Solution Quality Assessment

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This chapter presents a set of guidelines for assessing the quality of the various solutions produced by the available postprocessing modes in the POSPac MMS software.

Imported and extracted data

Examine the following message logs after the POS data are imported into the project. To access the message logs, select *Reports / Message Log*.

- ***POS Data Import*** —review the messages from the real time mission data and check for any suspicious error messages. Ensure that the POS status reached Full Navigation or at least Fine Align.

- ***IMU Data Continuity***—check for reported IMU data gaps. No IMU data gaps should be present in the data. An IMU data gap is typically caused by a data communication failure between the IMU and the POS computer system (PCS) that should be repaired before any further use.

- ***Primary/Secondary GNSS Import***—check for reported decoding errors. The GNSS data should be decoded without errors. A decoding error is usually caused by one or more corrupted bytes in the GNSS receiver data stream, again likely due to a data communication failure.

Real-time solution

Examine the following display plots after the POS data are imported into the project. To access the display plots, select *Reports / Display Plots*. See also Chapter 14, Data Display and Reports.

- *Real-Time Trajectory / Top View*—become familiar with the mission trajectory.
- *Real-Time Trajectory / Altitude*—determine when and how the POS was initialized. If a POS AV was used, determine whether it was initialized on the ground or in the air. If a POS LV was used, determine whether it was initialized while the vehicle was stationary or moving. Determine how many GNSS satellites were visible during the initialization.
- *Real-Time Trajectory / Roll and Pitch*—ensure that the POS was operated with the correct mounting angles.

GNSS QC Processing

GNSS QC processor can be used to check the quality of GNSS observables before running GNSS-Inertial processor in *Single Base* or *SmartBase* modes. After the user imports a base station and clicks the *Set Base* option, POSPac will decode the base data and launch the GNSS QC processor. When the user runs Applanix SmartBase, POSPac will generate the SmartBase data and launch the GNSS QC processor.
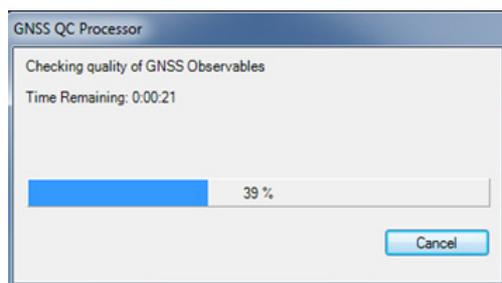
The GNSS QC results include the baseline length, number of satellite, PDOP, QC solution status and satellite elevation and residuals. These results are summarized in *GNSS QC Statistics* window as well as in the GNSS QC processing message logs as shown below:

Statistics	Min	Max	Mean
Baseline Length (km)	0.08	3.32	N/A
Number of GPS SV	4	9	8
Number of GLONASS SV	2	7	6
Total Number of SV	8	16	14
PDOP	1.12	3.44	1.37
QC Solution Gap (s)	0.00	0.00	N/A

Fixed Epoch: 4504.0 s Float Epoch: 0.0 s No Solution: 0.0 s
Fixed Solution: 100.00% Float Solution: 0.00% No Solution: 0.00%

```
Message Logs

GNSS QC Processing                    [▼]                              [ Close ]

-----------------------------------------------------------------------------
Satellite   Number  Start Time  End Time   MinElv(deg)  MaxElv(deg)  MinRes(m)  MaxRes(m)
GPS PRN 02   2352   319901.00   322252.00    67.55        76.73       -0.008      0.005
GPS PRN 04   2333   319901.00   322252.00    21.18        34.82       -0.009      0.015
GPS PRN 05   2352   319901.00   322252.00    55.22        74.65       -0.028      0.007
GPS PRN 10   2352   319901.00   322252.00    42.53        59.41       -0.010      0.010
GPS PRN 12   2306   319901.00   322252.00    22.05        36.09       -0.015      0.030
GPS PRN 13   2248   319901.00   322252.00    13.03        20.14       -0.035      0.025
GPS PRN 25   2291   319901.00   322252.00    27.74        32.50       -0.050      0.021
GPS PRN 26    852   321239.00   322252.00    10.02        16.86       -0.056      0.028
GPS PRN 29   2287   319901.00   322252.00    20.53        36.35       -0.021      0.020
GLONASS 01   2339   319901.00   322252.00    18.06        36.83       -0.026      0.034
GLONASS 02   2352   319901.00   322252.00    74.76        83.06       -0.006      0.013
GLONASS 03   2325   319901.00   322252.00    28.75        49.63       -0.028      0.009
GLONASS 17   2352   319901.00   322252.00    72.35        78.82       -0.013      0.007
GLONASS 18   2339   319901.00   322252.00    28.90        48.03       -0.010      0.064
GLONASS 24   2321   319901.00   322252.00    17.03        33.88       -0.026      0.048

-----------------------------------------------------------------------------
Statistics                    Min         Max         Mean
Baseline Length (km)          0.16        3.32
Number of GPS Satellite       4           9           8
Number of GLONASS Satellite   4           6           6
Total Number of Satellite     8           15          14
PDOP                          1.25        3.44        1.41
QC Solution Gap (s)           0.00        0.00

Solution Type         Fixed       Float       No Solution
Epoch (s)             2354.00     0.00        0.00
Percentage            100.00      0.00        0.00
-----------------------------------------------------------------------------
Termination status : Normal
Execution time     : 17.10
-----------------------------------------------------------------------------
Processing completed.
Warning: One or more GNSS QC optional input files cannot be found - This is typically because the
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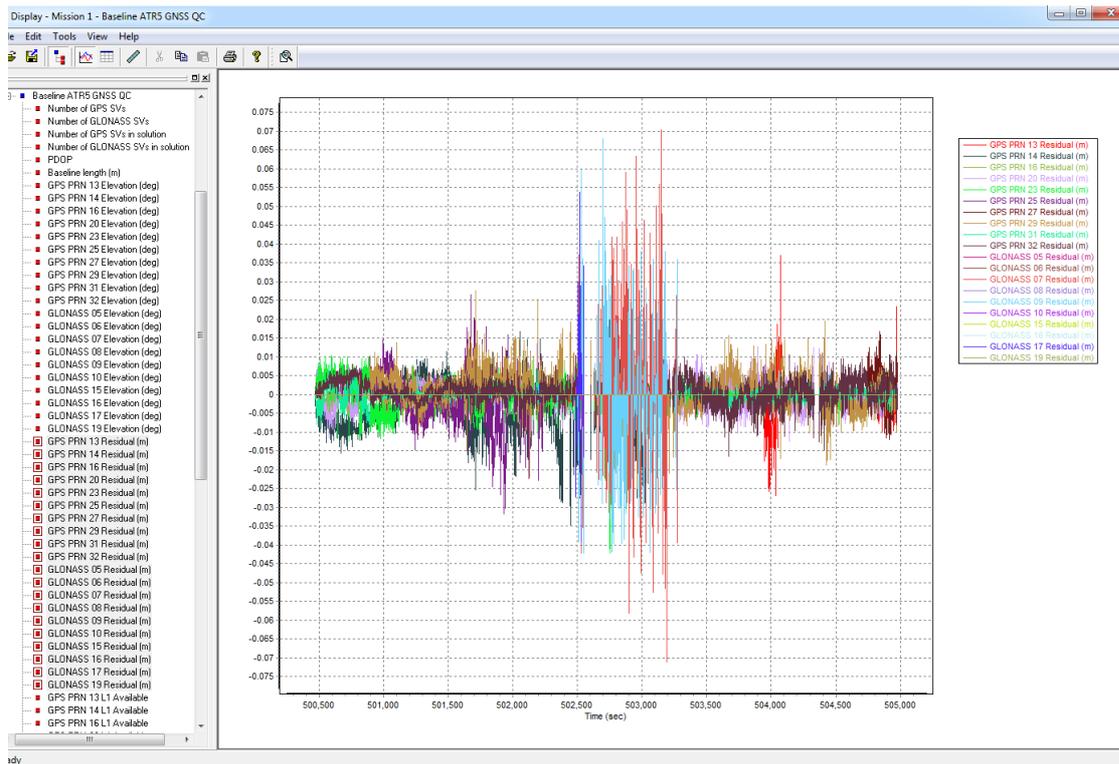
The GNSS QC results are also available in *Display Plot* for further analysis.

GNSS QC information is useful for analysis before GNSS-Inertial processing. For example, the user can determine which single base station is the most suitable for processing by inspecting the GNSS QC information (baseline length, the number of GPS/GLONASS satellites for each of the imported base stations, PDOP, etc.).

In the example below, we have imported raw POS data as well as three base stations (MLVL, ISLA, and CREI). After all the desired base stations are imported and *Set Base* is used for each base, open *Display Plot* to check the GNSS QC information for all the stations as shown below. Note that a maximum of 10 baseline GNSS QC plots will be displayed.
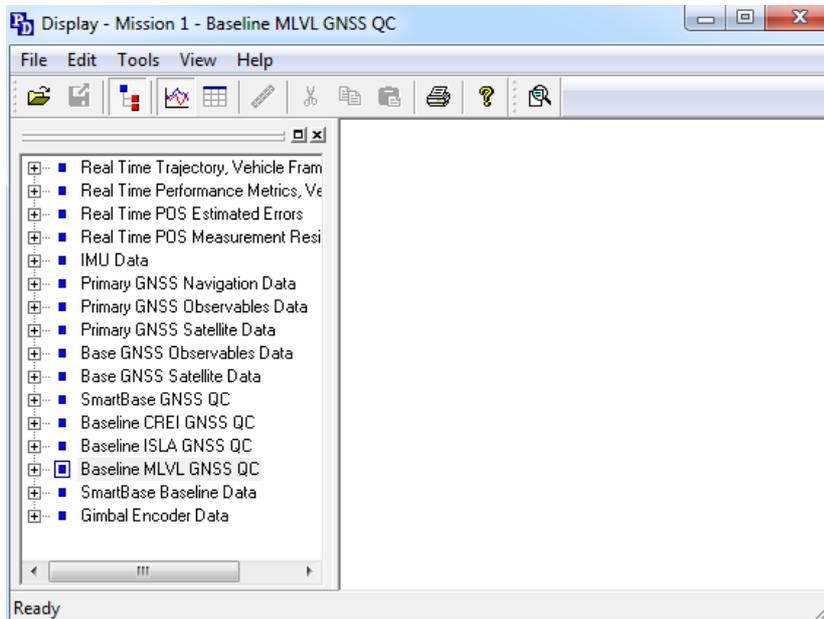
Inspecting the GNSS QC information for each base station can help determine the most suitable base station for processing. Given the GNSS QC information for each station below, the base station MLVL is the recommended station to be used in the single base processing as it has shortest baseline lengths and the most numbers of satellites throughout the whole mission. Therefore, the user can go back to POSPac to right-click the desired base station MLVL point in the *Project Explorer* or *Plan View* and select the *Set Base* option and then run GNSS-Inertial Processor with Single Base processing.
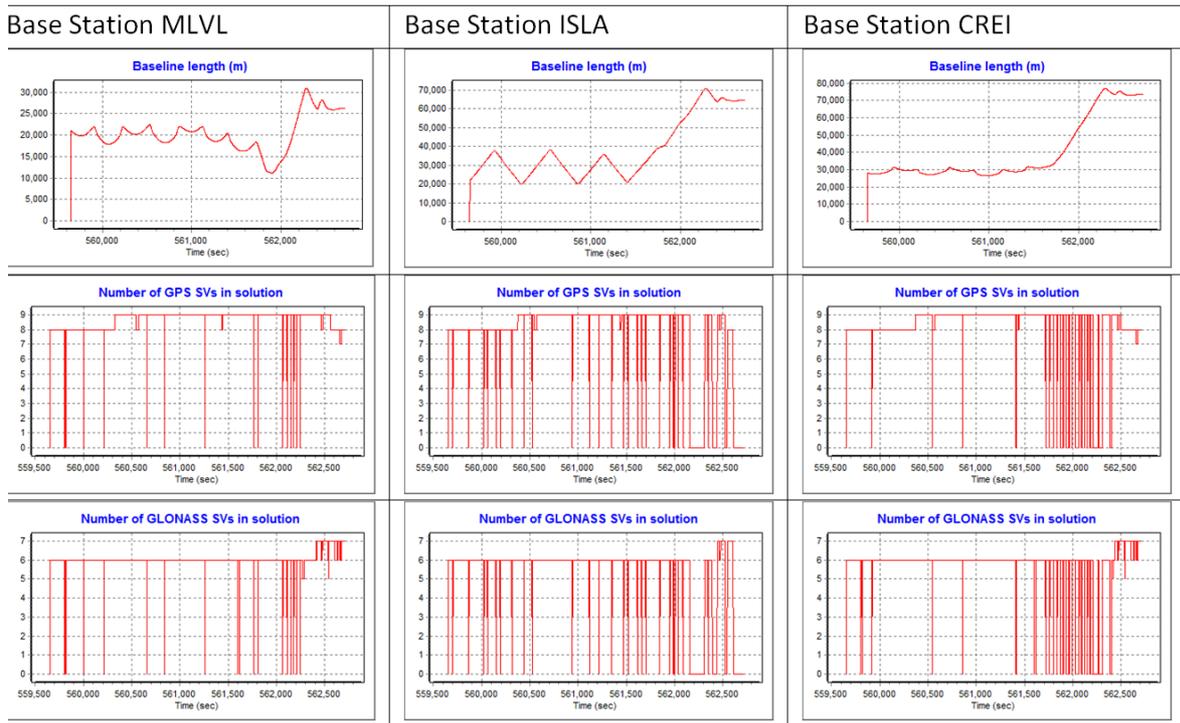
Applanix SmartBase solution

Review the quality of the coordinates used for each station in an Applanix SmartBase network before generating the Applanix SmartBase solution. Do this by running the Applanix SmartBase Quality Check and then reviewing the reported results:

Quality Check computes adjusted coordinates for reference stations for which at least 18 hours of continuous observables data are available to process.

- It reports an *OK* status for those reference stations whose adjusted horizontal and vertical coordinates differ from the published coordinates by less than 5 cm, and recommends the output coordinates in the *Output Coord* field, that SmartBase will use to be *Original,* which are the published coordinates in the RINEX observables file.

- It reports a *Good Estimate* status if the adjusted coordinates differ from the published coordinates by more than 5 cm, and recommends the output coordinates that SmartBase will use to be *Adjusted*, which are the adjusted coordinates.

- It reports a *Bad Estimate* status for a reference station if the adjusted coordinates differ from the published coordinates by more than 5 cm and less than 18 hours of observables are available, and recommends the reference station to be *Disabled* in the corresponding *Output Coord* field.

- It similarly reports a *Not Processed* status for a reference station and recommends *Disabled* if not enough observables data are available to compute a reliable adjusted position.

You can override the recommended output coordinates for any reference station by editing the *Output Coords* field. If one or more reference stations are recommended as Disabled, then you should delete them and rerun Quality Check. To view the SmartBase Quality Check summary, select *Reports / Message Logs*.

Interpretation of Applanix SmartBase Quality Check Results summary

Table 16.1   Reference Station Raw Data Analysis

| Field	Unit	Description	Remarks
Station ID		Station name, usually 4-letter string.	
Time Span	Seconds	Time span of station raw data (last epoch - first epoch).	
Data rate	Seconds	Data rate of raw observations.	
Start Time	Week		
Seconds	GPS time of the first epoch		
End Time	Week		
Seconds	GPS time of the last epoch		
Total Gap	Seconds	Total data gap in station raw data file.	These values reflect the statistics of all stations during the time span of control station. (Some station may have longer data than the control station. Process ends once control station reaches end of file.)
Max Gap	Seconds	The biggest data gap in the station raw data file.	
Min Gap	Seconds	The smallest data gap in station raw data file.	
Unrepaired CS	Occurrence	The total number of unrepaired cycle slip accumulated among all satellites.	
Simul Unrepaired CS	Occurrence	The total number of simultaneous unrepaired cycle slip. One occurrence indicates all satellites experiences simultaneous unrepaired cycle-slip in the same epoch. This usually happens after a data gap. Also in the beginning of the processing, ObsQuality class need 4 epochs to initialize its filter and detect gross error, all the 4 epochs are flagged as Unrepaired CS.	
Data Rate	Seconds	Observation file data rate.	
MinNum Sats		The minimum number of satellites per epoch	
MaxNum Sats		The maximum number of satellites per epoch	
Min PDOP		The minimum PDOP	
Max PDOP		The maximum PDOP	

Table 16.2   Reference Station Applanix SmartBase Quality Check Processing Results

Field	Unit	Description
Station ID		Station name
Status		Indicates the quality of the coordinates of each reference station.
3DError	Meters	3D difference of adjusted coordinates from the input coordinates.
Process Time Span	Hours	The longest segment of processing time-span without a station reset. Value can be different for each station and cannot be bigger than the control station process time-span as the accuracy of other stations depends on the control station. Process Timespan = Process Interval * Solution Epochs Process Timespan End Time - Start Time
Process Interval	Seconds	Process interval.
Start Time	Week Seconds	The first epoch of the process time span.
End Time	Week Seconds	The last epoch of the process time span.
Solution Epochs	Epochs	Number of epochs with solutions during the segment
No Solution Epochs	Epochs	Number of epochs without solutions during the segment
Mean Sats per Epoch		The mean number of satellites during the segment
Station Reset	Times	The number of station reset during the processing
Max Rx-Clk	Seconds	The maximum receiver clock offset during the processing

Prior to running the GNSS-Inertial processor, verify the quality of the Applanix SmartBase solution by reviewing the Applanix SmartBase Processing message log. Select *Report / Message Log*.

If the Applanix SmartBase data generation is successful, there is no need to review the message log. If the Applanix SmartBase solution has encountered an error or warning, a pop-up dialog appears prompting you to view the message log:
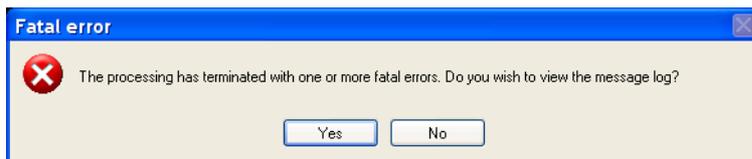
The Applanix SmartBase message log contains a raw data analysis for each reference station in the network and statistics on the Applanix SmartBase solution.

The **Reference Station Raw Data Analysis** reflects the data quality of each reference station for a period of 15 minutes + rover time span. Fifteen minutes of data prior to the rover time span is essential for Applanix SmartBase processing and ambiguity resolution:

· Values for *Total_Gap, Max_Gap*, and *Min_Gap* are in seconds.

· *Unrepaired_CS* shows the number of occurrences of unrepaired cycle-slip.

· *Simul_Unrepaired_CS* stores the number of occurrences of simultaneous unrepaired cycle-slip for all satellites in the same epoch.

- *REF2Traj_Centre (km)* refers to the distance between the reference station and the average center of the trajectory.
- Data rate of each station is in seconds.

The **SmartBase Statistics** reflects the status of the computed Applanix SmartBase solution:

- *SmartBase Status*—the status of the Applanix SmartBase solution may be one of the following:

  – PROC_STATUS_VRS_OK

  – PROC_STATUS_VRS_LOWPERCENTAGE

  – PROC_STATUS_VRS_DATAGAP

- *Total full data gap* indicates the total missing epochs in the Applanix SmartBase solution. If data gaps occur, the status will report PROC_STATUS_VRS_DATAGAP.

- *Total individual satellite data gap* shows the total number of satellites with missing observation data, either due to poor quality or low elevation (in the Applanix SmartBase solution) for the whole mission time span.

- *Percentage of Primary Station Measurement Usage* is another indicator of the Applanix SmartBase quality; indicates the percentage of the primary station measurements projected into the Applanix SmartBase solution. The current threshold value is 90%. Below 90% reports PROC_STATUS_VRS_LOWPERCENTAGE.

The following table outlines the various Applanix SmartBase Status messages, the possible source of the problem, and recommended actions.

	PROC_STATUS_VRS_DATAGAP	PROC_STATUS_VRS_LOWPERCENTAGE
Possible sources	1. Physical data gaps in the Primary station raw data file. This is usually the main source. 2. Poor quality primary station data, Where there are simultaneous unrepaired cycle-slips present and ambiguities cannot be fixed. 3. Poor quality primary station data where ambiguities for all satellites cannot be fixed. 4. Possibly network ambiguity is unresolved.	1. Data gap in the Applanix SmartBase solution file caused by physical data gap in Primary station. 2. Data gap in the Applanix SmartBase solution file caused by simultaneous unrepaired cycle-slip in Primary Station. 3. Bad data quality causing many unresolved ambiguities if there are no data gaps. 4. Data gap in the Applanix SmartBase solution file caused by Bad network configuration and data quality, network ambiguity resolution fails.
Action	For the first three cases, the recommendation is to change Primary station based on the raw data analysis information. For the fourth case, the only course of action to follow is to change the network configuration, for example, reduce the inter-station distance by adding more reference stations.	
Criteria for choosing a good Primary Station	*The list is in the order of priority*. 1. No continuous data gaps larger than 30 seconds (Max-Gap, Min-Gap). 2. No occurrences of Simul_unrepaired_CS (simultaneous unrepaired cycle-slips). 3. Nearest distance to trajectory center. 4. Lowest number of unrepaired cycle-slip.	

POSGNSS KAR and PPP solutions

When a user chooses to run POSGNSS to generate a differential GNSS or a PPP solution, it is critical to review the processed solution and refine the processing settings in order to yield an optimal navigation solution.

Click the Plot GPS Data icon in the *POSGNSS* dialog to display the *Plot Results* dialog:
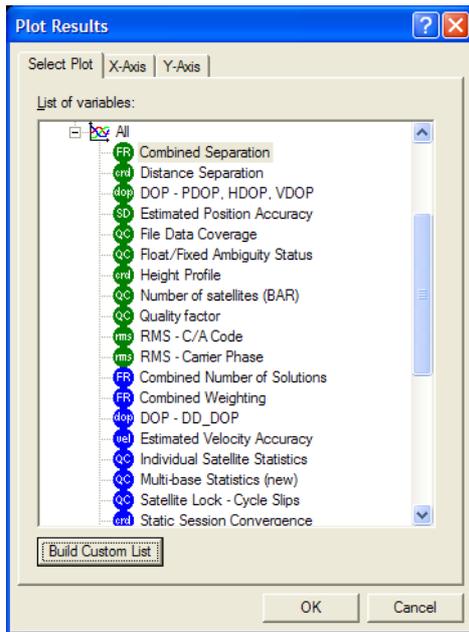
The following table outlines the plots to review, the quality indicators, as well as a suggested course of action if the quality indicator is not met.

Table 16.3   Quality Indicators and Suggested Course of Action

Plot	Quality Indicators	Suggested Course of Action
Combined Separation	±15 cm between forward and reverse solution	For Differential Processing, ensure KAR is engaged at an appropriate time and that the integer ambiguity is fixed throughout the trajectory. If baselines are short (less than 10 to 20 km), ensure that ionospheric corrections are deactivated. For PPP processing, ensure that precise ephemeris files are used by the processor.
DOP	PDOP < 2.5 = ideal PDOP < 4 is acceptable	Use POSGNSS Mission Planning tools to plan around PDOP spikes before flying missions.
Number of Satellites	5+ satellites throughout the entire mission	Reduce the elevation mask to a minimum value of 8° (for differential processing) and 5° (for PPP).
Quality Factor	1 = best 2 = good	For differential processing, change KAR settings to remain in a fixed solution for the entire trajectory. A maximum quality factor of two is expected for a PPP solution.
Satellite Lock - Cycle Slips	Minimum cycle slips, only at low elevation angles	Keep bank angles less than 25° when flying the mission.
RMS - C/A Code and Carrier Phase	Random RMS values without a saw tooth or sinusoidal pattern	Check base station coordinates when using multi-base processing to ensure the accuracy of the network.

Smoothed Best Estimate of Trajectory (SBET) solution

The GNSS-inertial processor requires initial conditions that are reasonably accurate. The most accurate initial heading comes from the following sources in the stated preferential order.

- Real-time navigation solution.

- GNSS track angle.

- If the real-time solution is not available, from a True Heading value taken from the vehicle navigation solution.

The GNSS-Inertial processor must be initialized when the mobile mapping vehicle is stationary, or when it is in level flight with a constant heading for 3-5 minutes.

GNSS-Inertial Forward and/or Backward Processing Message Log

A few measurement rejections are normal. 120 consecutive measurement rejections cause the processor to fail. If this happens:

- Check that the installation parameters (lever arms and mounting angles) are correct.

- Try processing the data using another start time that meets the required initialization conditions.

- Ensure that the IMU mounting angles are correct.

- Large numbers of cycle slips on different satellites will adversely influence the processor and the quality of the final solution. To remove specific satellites or adjust the elevation mask angle for the processing, select *Project Settings / Satellite Selection* dialog.

- Try decreasing the accuracy of the GNSS solution. Select *Project Settings / GNSS-Inertial Processor / Timing Multipath and Baseline* dialog (POSGNSS KAR or PPP only).

- Review the postprocessed GNSS solution to ensure it is of a high quality (POSGNSS KAR or PPP only).

- Check the Extract log to determine whether the real time data was logged in UTC or GPS time; ensure that the postprocessed GPS data was exported in the correct time (POSGNSS KAR or PPP only).

Reviewing the plots

POSPac plots show estimated parameters with **red** traces, and the estimation standard deviations in **dotted line** envelopes around the estimate traces.

Review the smoothed best estimate of trajectory plot:

- Check the plots to ensure the SBET solution is complete by reviewing start/end times to ensure that the SBET encompasses the entire mission time

- Verify that the Altitude plot appears reasonable for the mission, especially during take off and landing

- Review Roll, Pitch, and True Heading plots to verify the IMU orientation used in postprocessing

Review the IIN Solution status plots (Single Baseline and Applanix SmartBase only):

- Best processing mode in forward or reverse is 0 (Fixed).

- Number of Space Vehicles (SVs) greater than 7 should normally give a reliably accurate solution. This needs to be taken together wih PDOP.

- A-priori Positional Dilution of Precision (PDOP) less than 3.0 should normally give a reliably accurate solution.

- The quality of the Single Base mode solution will be degraded when the baseline length is over 20 km during start and end of the mission.

- When flying missions with roll angles exceeding 20 degrees, verify that the *SmartBase Baseline Data / 3D Distance to Closest Station* is always within 70 km (Applanix SmartBase only).

Open Forward GNSS Measurement Residuals and/or Backward GNSS Measurement Residuals:

- Plots should appear noisy and centered about zero

- Residuals should not show spikes associated with vehicle motion.

- Residuals should be within the dotted envelope most of the time

- Significant spikes in residuals may be due to cycle slips in GPS data

Open IIN KF Estimated Errors node:

- Plots show the Kalman Filter's estimate for the inertial sensor errors

- Estimated uncertainties are shown in dotted lines

- All plots should show stable sensor error estimations

- Check accelerometer and gyro bias and scale factor errors:

  – Accelerometer bias should not vary more than 500 micro-g

  – Accelerometer scale error should not vary more than 500 ppm

  – Gyro drift (bias) should not vary more than 5 deg/hr

  – Gyro scale error should not vary more than 500 ppm

  – Sudden changes could mean problems

***Note –** The values suggested here are for AV410 and AV510 systems.*

If youyou is uncertain about the interpretation of any sensor error plots, please contact Technical Support and Service. See Technical Support, page 15.

Open Smoothed Performance Metrics node:

- The plots represent the accuracy of the estimated navigation errors that were modeled and removed.

- The plots represent the final solution accuracy.

- Position (N,E,D) RMS plots show the relative positional accuracy (sample to sample) of the navigation solution

- View the roll, pitch and heading error RMS plots:
  – The plots should show a bouncing ball pattern
  – Low points correspond to turns where heading error is calibrated

  Tip – To see several plots within one graph, press the control key, mark the plots and then right-click and select *Display Selected*.
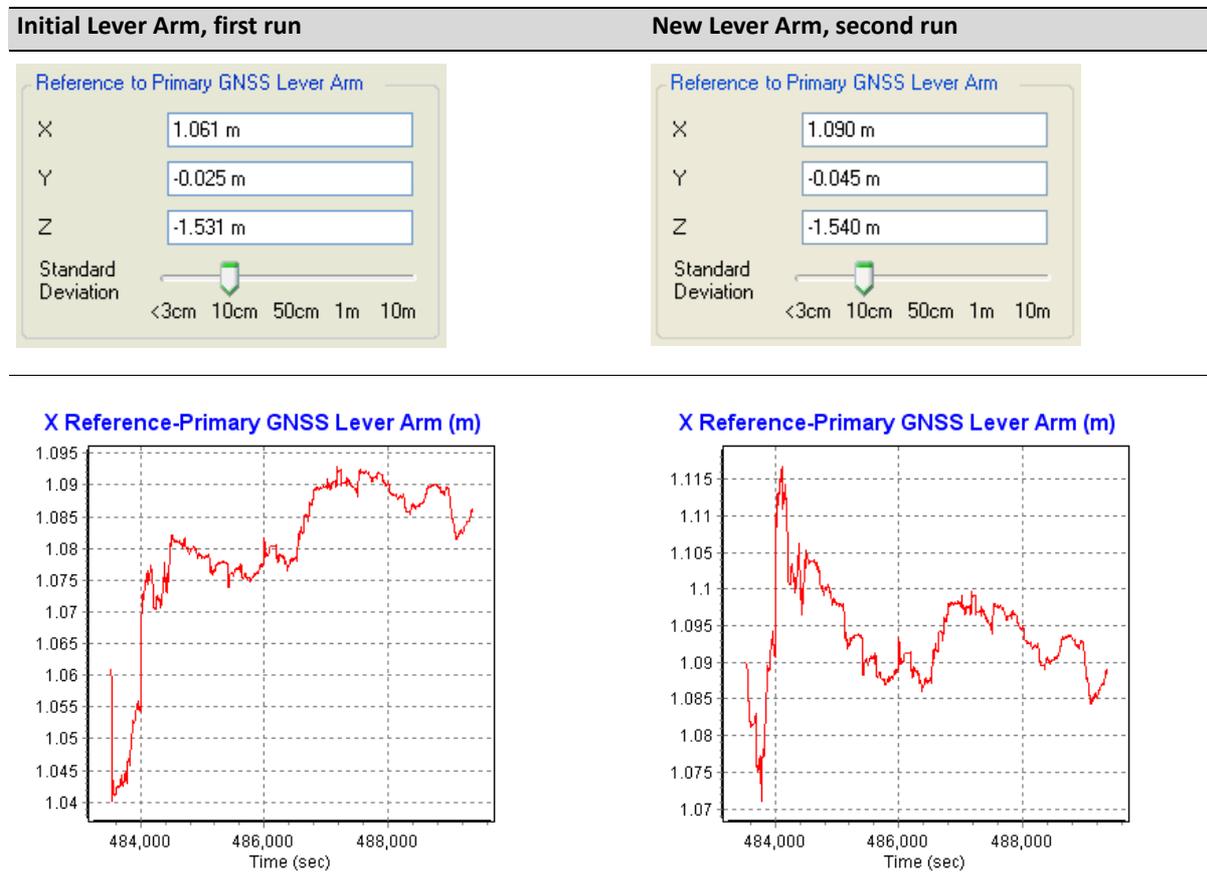
Calibrating the reference to GNSS Lever Arm values

After the first few missions are conducted with a new IMU installation, the Reference to GNSS Antenna lever arm should be calibrated using POSPac MMS and the values saved in the POS Computer System should be updated to the calibrated values.

Calibrated Installation Parameters Plots: X, Y, and Z Reference-Primary GNSS Lever Arm (m).
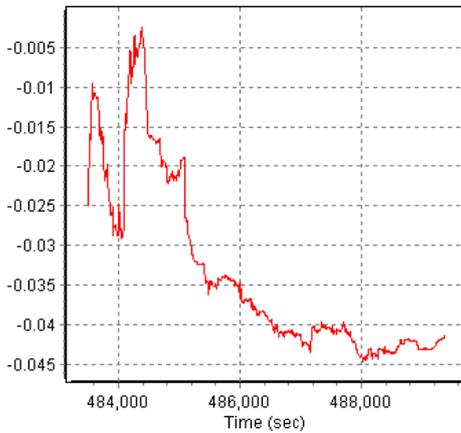
The lever arms should converge correctly to an approximate single value with a few centimeters variation. You can run the GNSS-Inertial Processor the first time with initial values (extracted values from the raw data or manually inserted values, as for example 0,0,0), then calibrate the GNSS lever arm and extract the values afterwards. Always extract the last value from the plot and not the average. Insert the values determined from the first run as new start values for the lever arm and run the GNSS-Inertial Processor again. Now, the lever arm values should converge to a single value. Select *Project / Project Settings / Lever Arm and Mounting Angles.*
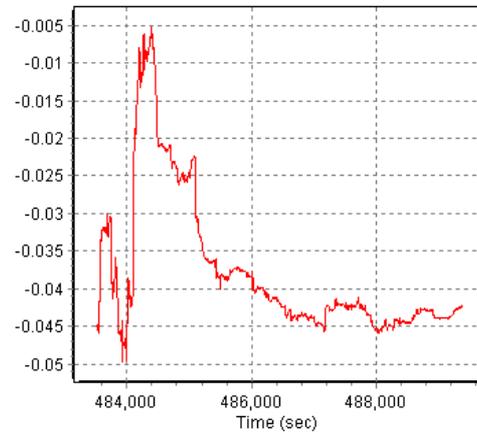
Table 16.4   Lever arm values
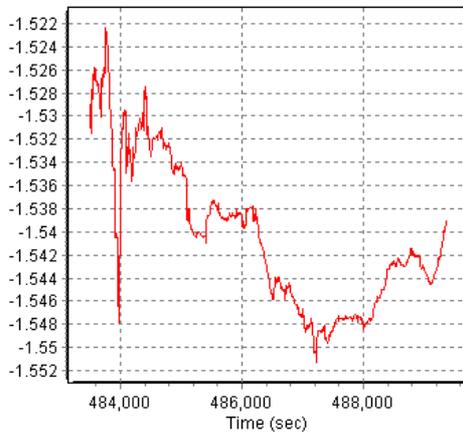
Initial Lever Arm, first run	New Lever Arm, second run

Initial Lever Arm, first run	New Lever Arm, second run

In this example, the initial values are already quite close to the final calibration values. Nevertheless, small improvements can be achieved by refining the lever arm, especially in the X and Y component. Always extract the final value from the plot and not the average as the Kalman filter takes time to converge on the correct lever arm value estimation.

If the lever arms converge and you still get unexpected solution results, verify your antenna settings for each base station using the *Coordinate Manager,* which can be accessed by right-clicking on a base station point in the POSPac *Project Explorer.*