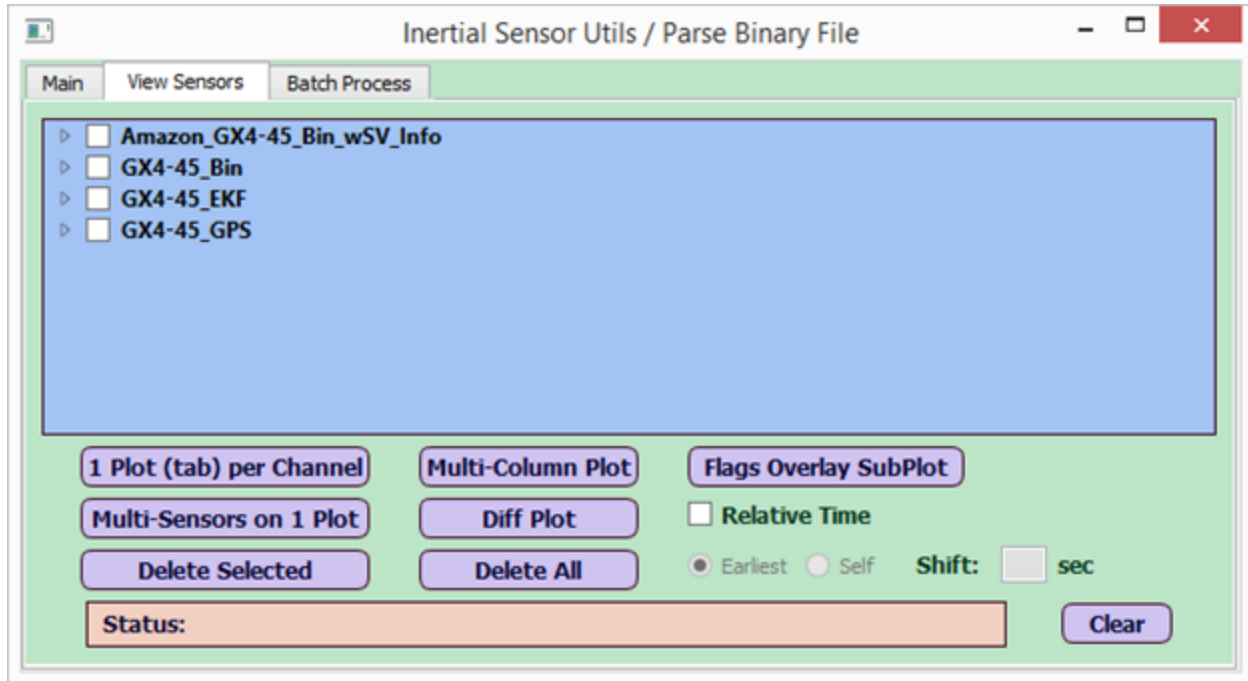


Figure 28 -View Sensors Tab

It shows 4 sensors that were associated with the Device ID for this user on SensorCloud™.

- Each sensor has one or more channels. A channel is similar to a column in a csv file. The channel names for each sensor in the View Sensors tab are sorted to be in the same sequence as in a csv file.
- When logging with 'SensorCloud' checked, it shows a check-box: 'Upload to SensorCloud' as one of the Desired Actions, as shown in Figure 29 below. When the user checks that box, the Sensor Name field which is a drop-down, gets enabled, so the user can either enter a new sensor name or pick an existing sensor from the drop-down.
 - If an existing sensor is selected, the upload would append data to data already existing on SensorCloud™ for that sensor.
 - If a new sensor is entered, it would create a new sensor on SensorCloud™ and upload the data to that sensor.

This is shown below:

Inertial Sensor Utils / Parse Binary File

Main View Sensors Batch Process

Inertial Sensor Utils Logout ?

Input Spec: File Type: Binary Protocol Used: MIP

Binary Filename: Browse

Descriptor Filter: [Optional: Ex: 8012800C810981038105]

Desired Action(s): ☐ Parse to CSV ☒ Upload to SensorCloud

Sensor Name: Device ID: GX4-45_EKF GX4-45_Bin Amazon_...SV_Info GX4-45_GPS

Submit

Status:

Figure 29 -Uploading A New Sensor To SensorCloud™

6.2 Batch Process Tab

When logging in with 'SensorCloud' checked, it shows an extra tab called 'Batch Process'. The user can upload up to 5 binary and/or csv files at a time to SensorCloud™ using this tab. See below:

Inertial Sensor Utils / Parse Binary File

Main View Sensors Batch Process

Batch Process for SensorCloud Upload

File Type	Protocol	Filename	Descriptor Filter	Sensor Name
Binary	MIP	Browse		
Binary	MIP	Browse		
Binary	MIP	Browse		
Binary	MIP	Browse		
Binary	MIP	Browse		

Clear Status Text Submit

Status:

Figure 30 -Batch Process Tab Menu

At the end of the job, it generates a Batch Process Report as a .csv file with the timestamp of the batch request included in the filename (example: "BatchProcess_Report_2017-01-11_15_48_51.csv", content shown below). The report would reside in the 'root' folder (location of QInertialSensorUtils_GUI.exe)

***** Batch Process Report for command issued at: 2017-01-11 15:48:51

File					
Row	Type	Protocol	Filename	Sensor Name	Status
1	CSV	MIP	GPS_Log.csv	GX4-45 GPS csv	ERROR: CSV File must have GPS TOW col
2	Binary	MIP	GX4-45 6-30-2016.bin	GX4-45 GPS	DONE Batch Process: Time taken: 60 sec
3	Binary	MIP	GX5-45 7-19-2016.bin		ERROR: Sensor name cannot be empty
4	Binary	MIP		ExampleSensor	ERROR: File name cannot be empty
5	CSV	MIP	EKF_Log.csv	GX4-45 EKF csv	DONE Batch Process: Time taken: 31 sec

6.3 GPS Leap Seconds

When uploading to SensorCloud™ or creating a .gpx file from .csv, it converts the GPS Timestamp to a Unix Timestamp. To convert from GPS to UTC time, it uses 18 leap seconds as a default (valid for Jan 2017 and later). If GPS Week is less than 1930 (the first week of 2017), it uses 17 leap seconds as difference between GPS and UTC, so that should cover log files obtained during the second half of 2016.