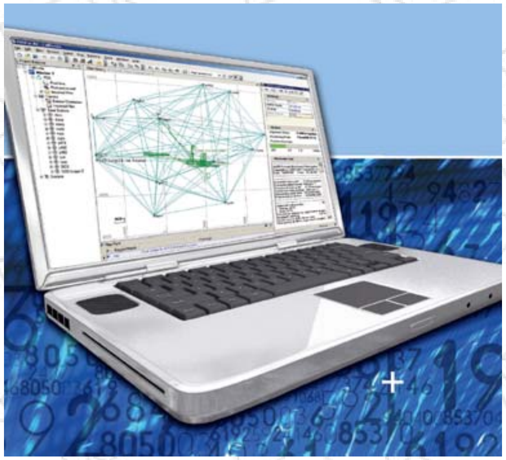
POSPac MMS Overview

For POS LV Users



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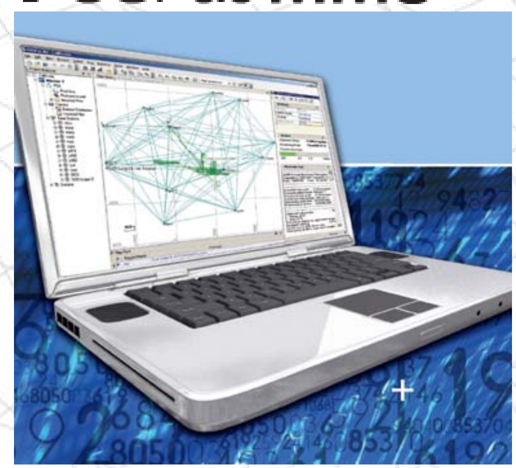
Objective

- The purpose of this presentation is to familiarize new users with the POSPac MMS engines and processing workflow.
- Differences between POSPac MMS and POSPac Land 5.0 will be highlighted to emphasize differences in and post-processing procedures.

Outline

- **What is POSPac MMS?**
- **Integrating GNSS/INS Navigation Systems**
  - POSPac Land 5.0 vs. POSPac MMS
- **New Technologies**
  - Applanix SmartBase™
  - IN-Fusion™
- **New Support**
  - Windows Vista compatible
  - 64-bit architecture support
- **POSPac MMS Workflow**
  - Import
  - Find Base Stations
  - SmartBase™ Quality Check
  - Applanix SmartBase™
  - GNSS-Inertial Processor
  - Generate Exterior Orientation
  - POSGNSS 5.1

POSPac™ MMS



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What is POSPac MMS?

- **POSPac Mobile Mapping Suite (MMS) is a user-friendly suite of tools used to create an accurate solution of position, orientation, and dynamics from the GNSS and IMU data collected with Applanix's POS LV system.**
- **POSPac provides and displays all of the information necessary to analyze the navigation solution to ensure its quality.**

Input

- **Raw POS LV data**
- **Base station data**

Output

- **SBET Solution**

Figure 1: POSPac Inputs and Outputs

What is POSPac MMS?

- The generations of POSPac are shown on the rough timeline below.
- POSPac MMS can be used for land, air and marine vehicle applications.
- POSPac Land 5.0 can be used for land vehicle applications only.

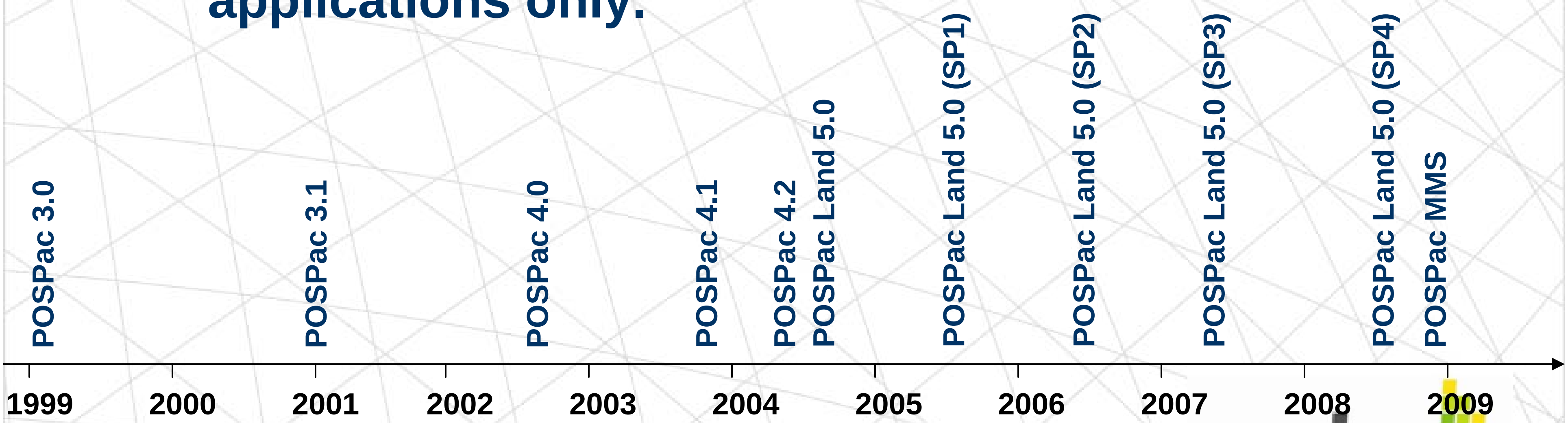

Figure 2: POSPac Generations

Loosely Coupled GNSS/INS

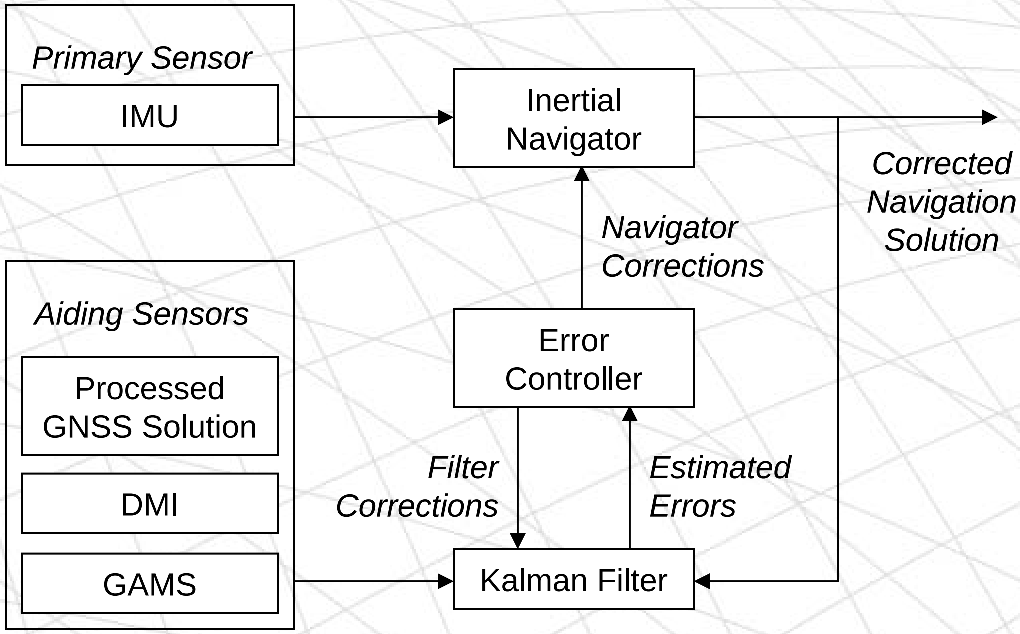

Figure 3: Loosely Coupled GNSS/INS Kalman Filter

- **GNSS errors are estimated, and corrected for, in an independent GNSS Kalman Filter.**
- **The processed GNSS solution aids the inertial solution in a GNSS/INS Kalman Filter.**
- **Used in Real Time, Differential, and PPP GNSS Modes in POSPac MMS and POSPac 4.**

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Tightly Coupled GNSS/INS

- **Single Kalman Filter is used to estimate inertial and GNSS errors.**
- **Uses Inertially-Aided Kinematic Ambiguity Resolution (IAKAR)**
- **Used in SmartBase and Single Base GNSS modes in POSPac MMS**

Advantages of IAKAR:

- Maintains inertial position accuracy during GNSS outages - maintains "memory" of ambiguities
- Aids in rapid ambiguity resolution after an outage leading to an improved ability to maintain centimeter level position accuracy

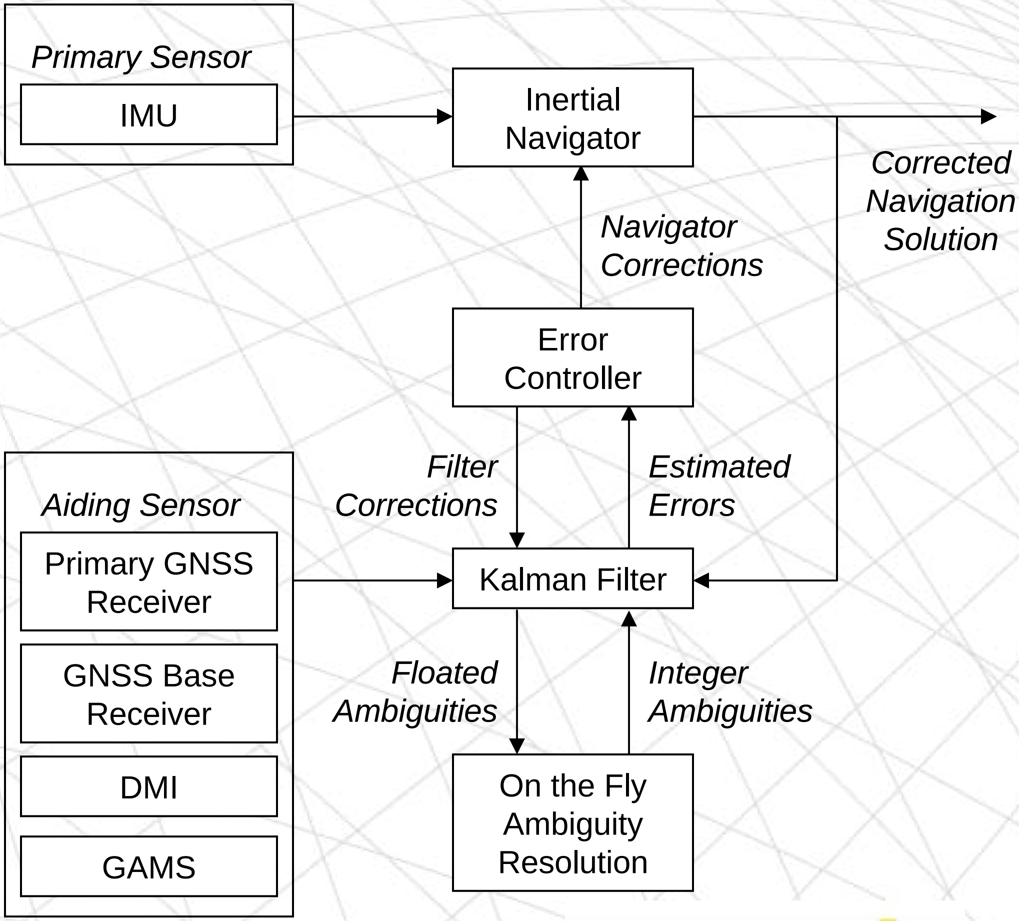

Figure 4: Tightly Coupled GNSS/INS Kalman Filter

Loosely vs. Tightly Coupled GNSS/INS

	Loosely Coupled	Tightly Coupled
Advantages	• Processed GNSS solution can be reviewed and refined	• IAKAR makes rapid ambiguity resolution possible, allowing position accuracy to recover quickly after GNSS outages • Observables from 1 or more satellite will aid the solution
Disadvantages	• GNSS outages should be kept to a minimum for the highest accuracy solutions • 5 or more satellites required to aid the solution	• "Black Box" processing – the user has less ability to refine the GNSS solution used

Table 1: Loosely vs. Tightly Coupled GNSS/INS Processing

POSPac Land 5.0 vs. MMS

	POSPac Land 5.0	POSPac MMS
Aided Inertial Processing Engine	Tightly Coupled (Navigate)	Loosely or Tightly Coupled (GNSS-Inertial Processor)
GNSS Processing Engine	Single Base Station Processing	Applanix SmartBase™ or POSGNSS 5.1
Required Baseline Length	Less than 30km	70km+
Number of satellites required	5+	1+
Improved Robustness		✓
Modern Graphical User Interface (GUI)		✓

Table 2: POSPac Land 5.0 vs. MMS

POSPac Land 5.0 vs. MMS

- **POSPac MMS contains all of the functionality of POSPac Land 5.0, plus:**
  - Applanix SmartBase^{TM} technology
  - IN-Fusion^{TM} technology
  - POSGNSS module
  - External Orientation output utility
  - Easy-to-use Batch processing
  - Automatic base station downloads/adjustment
  - Modern GUI

Applanix SmartBase^{TM} (ASB^{TM})

- **What is Applanix SmartBase^{TM}?**
  - Post-Processed Virtual Reference Station (PPVRS)
  - Joint development by Trimble GNSS Centre of Excellence and Applanix
  - Based on Trimble VRS^{TM} technology
- **How does it work?**
  - Uses a network of reference stations
  - Performs ambiguity fixed solution
  - Spatially models ionospheric and geometric errors at base and rover locations
  - Generates an optimal observation set for a VRS near the rover location

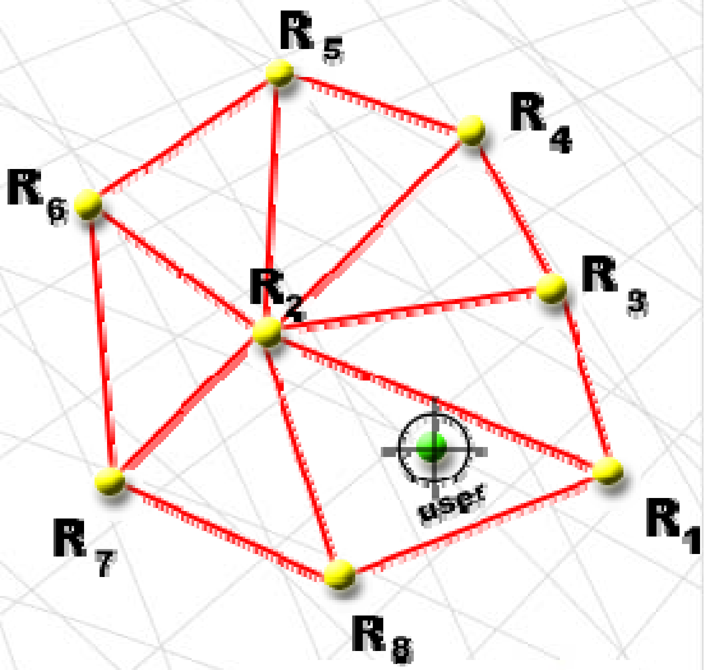

Figure 5: Virtual Reference Station Network

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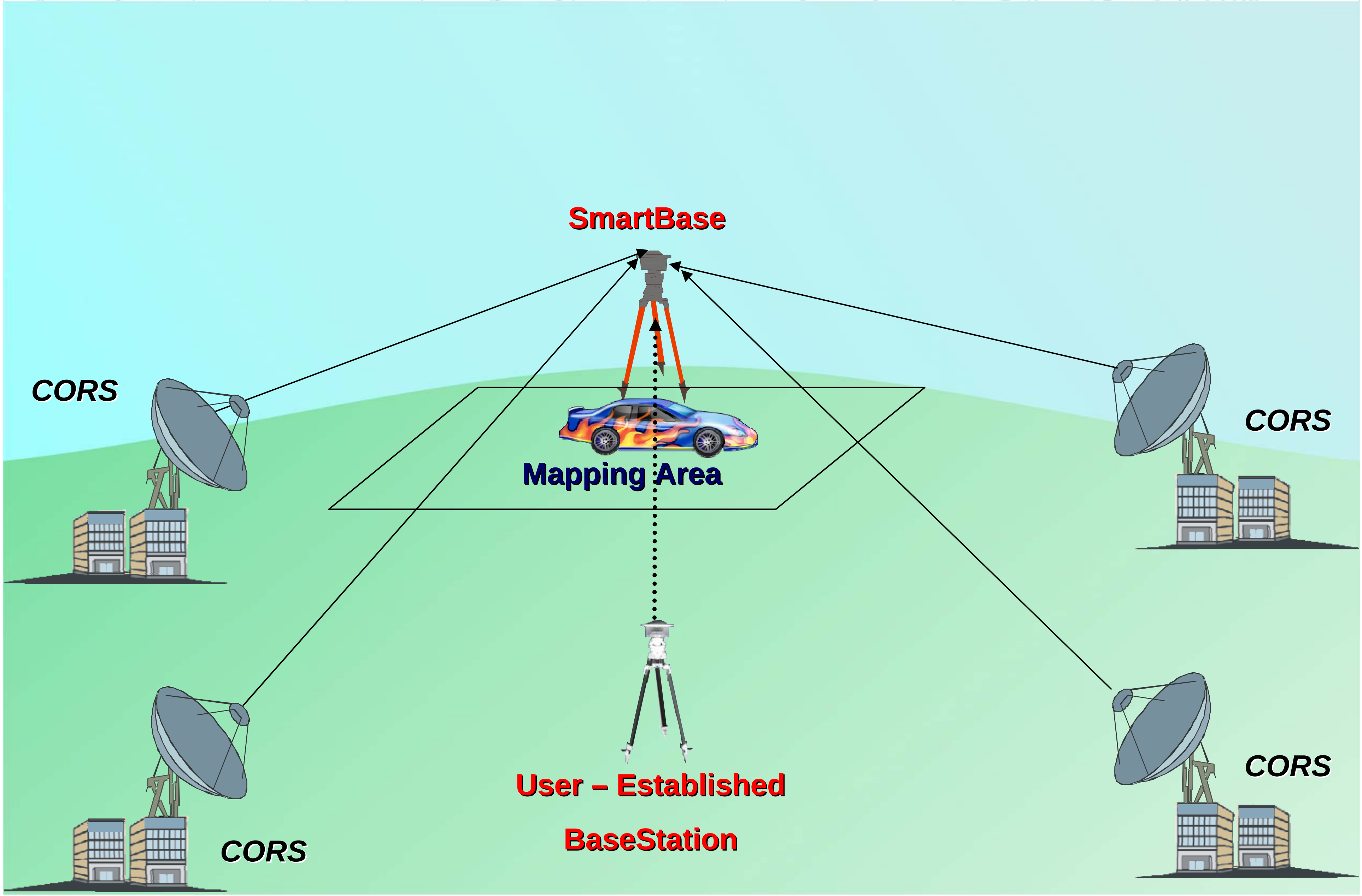
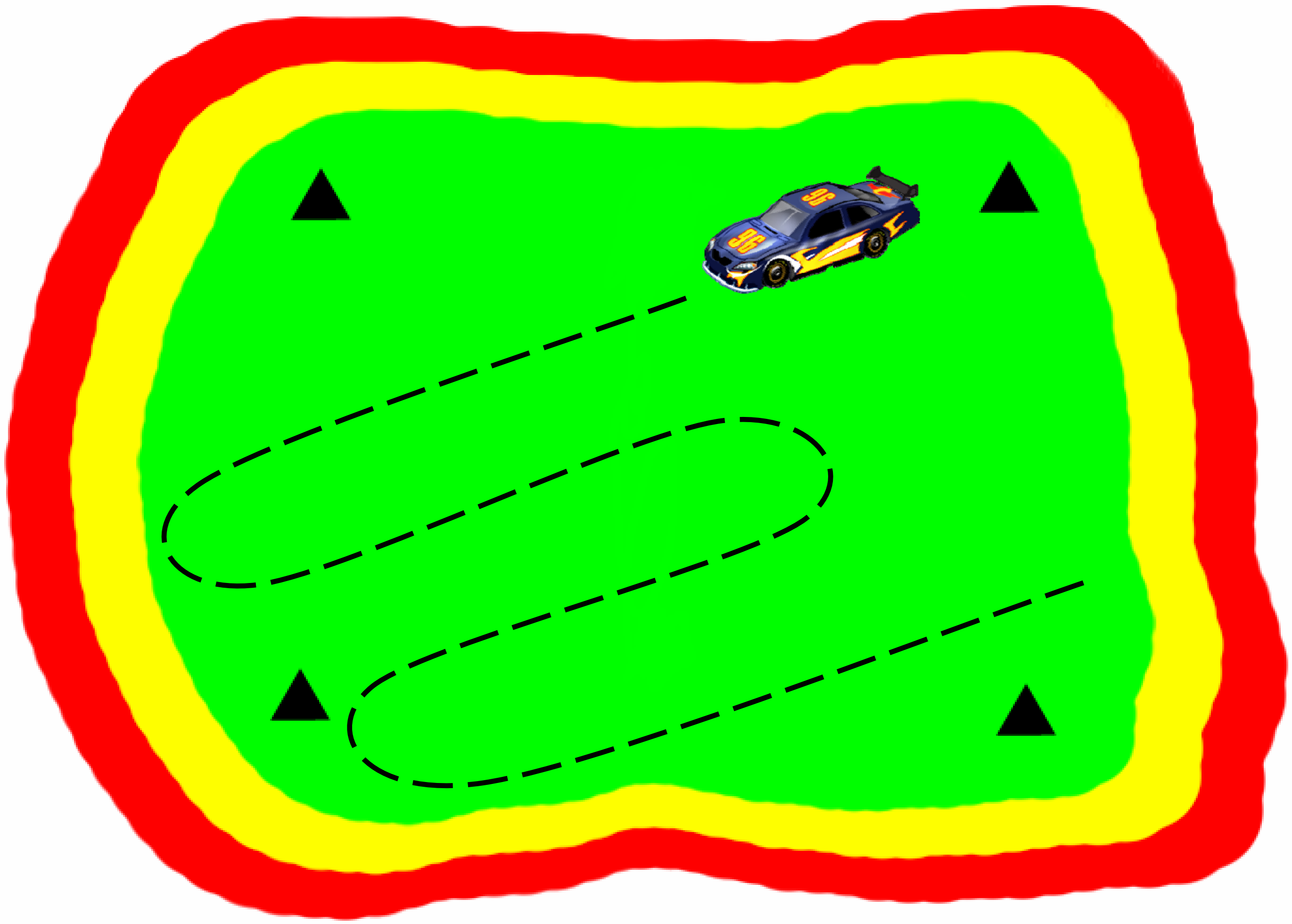
Applanix SmartBase (ASB™)



Applanix SmartBase (ASB^{TM})



IN-Fusion™

- A tightly coupled GNSS/INS processor.
- Uses IAKAR to resolve ambiguities robustly and rapidly.
- Provides optimal results when using SmartBase™ solution.
- Can also be run in Single Base processing mode.

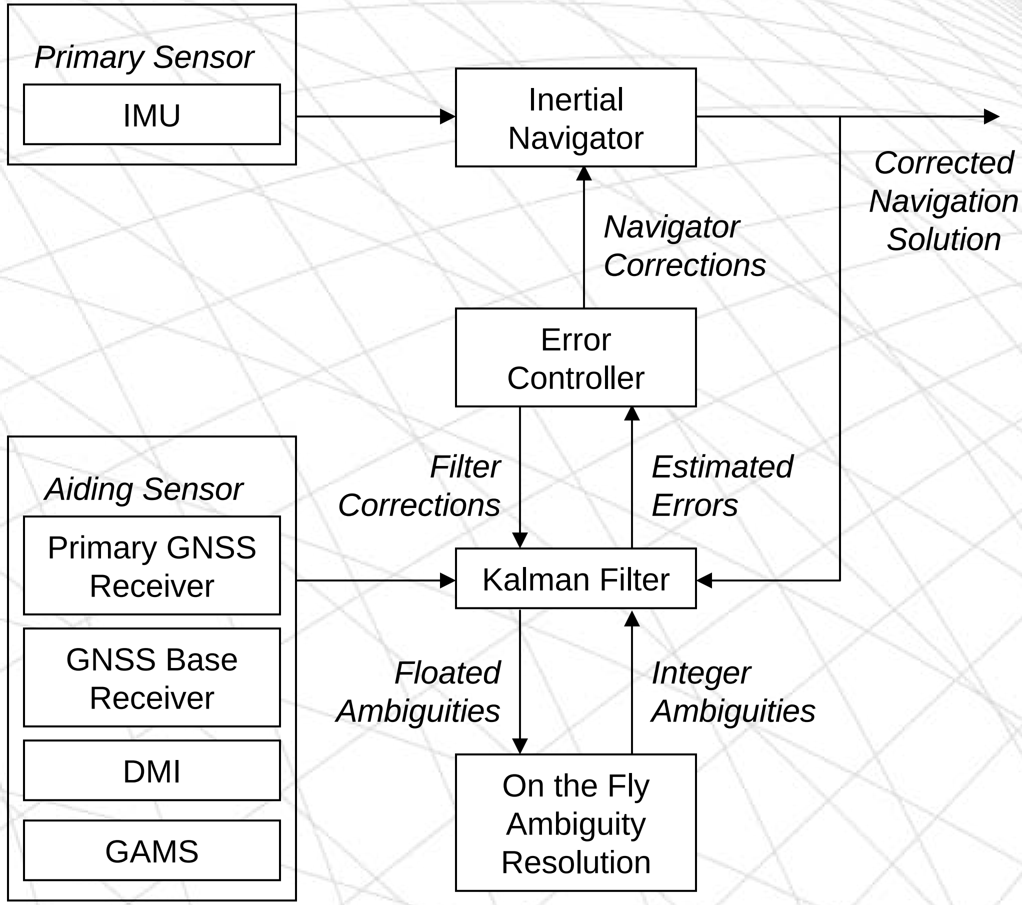


Figure 6: Tightly Coupled GNSS/INS Kalman Filter

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IN-Fusion™

- **Four processing steps:**
  - Forward
  - Backward
  - Combined
  - DMI Smoothing
- **Used to reduce inertial drift that occurs during GNSS outages.**
- **Generates a Smoothed Best Estimate of Trajectory (SBET) with greater precision and reliability.**

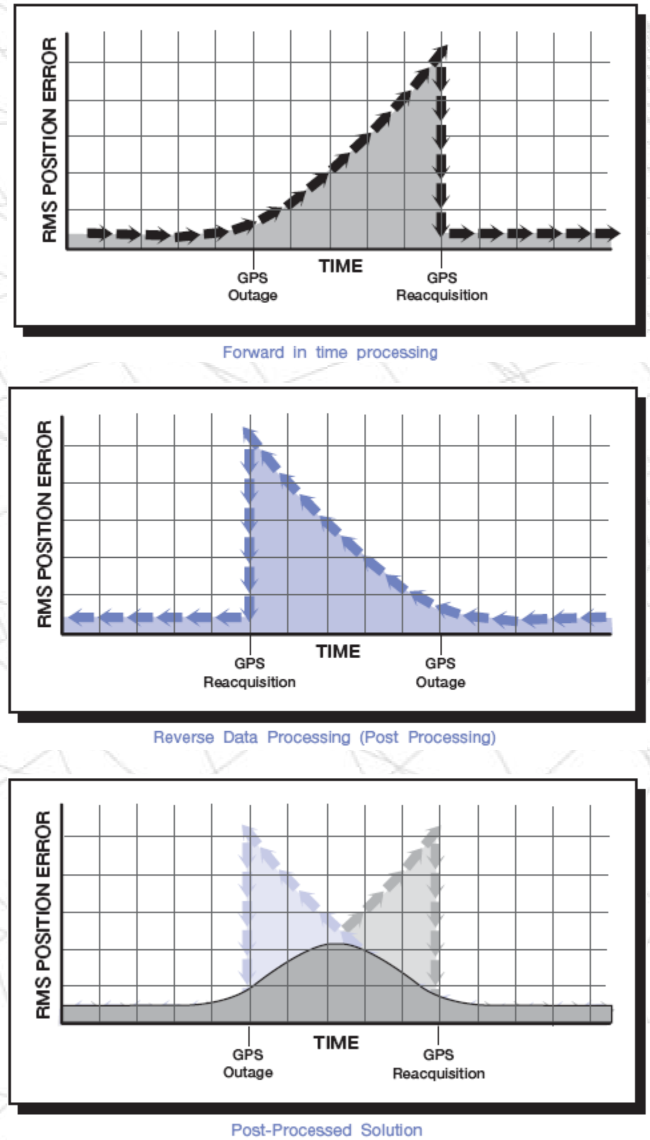


Figure 7: GNSS-Inertial Processor steps

Applanix SmartBase™ and IN-Fusion™

- **Together, Applanix SmartBase™ and IN-Fusion™ allow high-accuracy land positioning without the need of:**
  - Starting close to a reference station to initialize
  - Driving close to a reference station to meet required accuracy
  - Setting up a dedicated reference station or network
- **Improves accuracy, robustness, and reliability of the trajectory**
- **Improves productivity**

POSPac MMS Processing Modes

- **GNSS-Inertial Processor Processing Modes:**
  - Applanix SmartBase™ and IN-Fusion™
  - IN-Fusion™ Single Base
  - POSGNSS Loosely Coupled
  - Real-Time Loosely Coupled

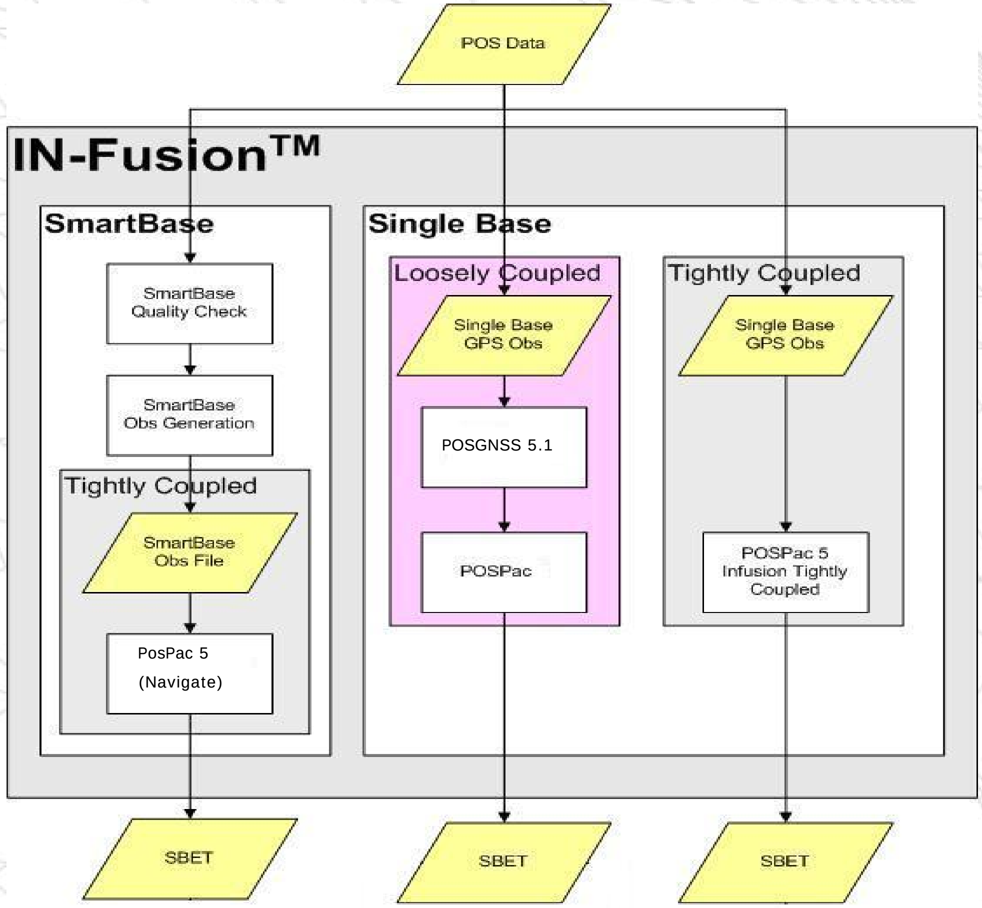


Figure 8: GNSS-Inertial Processor Processing Modes

POSPac MMS Processing Modes

	Applanix SmartBase™ and IN-Fusion™ Processing		IN-Fusion™ Single Base Processing		POSGNSS Loosely Coupled Processing		Real-Time Loosely Coupled Processing	
	Optimal Accuracy[c]	**Reduced Accuracy**	**Short Baseline**	**Long Baseline**	**Differential GNSS**	**PPP**	**Real-Time GNSS**	**Auxiliary GNSS**
Positional Accuracy	3-10cm	10-15cm	<10cm	<10cm	<10cm	10-50cm	4-6m	<1m
Maximum Baseline[a]	70km	>70km[b]	20-30km	100km	30km	n/a	n/a	n/a
Maximum Start and End Baseline[a]	Within SmartBase Network	Within SmartBase Network	10-20km	10-20km	30km	n/a	n/a	n/a
Minimum Number of Base Stations	4	4	1	1	1	0	0	0
Maximum Number of Base Stations	50 (recommend 6-10)	50 (recommend 6-10)	1	1	8	0	0	0
Additional Ephemeris Required?	Y Precise and Broadcast	Y Precise and Broadcast	N	N	N	Y Precise	N	N

Table 3: POSPac MMS Processing Modes

[a] "Baseline" refers to the 3D distance to the nearest base station in the SmartBase™ processing modes, and to the 2D planar distance to the nearest (or single) base station in all other modes.

[b] At some point in the mission, the baseline must be less than 70km for a few minutes.

[c] Typical accuracies apply to good GPS conditions only. Results may vary.

Mission Planning

- **Before implementing a mission, it will be imperative for operators to decide what processing mode they will be using.**

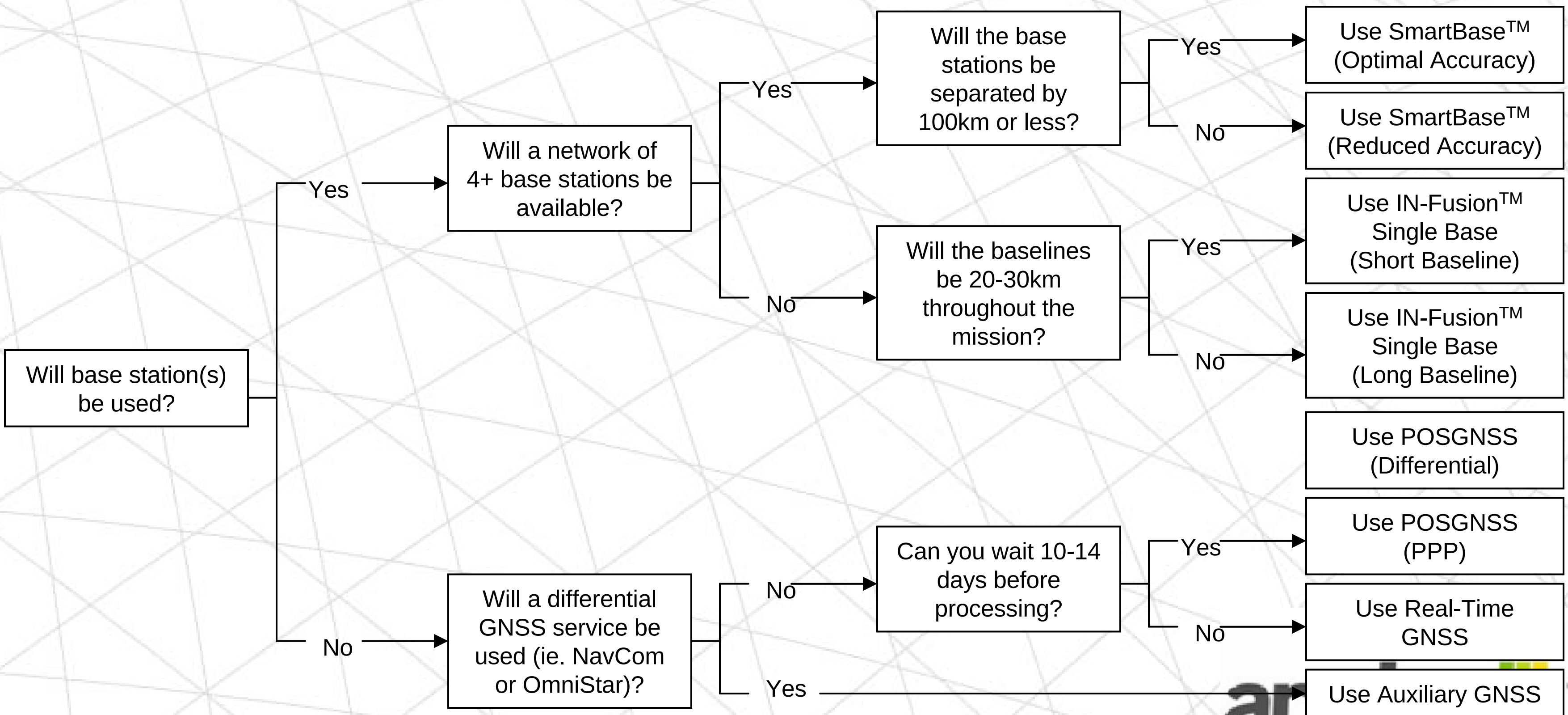
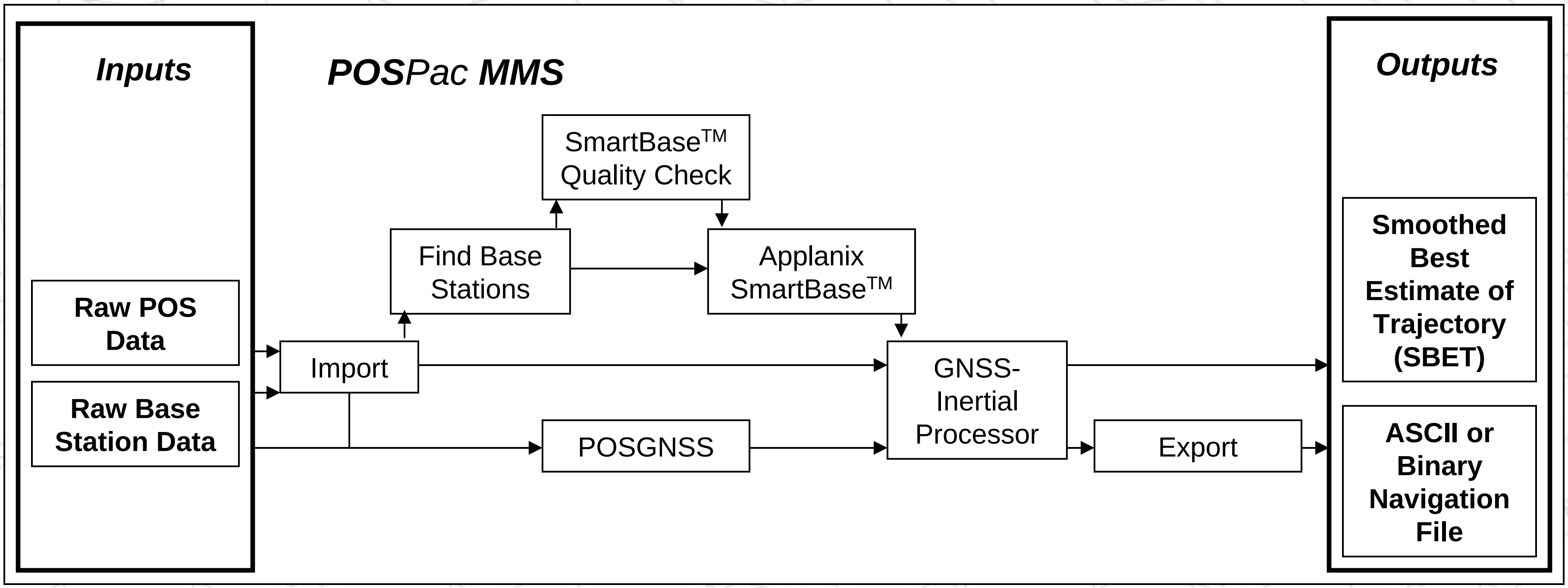


Figure 9: POSPac MMS Processing Mode Decision Tree

POSPac MMS Workflow



POSPac MMS Workflow

- **Aided Inertial Tools** (Options: Navigate, SmartBase^{TM})
  - **Import –** Extracts POS LV and dedicated base station raw data, and imports it into the project
  - **Find Base Stations –** Searches for, downloads, and imports publicly available base station data
  - **SmartBase^{TM} Quality Check –** Performs a network adjustment on base station network
  - **Applanix SmartBase^{TM} –** Generates a post-processed virtual reference station (PPVRS)
  - **POSGNSS –** Post-processes GNSS data
  - **GNSS-Inertial Processor –** Blends IMU and GNSS data to create the Smoothed Best Estimate of Trajectory (SBET)
  - **Export** – Outputs ASCII or binary navigation file

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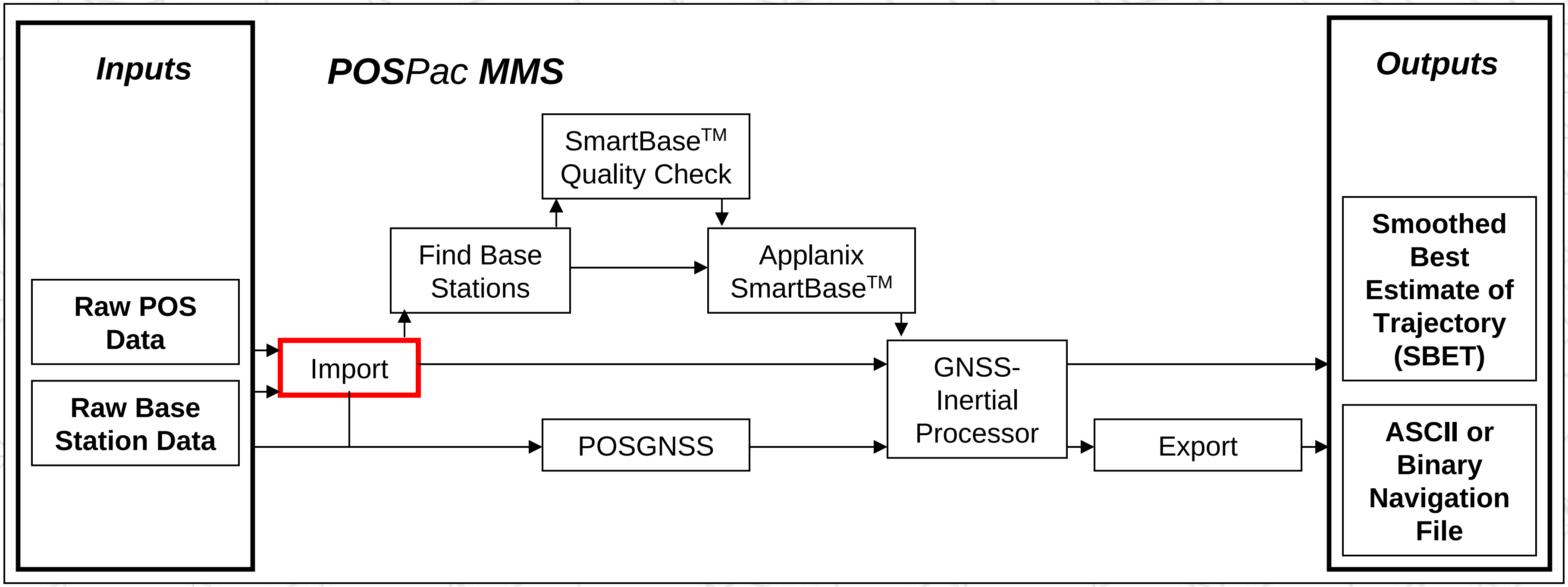
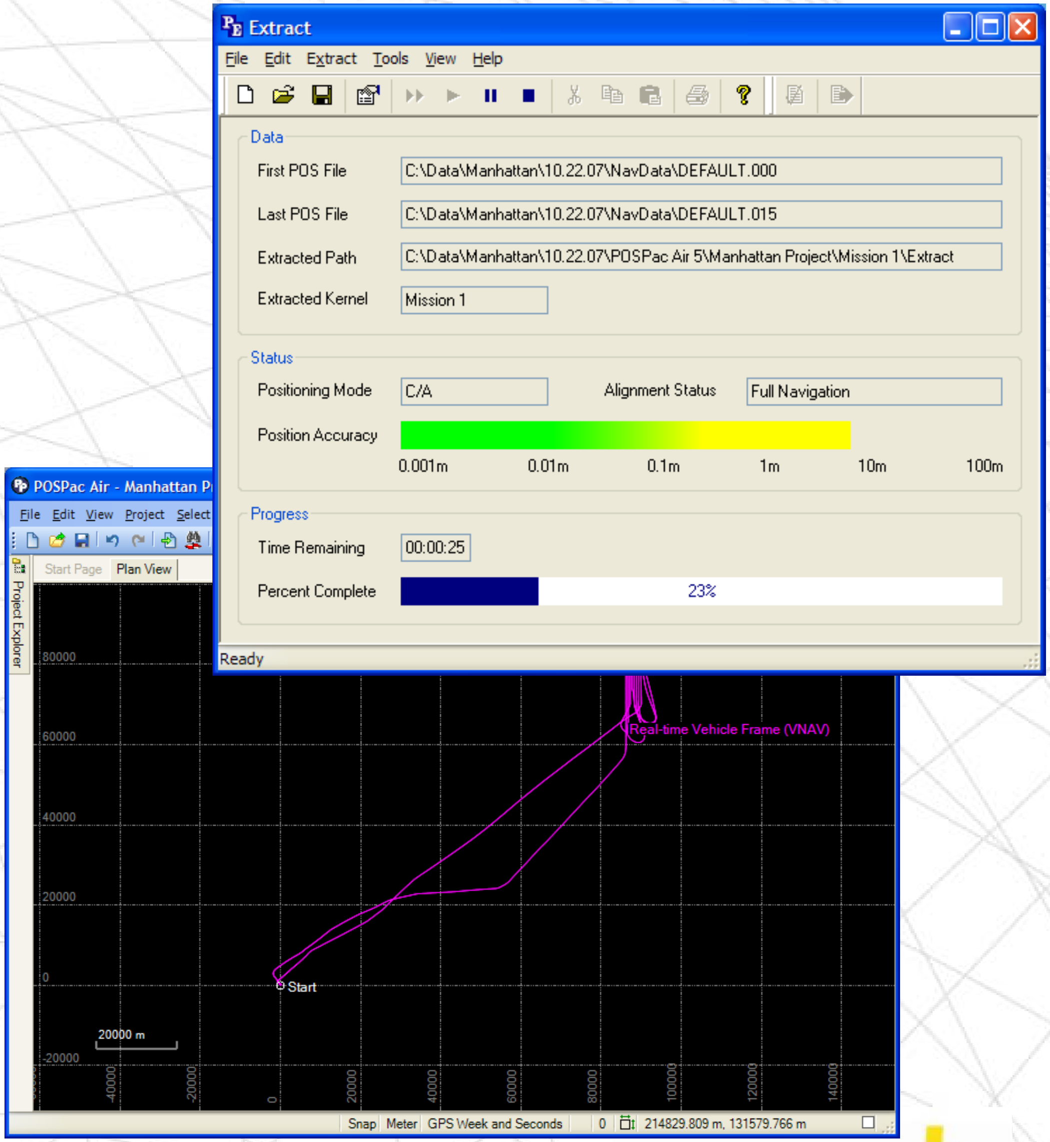
POSPac MMS Workflow



Import

- **Drag and drop raw POS LV files into the Plan View, or use the “Import” icon and select the first POS file to start importing**
- **Review the real time solution by viewing:**
  - Message Logs
    - POS Data Import
    - IMU Data Continuity Checking
    - Primary GNSS Import
  - Real Time Display Plots



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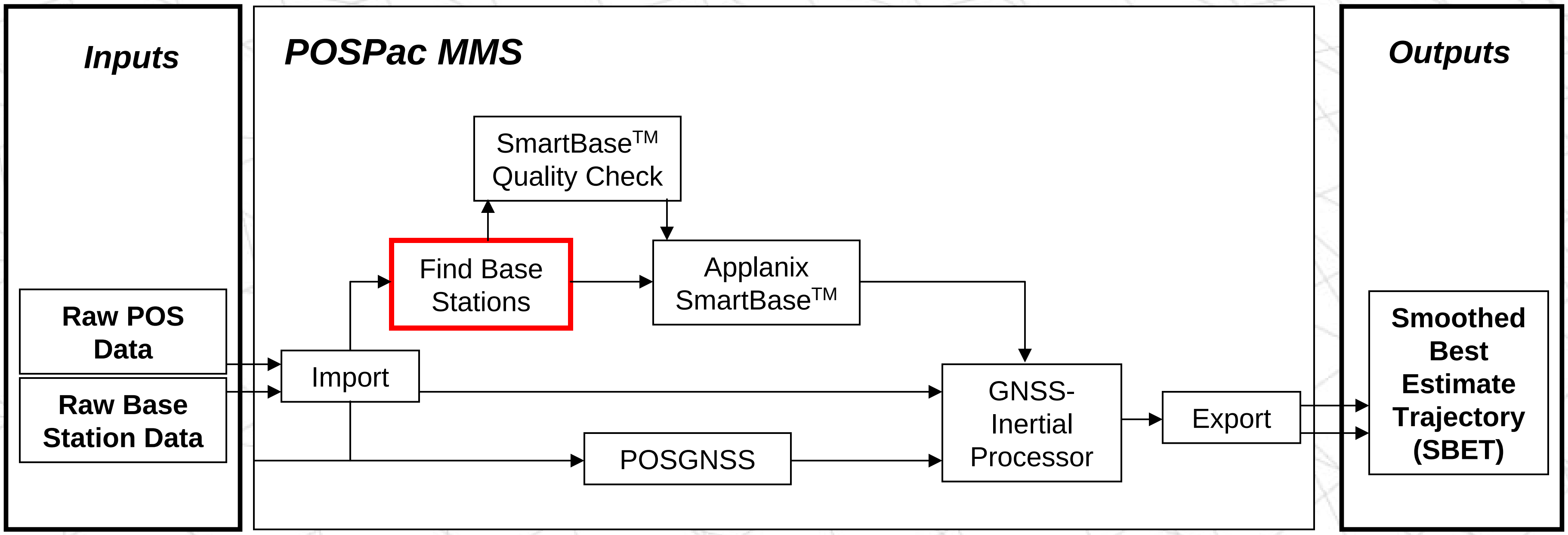
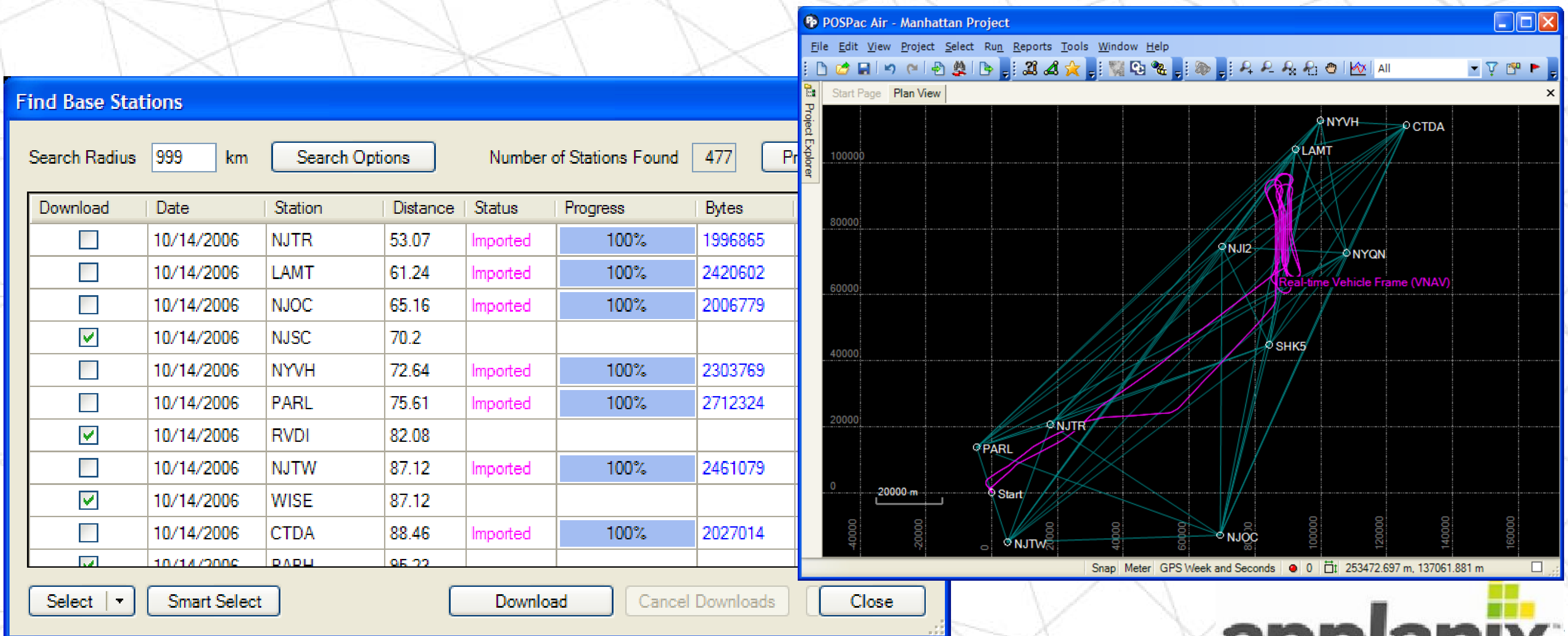
POSPac MMS Workflow



Find Base Stations

- Search for, download, and import base station data publicly available on the internet.
- Download precise and broadcast ephemeris files.
- Use Smart Select button to automate the process.



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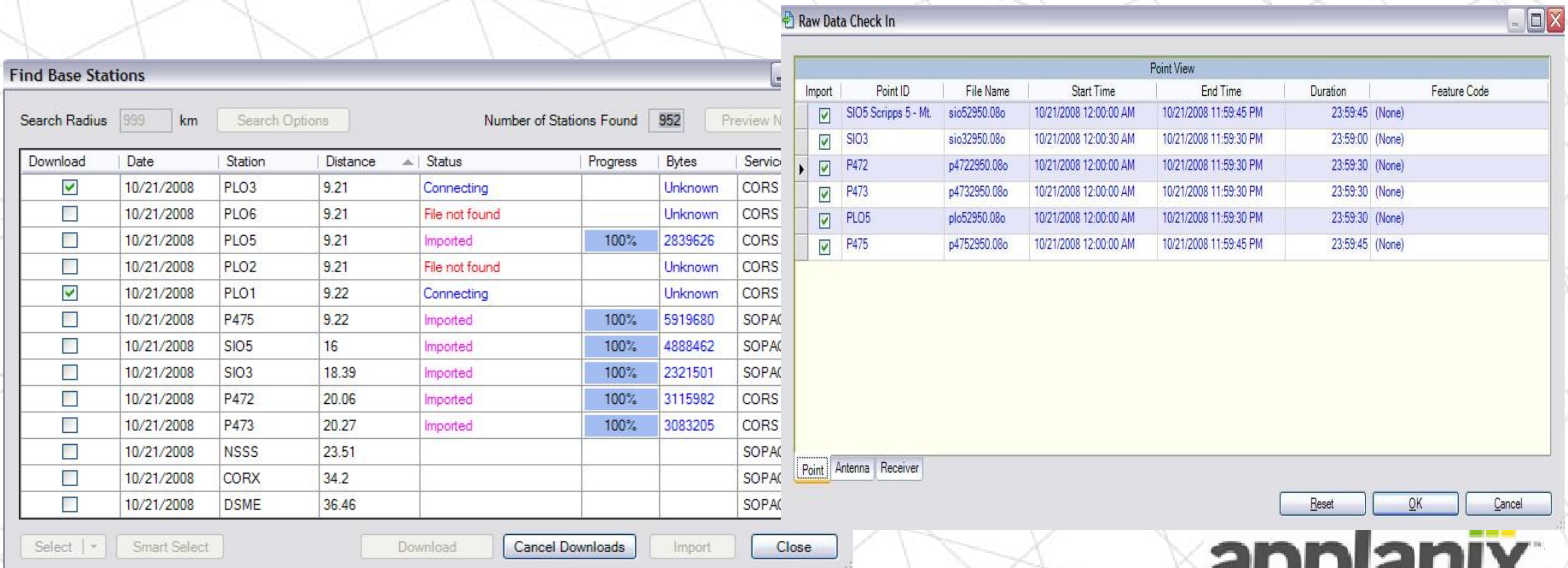
Smart Select

- Downloads 24hrs of data from 6-10 publicly available stations that enclose the mission trajectory.
- Performs data analysis to assign a data indicator for each station based on the duration of clean data, the average PDOP values, as well as number of cycle slips.
- Automatically searches for additional stations if downloaded data does not pass data analysis.



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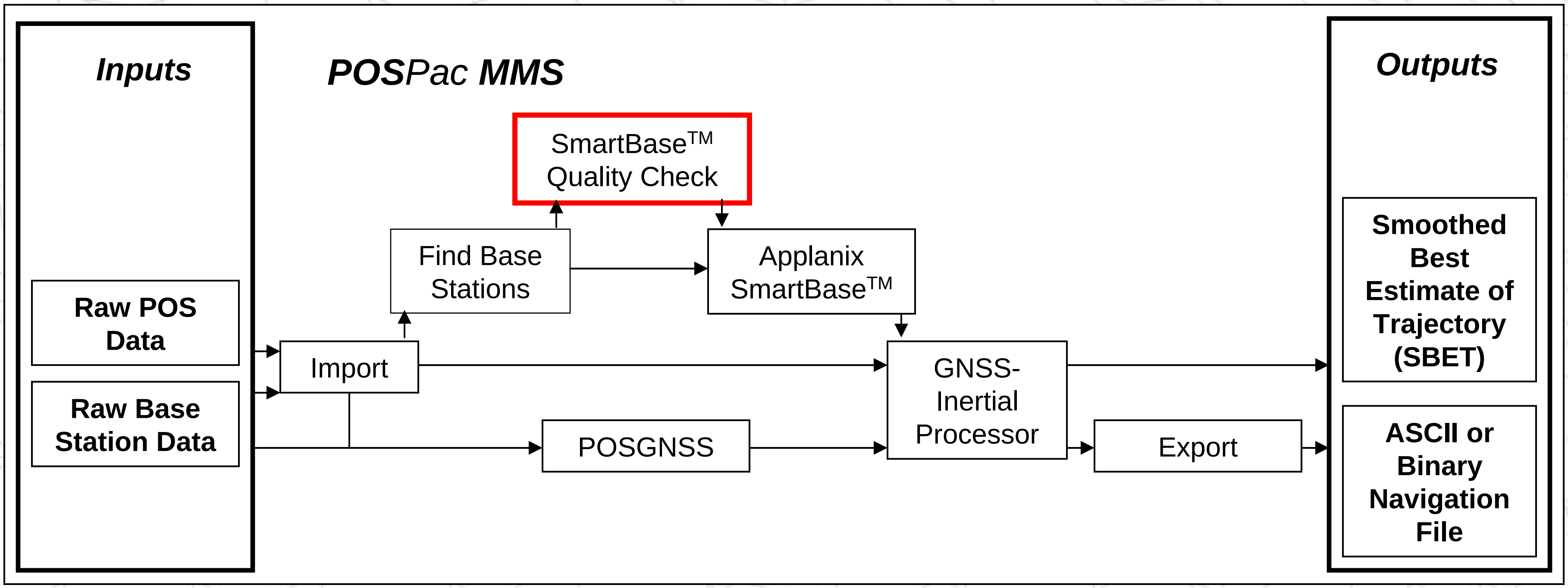
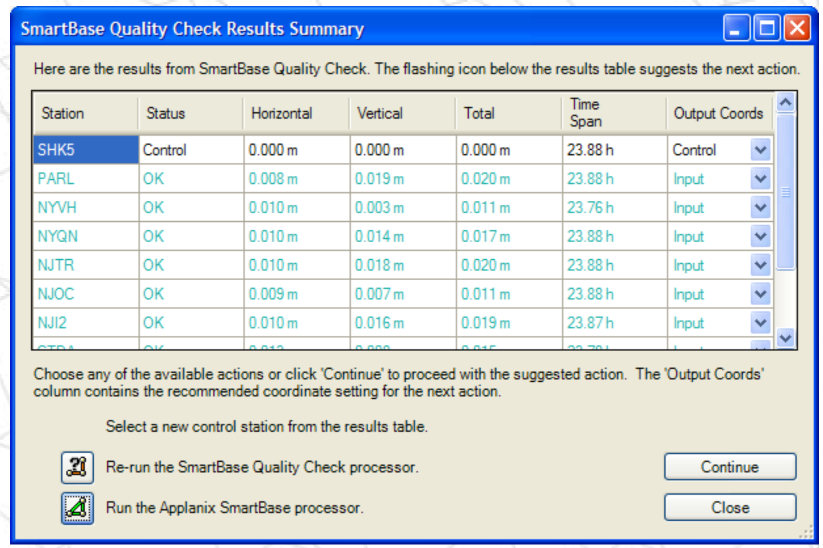
POSPac MMS Workflow



SmartBase^{TM} Quality Check

- **Scans imported base station files to ensure quality.**
- **Quality Check requires:**
  - 18 hrs of continuous data
  - Precise ephemeris files from three days (previous, present, and next)
- **Performs a network adjustment on the stations' coordinates, with one station selected as the Control Station**
- **Need not run Quality Check if using a network of dedicated base stations with accurate coordinates**



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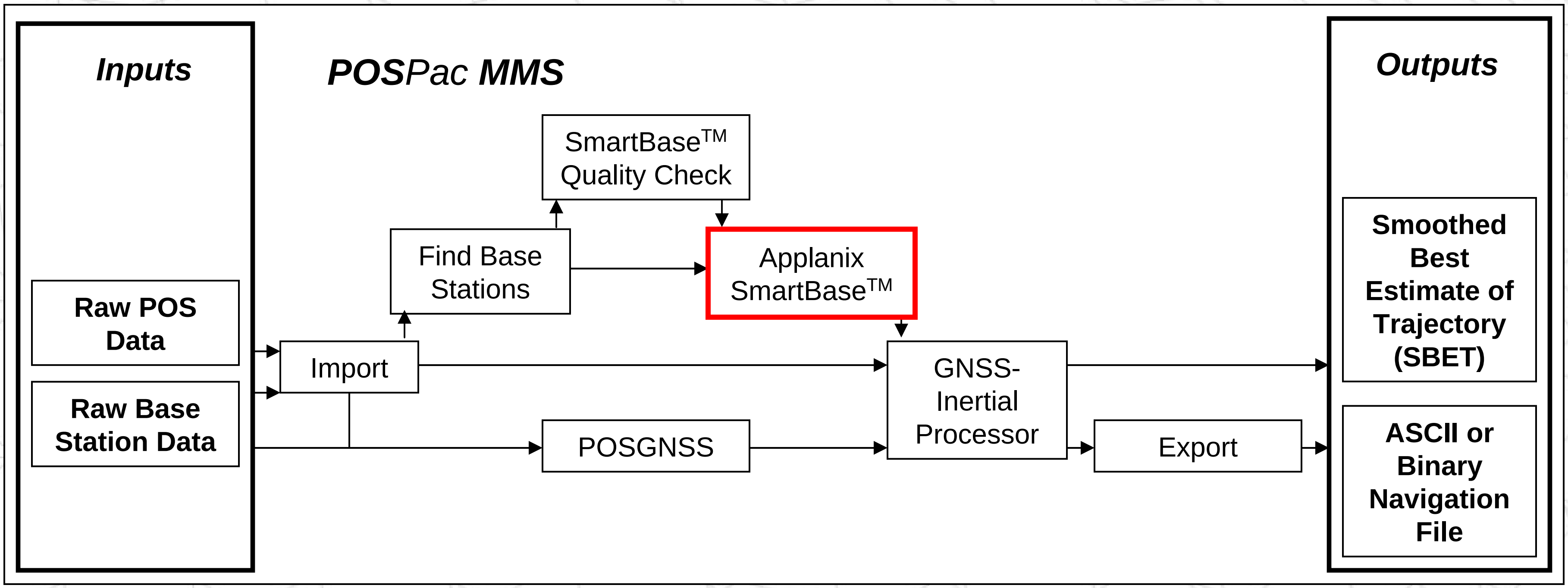
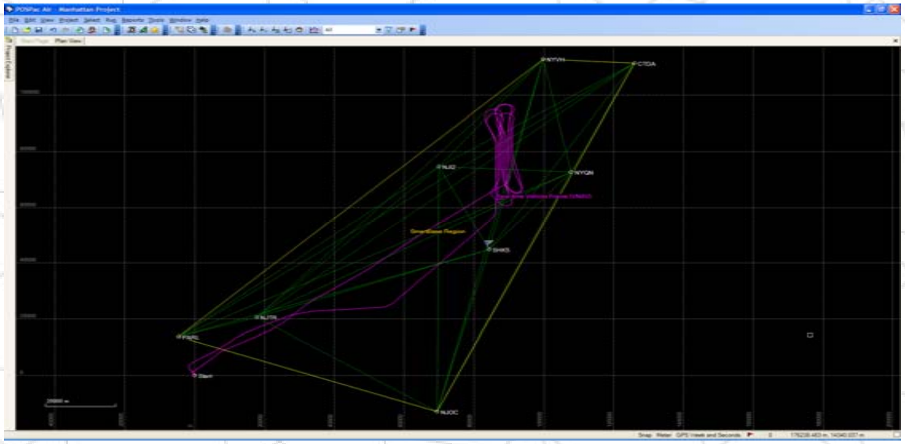
POSPac MMS Workflow

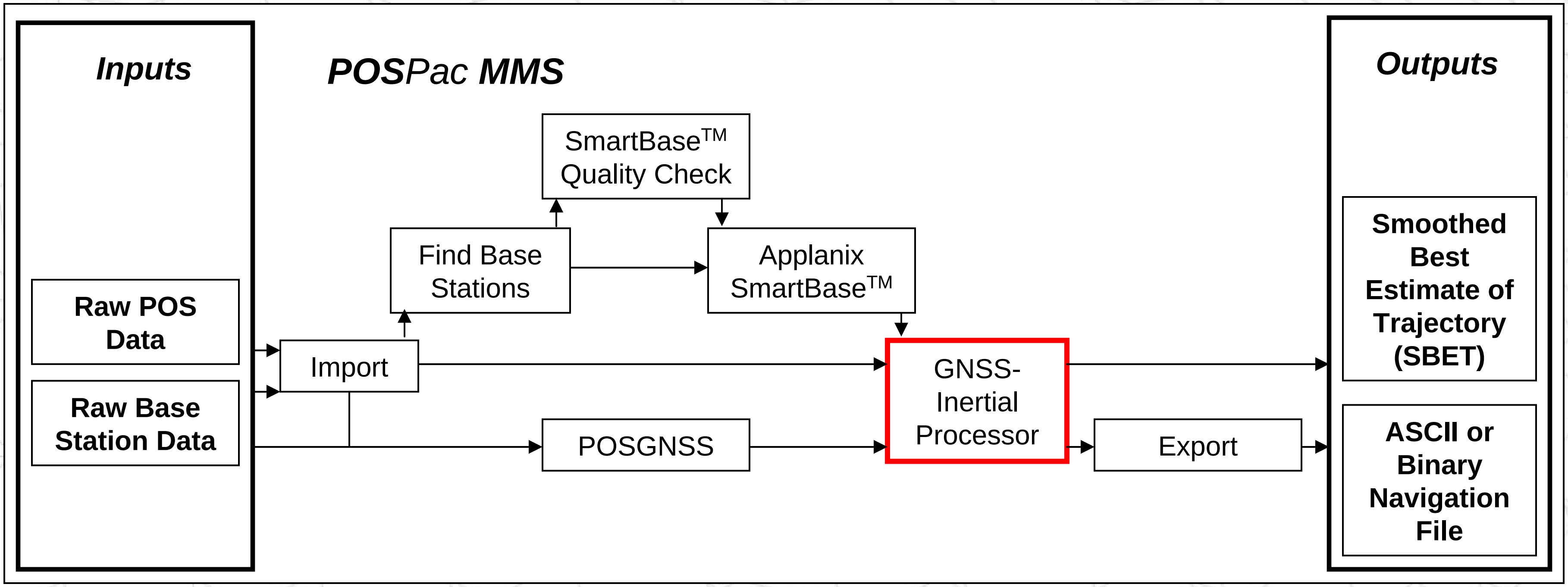


Applanix SmartBase™ (ASB™)

- **The station in closest proximity to the start of the mission trajectory with the highest quality indicator assigned by SmartSelect will automatically be selected as the Primary Station.**
- **The Primary Station must have no data gap larger than 30s and few cycle slips**
- **To ensure a quality solution, review:**
  - Message Logs: Applanix SmartBase™ Processing
  - Display Plots: SmartBase™ Baseline Data

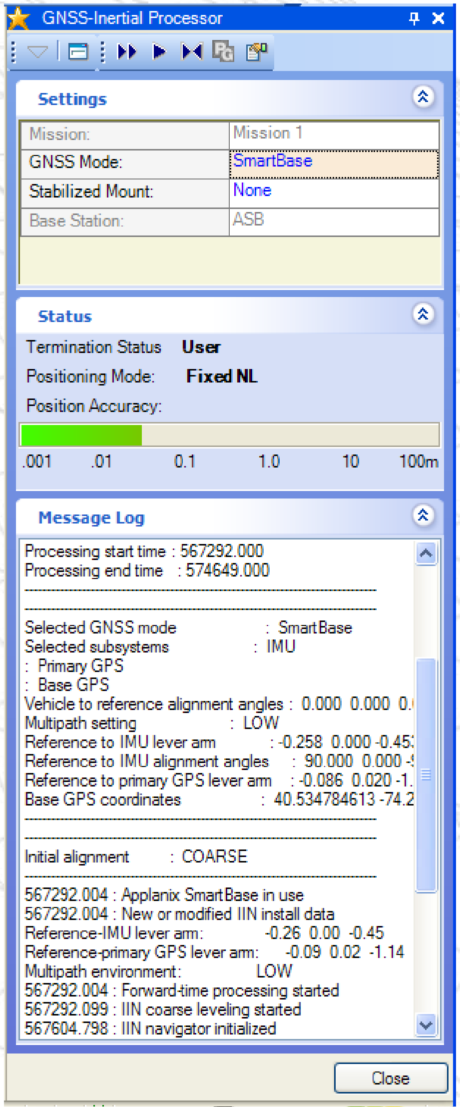


POSPac MMS Workflow



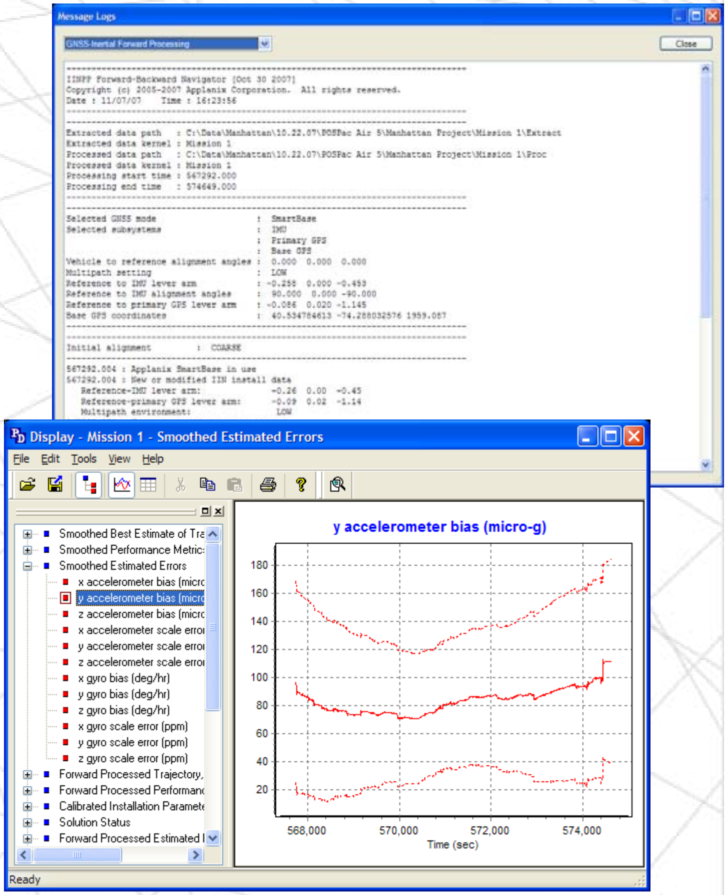
GNSS-Inertial Processor

- **GNSS and Inertial observables are simultaneously manipulated in a tightly coupled fashion to generate a Smoothed Best Estimate of Trajectory (SBET) solution**
- **GNSS Mode is automatically selected, based on the project's imports. Processing modes are:**
  - SmartBase™
  - Single Base Station
  - Differential GNSS
  - PPP
  - Real-time GNSS
  - Auxiliary GNSS
- **Performs a forward and reverse pass, and then combines the two to generate the SBET**



Reviewing GNSS-Inertial Solution

- **To ensure a quality solution, review:**
  - Message Logs
    - GNSS-Inertial Forward Processing
    - GNSS-Inertial Backward Processing
    - GNSS-Inertial Combined Processing
  - Display Plots
    - Smoothed Performance Metrics
    - Calibrated Installation Parameters
    - Solution Status
    - Forward Processed Estimated Errors



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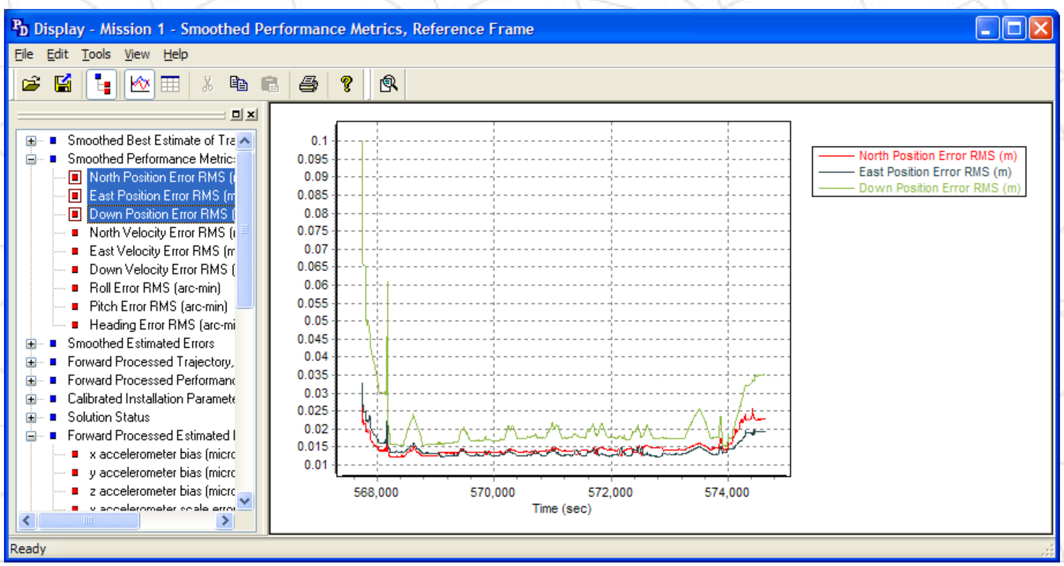
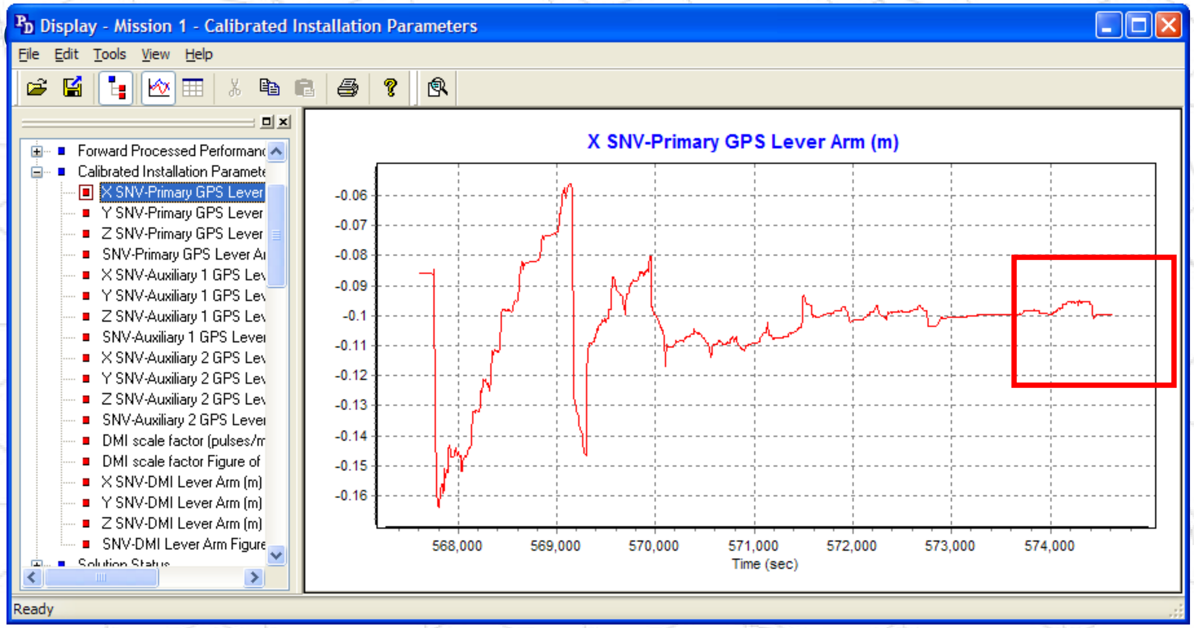
Reviewing GNSS-Inertial Solution

- **The "Smoothed Performance Metrics" should converge on a small value <<10cm unless the environment is challenging. During GPS outages spikes will occur.**
- **Spikes could also indicate cycle slips or data gaps in the Primary Station used in SmartBase^{TM}, or incorrect SNV-GNSS Lever Arm values.**



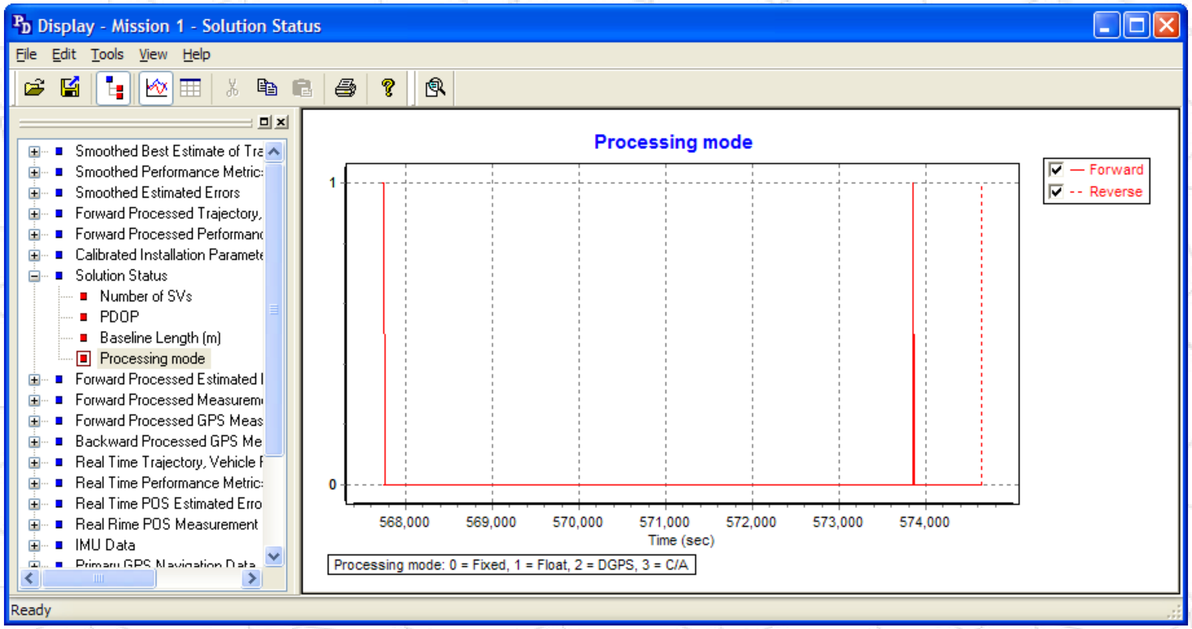
Reviewing GNSS-Inertial Solution

- The "Calibrated Installation Parameter" plots show the estimation of the Reference point to GNSS antenna lever arm values. Applies only if there is good GPS coverage.
- To update the lever arm values entered in GNSS-Inertial Processor settings, input the final value



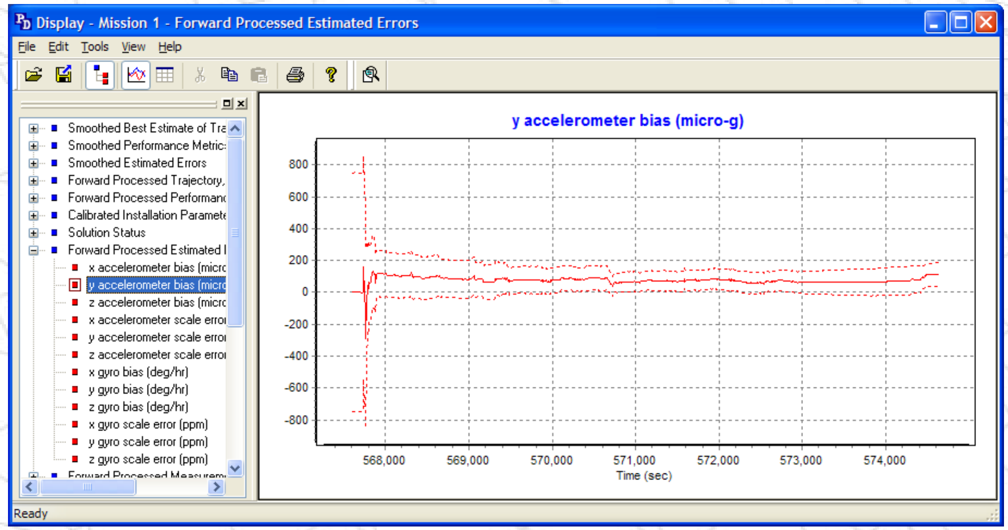
Reviewing GNSS-Inertial Solution

- For the optimal solution, the “Solution Status” Processing mode should be 0 = Fixed for the duration of the mission
- A base station must be located reasonably close to the mission route to maintain the fixed solution



Reviewing GNSS-Inertial Solution

- **The "Forward Processed Estimated Errors" plots show the IMU sensor performance.**
- **Good dynamics and 1-2 hours of data with good GPS coverage are needed to reflect accurate plot results.**
- **All plots should be stable, within the guidelines:**



Estimated Error	Absolute Floor and Ceiling Values	Should not vary by more than…
Accelerometer Bias	±2000 micro-g	500 micro-g
Accelerometer Scale Error	±2000 ppm	500 ppm
Gyro Bias	±10 degrees per hour	5 degrees per hour
Gyro Scale Error	±2000 ppm	500 ppm

Table 4: POS LV 420 IMU Assessment Guidelines

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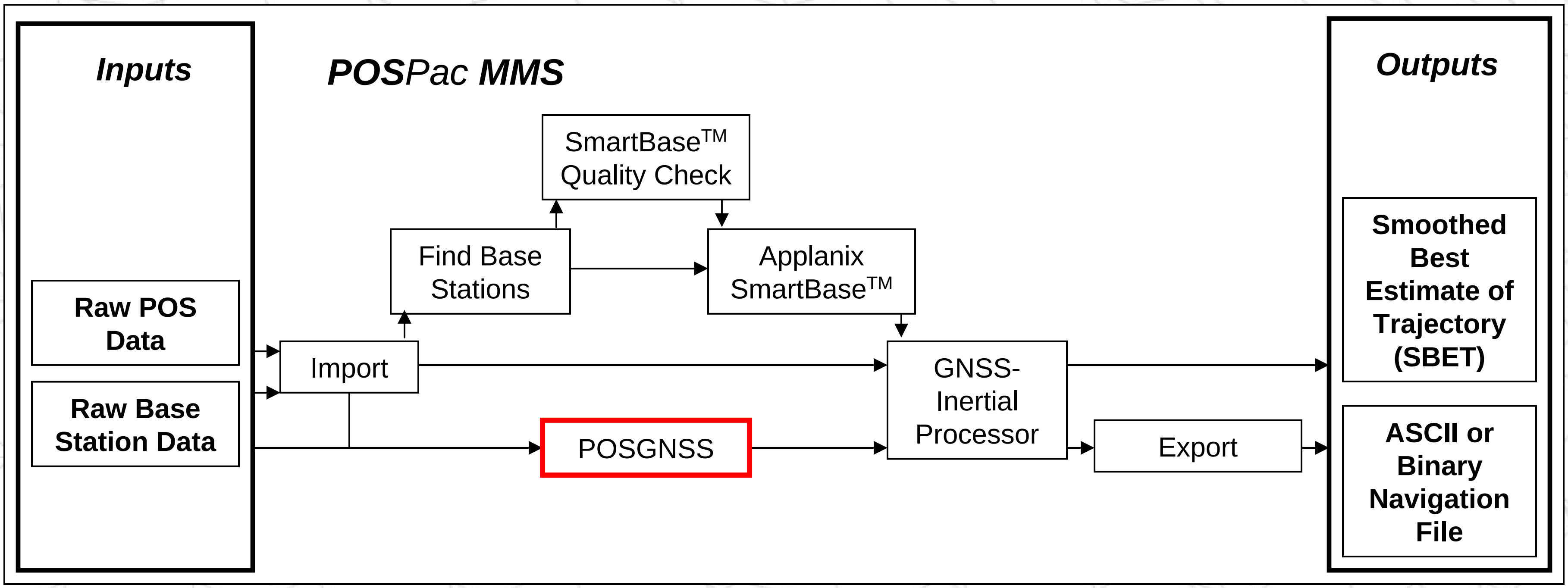
POSPac MMS Workflow



POSGNSS 5.1

- **Two processing modes:**
  - Differential
  - Precise Point Positioning (PPP)
- **Differential:** Double differencing is used to reduce clock and atmospheric errors. Requires a base station with known coordinates and GNSS data from POS LV.
- **Precise Point Positioning (PPP):** Download precise ephemeris and clock files to reduce errors in satellite positions and clocks. Does not require a base station.
- PPP processing is not recommended for normal LV data sets.

POSGNSS 5.1

	Differential Processing	Precise Point Positioning (PPP)
Advantages	• Positional accuracies of less than ~10cm possible.	• Positional accuracies of 10-50cm are possible, depending on mission conditions. • No base station is required.
Disadvantages	• Base station of known coordinates is required to be within 30km of the vehicle for the duration of the mission for optimal results.	• There is a latency of 10-14 days before precise ephemeris files are available on the internet for download. The latency for ultra-rapid and rapid ephemeris files are 6 and 13 hours, though using these files will reduce the achievable accuracy. • The PPP filter takes time to converge, requiring ~30min of logged data before and after a mission.

Table 5: Differential vs. Precise Point Positioning GNSS Processing

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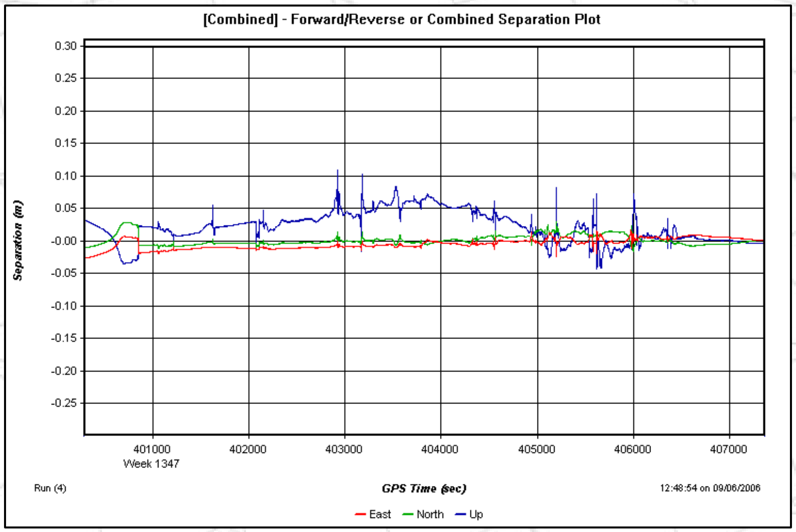
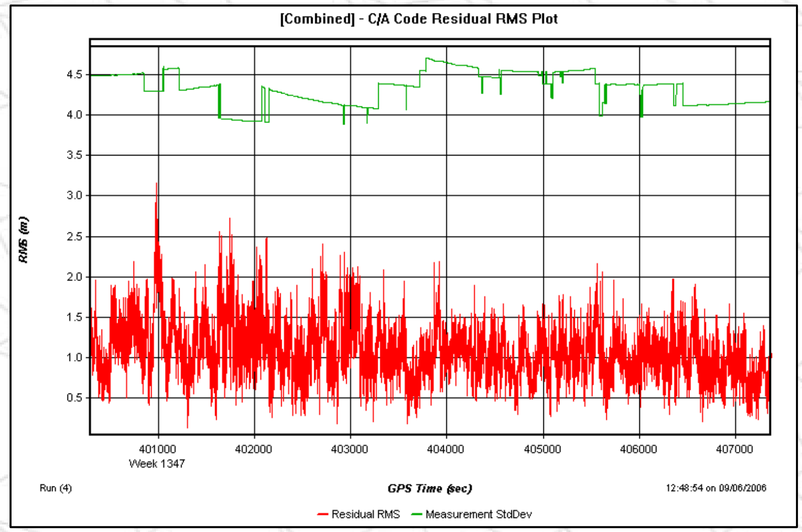
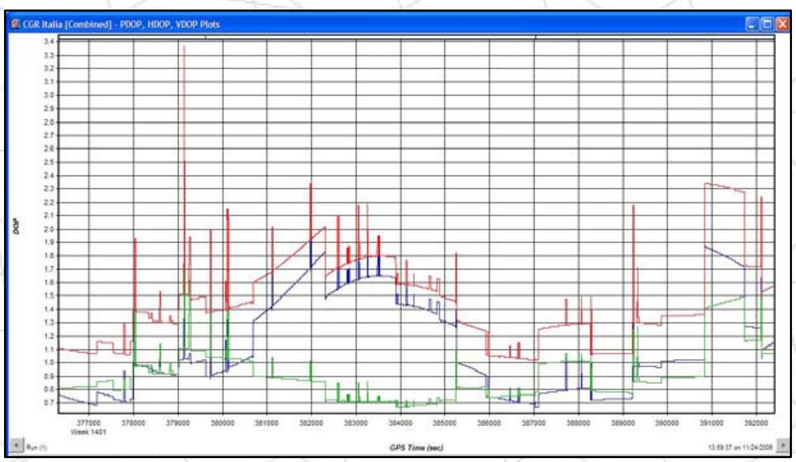
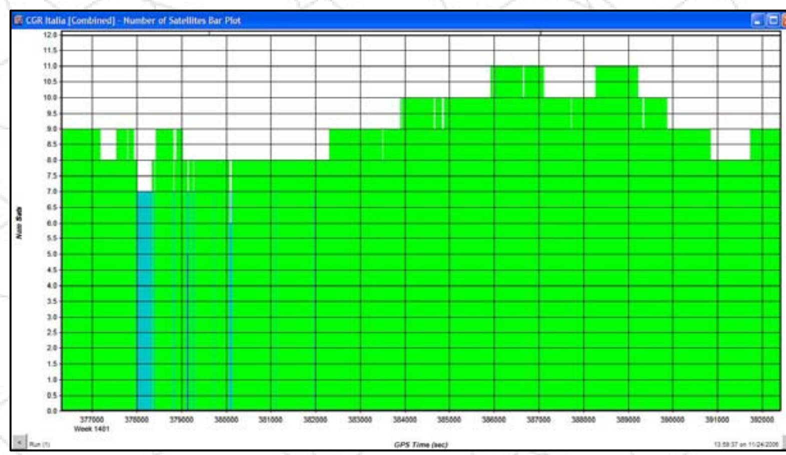
POSGNSS 5.1

- **Review GNSS solution**

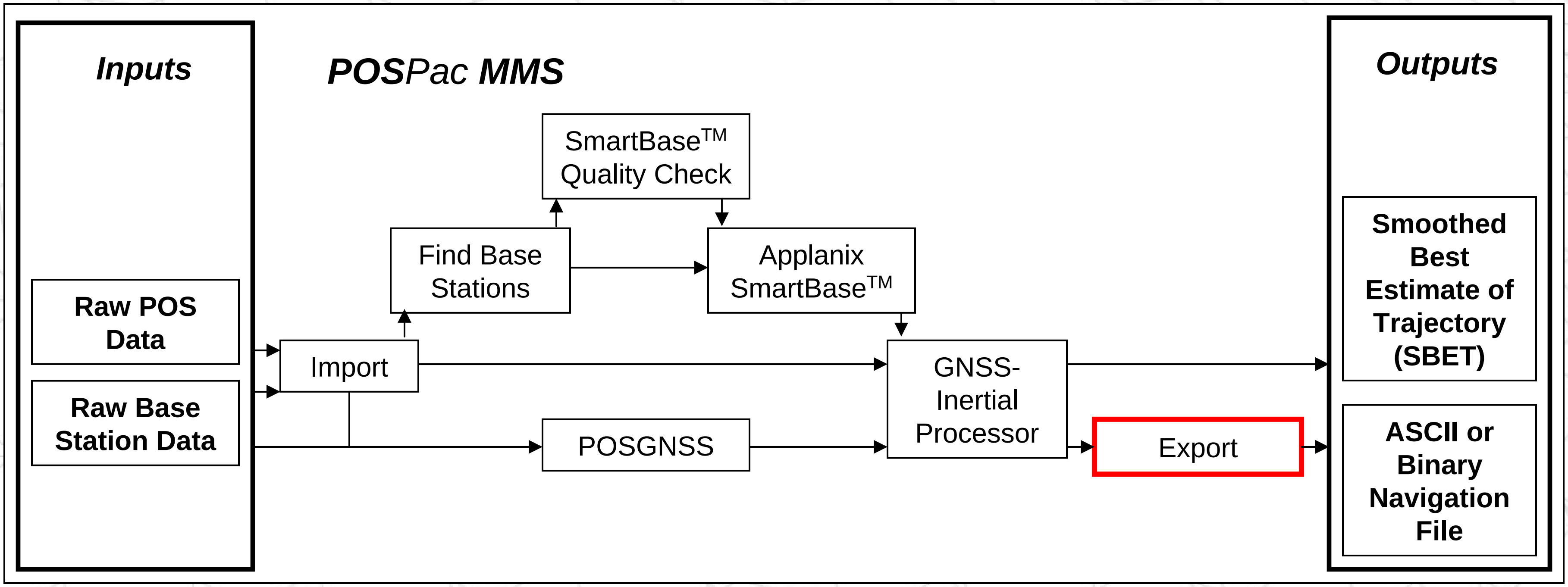




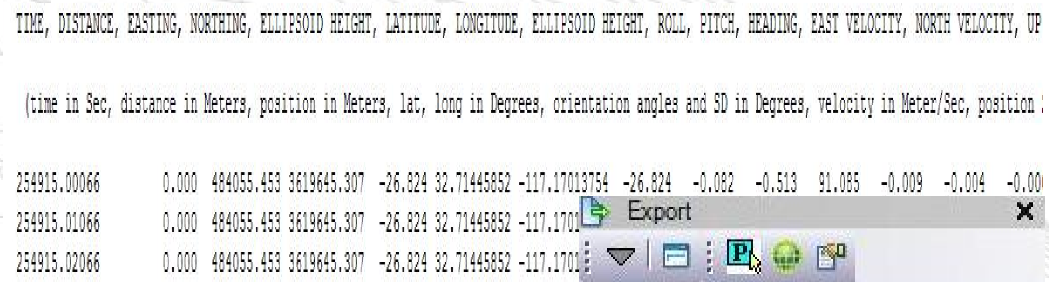




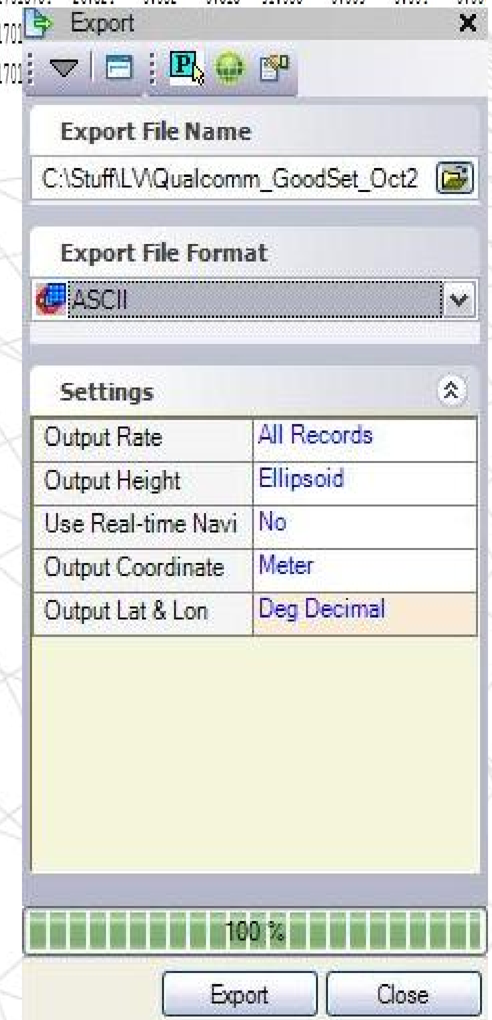
POSPac MMS Workflow



Export



- Navigation solution can be exported in user defined formats including Google's KML.
- User defined units, as well as time or distance interval output options are available.
- Export ellipsoidal or orphtometric heights in ASCII or Binary file formats.



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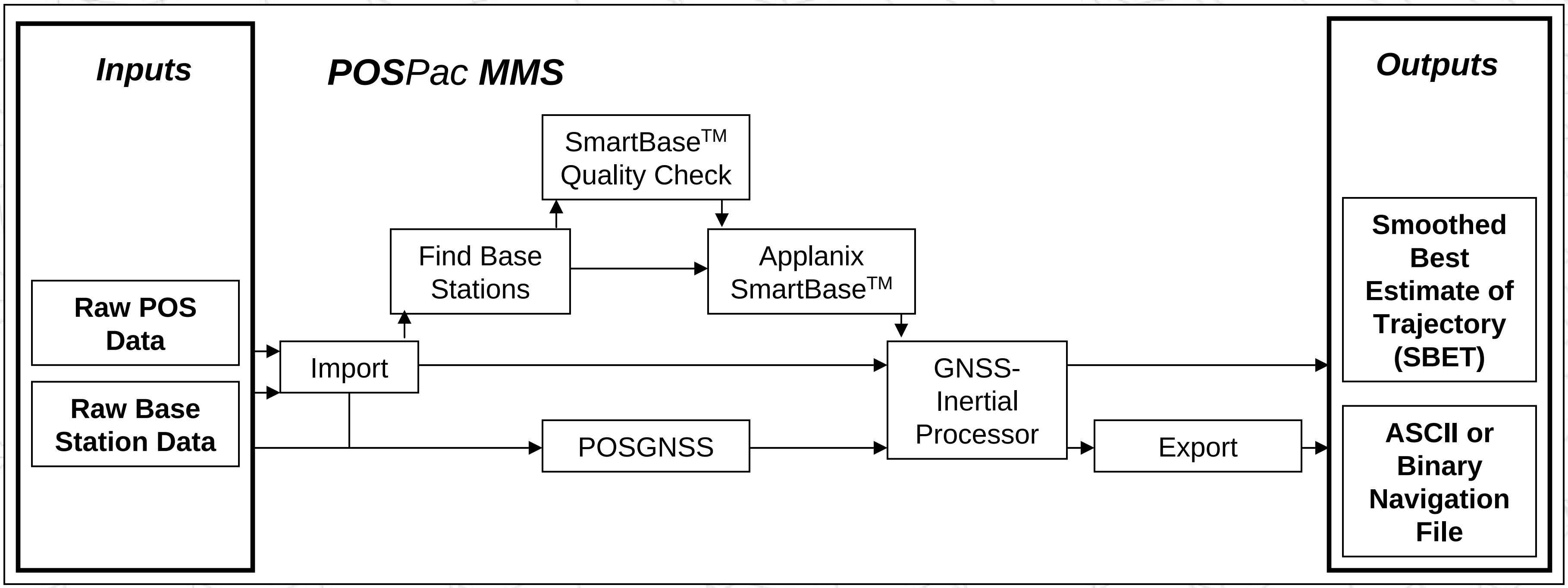
NAD83 & WGS84

- The original NAD 83 reference frame has been retained throughout the years, even though that frame is not geocentric by about 2 meters.
- This has lead to two seemingly contradictory statements found in literature:
    - WGS 84 is identical to NAD 83
    - WGS 84 differs from NAD 83 by about 2 meters.
- The 2 meter "error" between datums is not really an error, but rather a difference in the location of the origin.
- Satellite ephemeris is given in WGS84, so GPS positions are WGS84.

OmniSTAR Broadcast Corrections in NAD83 in North America

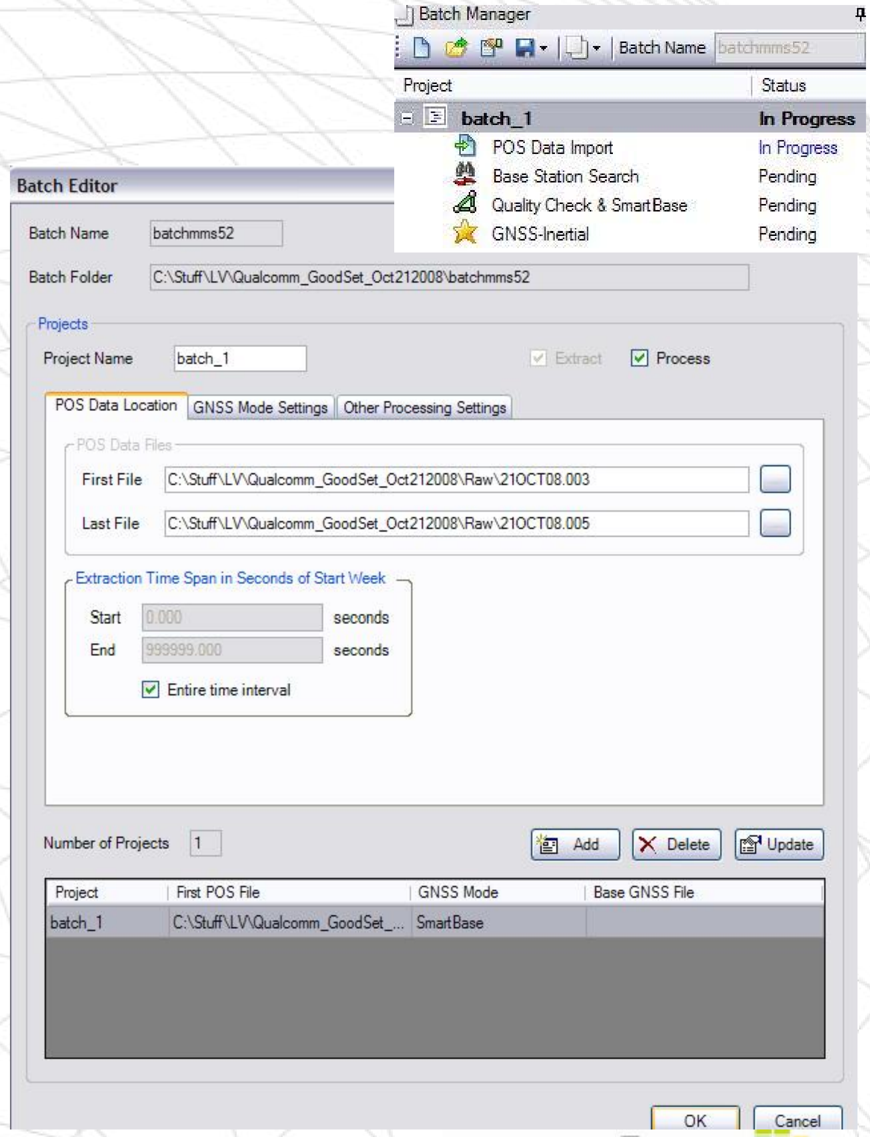
- From www.omnistar.com :
  - The OmniSTAR Network is on the NAD83 datum in North America and WGS84 in all other world areas. When a Base Station generates a correction, it is relative to its own datum. The resulting RTCM corrections from OmniSTAR to a user's GPS receiver will normally result in a user's coordinates in the same datum. However, some GPS receivers have the capability to convert and output in various selected datums. In North America, the receiver should be set to WGS84, and the result will actually be in NAD83. The same settings elsewhere in the world would result in a position in the WGS84 datum.
  - The reason for this is somewhat complex. When GPS was first installed in 1984, WGS84 matched NAD83, because it was a U.S. system. However, over the years, GPS has gradually moved to the new world datum, ITRF, and now matches it. OmniSTAR has elected to keep its North American system on the NAD83 datum to be consistent with prior surveys.

POSPac MMS Workflow



Batch Processing

- Convenient way to process multiple projects with minimal user intervention
- Skips erroneous set and continues to the next project
- All processing modes can be selected
- Processing templates can be created to increase productivity



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Summary

- **POSPac Land 5.0 uses a tightly coupled processing approach, while POSPac MMS provides the user the option to use a tightly or loosely coupled approach, based on the GNSS processing mode.**
- **POSPac MMS contains all of the functionality of POSPac Land 5.0, but allows for improved productivity due to Applanix SmartBase^{TM} and IN-Fusion^{TM} technology, as well as a batch processor.**

Questions?

- **Thank you!**