POS/LV
Training Guide

prepared by

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Scope

This tutorial focuses on POS/LV theory and operation.

Subjects to be addressed:

- What is POS/LV?
- What does POS/LV do?
- Benefits of POS/LV over other Motion Sensors
- POS/LV Theory of Operation
- POS/LV Performance Specifications
- POS/LV System Overview
- Generating Navigation Data using POS/LV

Introducing POS/LV

What is POS/LV?

POS/LV is:

- an <u>Aided Inertial Navigation System</u>
- configured for land-based surveys and terrestrial remote sensing

POS/LV includes:

- **POS computer system (PCS)** – Computational heart of the system
- **Inertial measurement unit (IMU)** - Contains 3 gyros, 3 accelerometers and related electronics
- **Distance Measurement Indicator (DMI)** - A distance sensor that mounts to one of the vehicle’s wheels.
- **Primary GPS receiver** - a dual frequency receiver within the PCS
- **Secondary GPS receiver -** a single frequency receiver for use with the GPS Azimuth Measurement Subsystem (GAMS)

What Does POS/LV Do?

- **POS/LV was designed to provide a complete integrated solution for the measurement of:**
  - position (latitude, longitude, altitude)
  - velocity (North, East, Down components)
  - orientation (roll, pitch, heading)
  - rates (acceleration, angular rate)
- **POS/LV thus replaces the following equipment:**
  - vertical gyro or roll/pitch gyro
  - heading sensor (compass or directional gyro)
  - GPS receiver
  - distance measuring instrument
  - data integration and collation computer
- **POS/LV provides a highly accurate navigation solution in real-time or with post-processing**

What Does POS/LV Do?

- **Provides Aided Inertial Navigation Solution**
  - Time (UTC or GPS seconds of the week)
  - Position (latitude, longitude, altitude)
  - Velocity (North, East, Down components), track, and speed
  - 3-axis attitude (roll, pitch, heading)
- **Records navigation and sensor data to PC Card for post-processing**
- **Monitors and reconfigures sensors for best solution**
- **Operates Stand Alone or with PC software monitoring**
- **AutoStart**
  - POS/LV startup/operation without user input
- **AutoRecovery**
  - POS/LV to recover from IMU/PCS comm. errors
- **Event Tagging**
  - Records event time

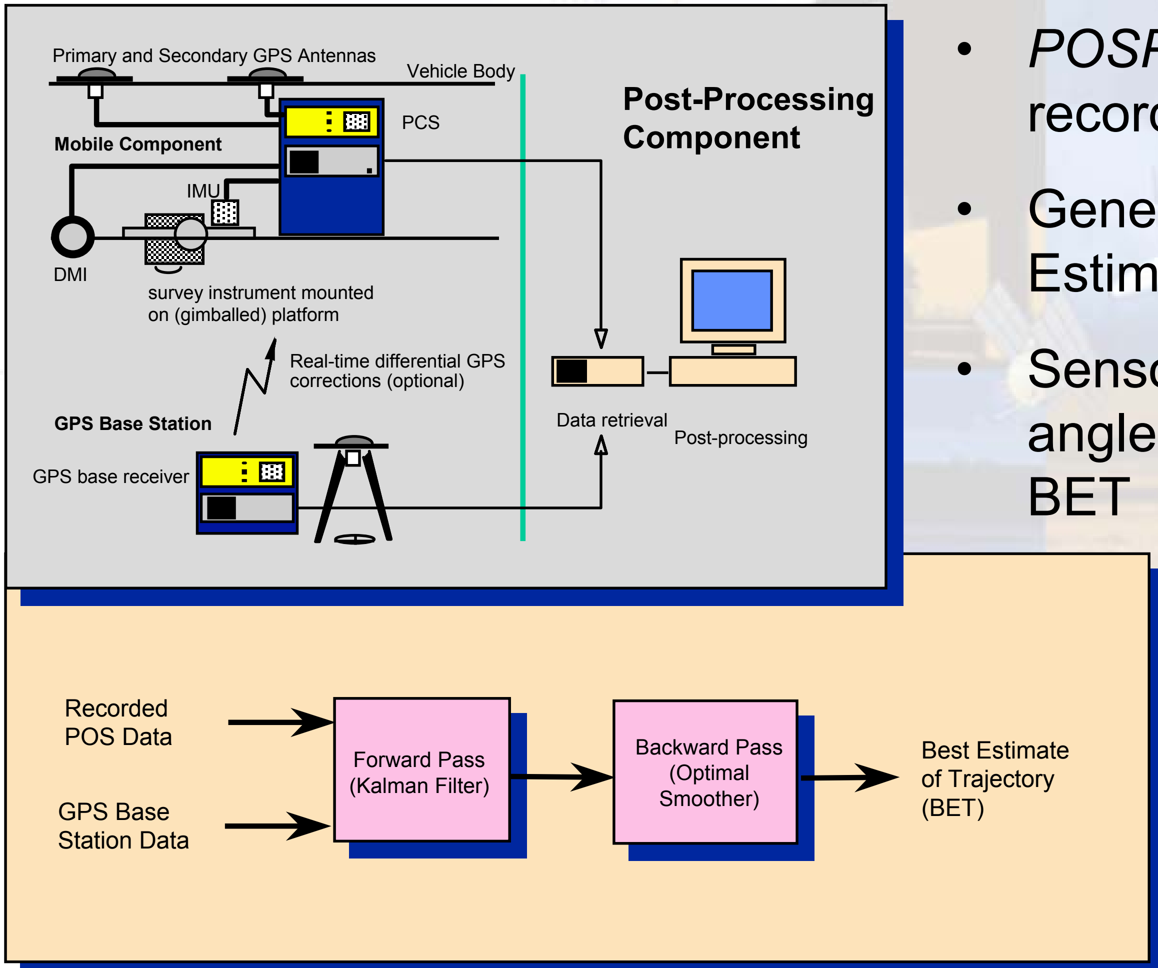
What Does POS/LV Do?
POS/LV Outputs

PC Card
- User-selectable raw sensor and navigation data
- Compatible with Type I PC Flash cards

Ethernet Data Port
- User-selectable raw sensor and navigation data
- Variable output rate – up to 200 Hz

Serial Port
- NMEA message output – up to 7 messages at 50Hz

POS/LV and POSPac



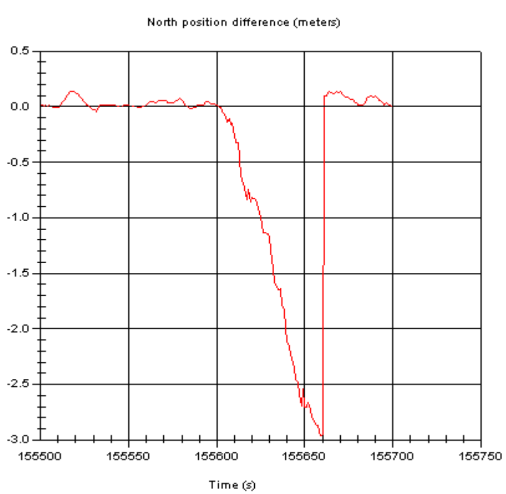
- *POSPac* post-processes recorded POS data
- Generates accurate Best Estimate of Trajectory (BET)
- Sensor positions and attitude angles are interpolated from BET

Advantages of Post-Processing

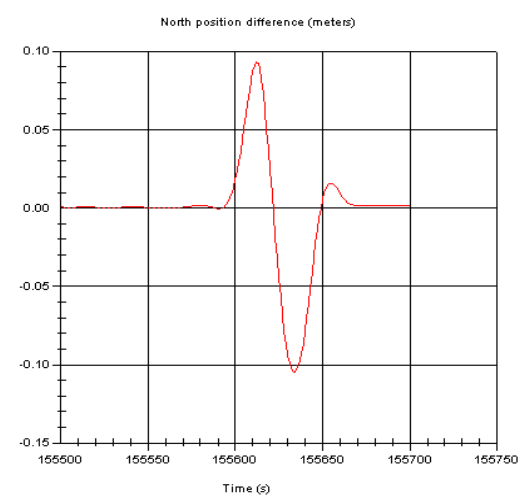
Post-processing

- Can provide a dramatic improvement in navigation accuracy
- Especially helpful with poor GPS / GPS dropouts

Simulated Real-Time Solution

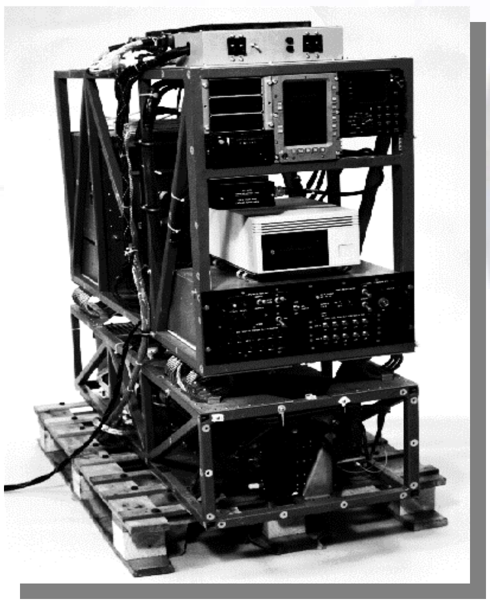


Post-Processed BET Solution



POS/LV Technology Heritage

POS technology evolved from Aided Inertial Navigation technology used in military aircraft since the late 1960’s



Helicopter Integrated Navigation System (HINS)
1986-91

POS/LV
Present

Benefits of POS/LV over other Sensors

POS/LV vs. GPS Only

GPS Receivers

- 1Hz position samples
- 90 km/h vehicle speed = 25 meter sample interval

POS/LV

- Up to 200 Hz data samples
- 90 km/h vehicle speed = 12.5cm sample interval

- Blending GPS data with Inertial and DMI data reduces GPS noise
- Inertial component fills in data between GPS position samples or during outages

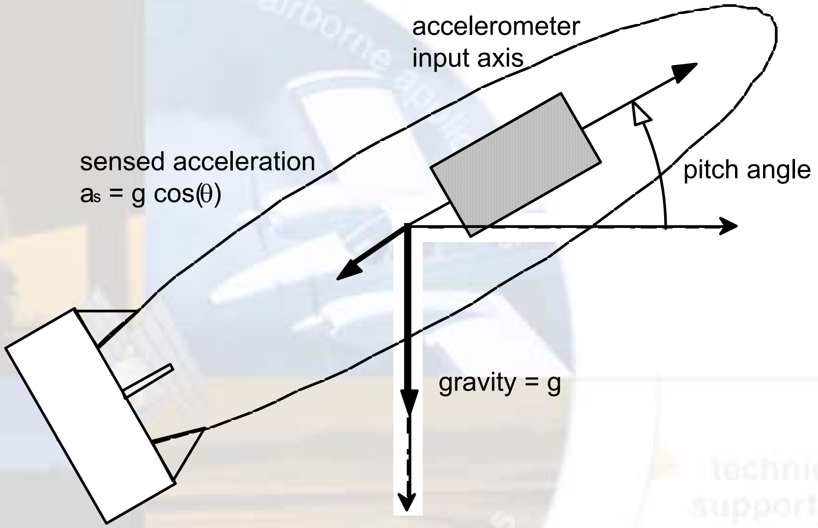
POS/LV Theory of Operation

How Does POS/LV Work?

Computing Roll or Pitch Using an Accelerometer

Accelerometers

- Sense Gravity
- Measure long-term roll and pitch



Calculations

- With no accelerations, pitch angle equals

$$\theta = arcsin(a_s/g)$$

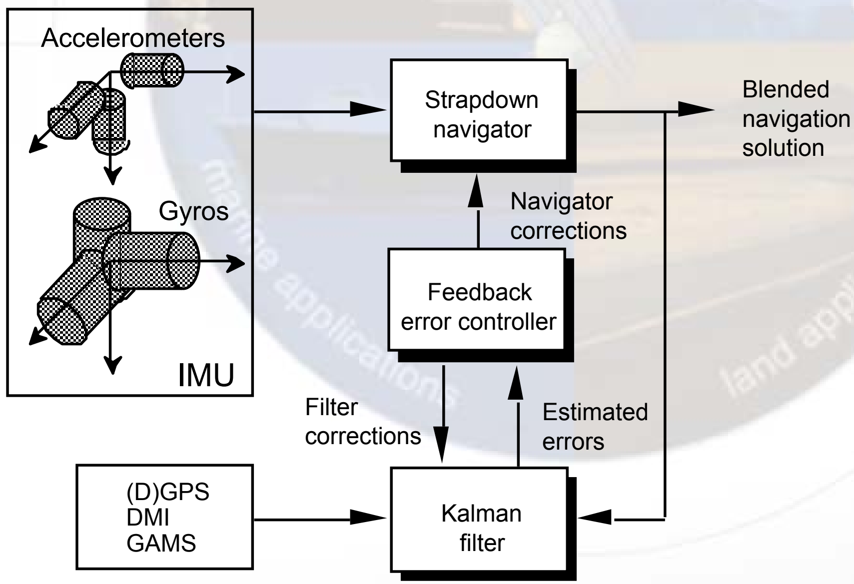
- Roll angle is computed in the same manner

This method is subject to short-term errors, and cannot be used by itself

POS Aided Inertial Navigation Algorithm

Aided Inertial Navigation System

- Blends IMU and aiding sensor data
- Outputs <u>position</u> and <u>orientation</u>



Kalman Filter

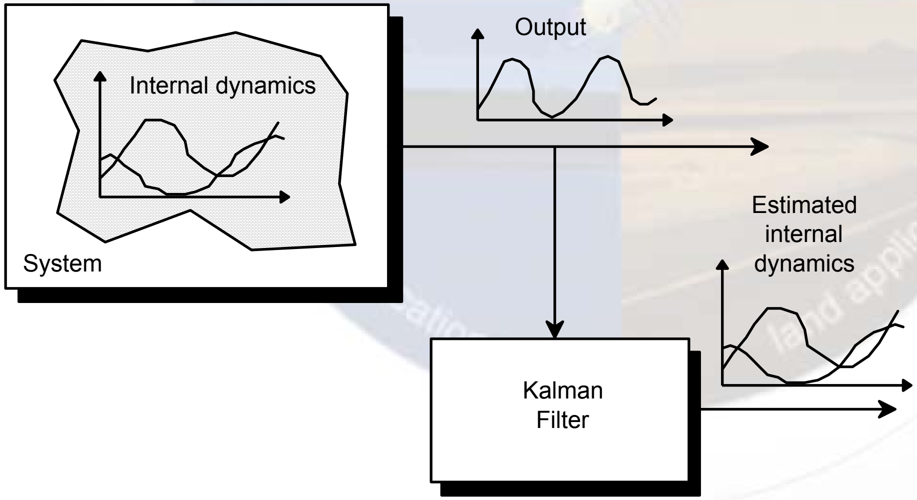
2 functions

- **Estimation**

  Estimates noise based on sensor data and system modeling

- **Noise Reduction**

  Adjusts navigation solution once per second using error estimate



Sensor Blending

Sensor Noise

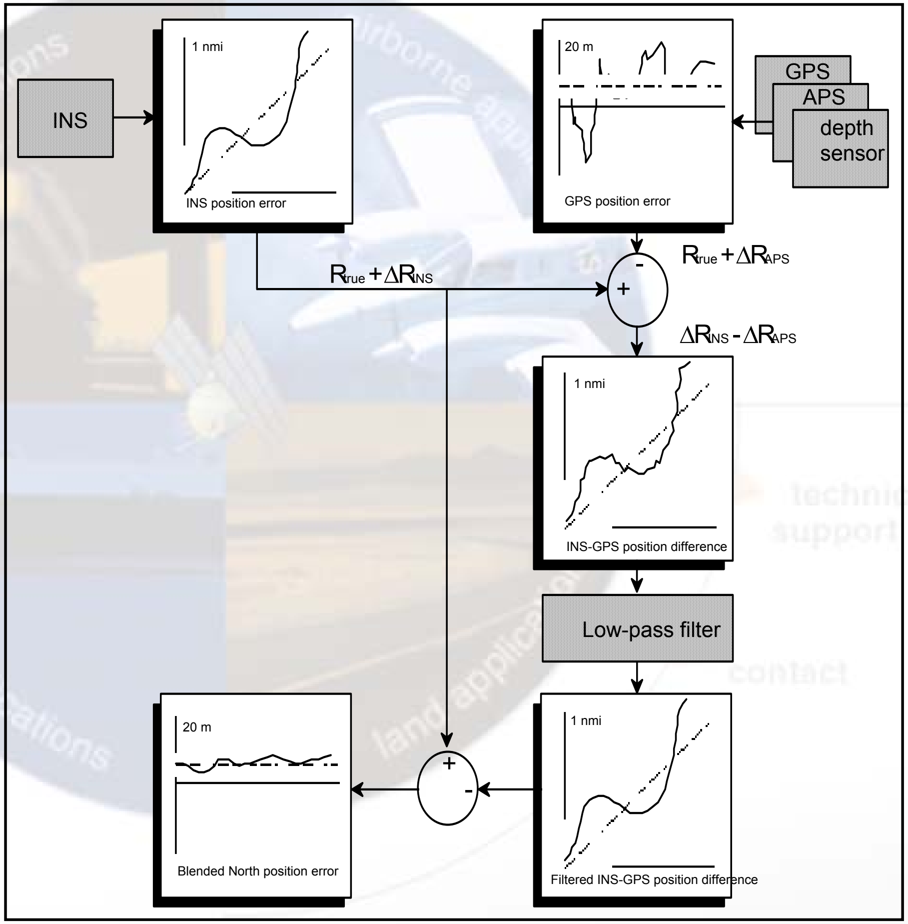
- Properties differ between sensor types
  GPS = broadband
  Inertial = low frequency

Eliminating Noise

- Inertial and GPS errors can be separated
- Complementary filter uses GPS + Inerial error sum to reset Inertial position data

Continuity

- Inertial data fills GPS gaps
- Solution is continuous



POS/LV Performance Specifications

Post-Processed Solution

- The solution is updated at 200Hz.
- Accuracies with GPS (values for POS/LV 420):

Quantity	With Carrier Phase DGPS*
Position	0.03m (1)
Velocity	0.005 m/s
Roll and Pitch	0.005 degrees
Heading	0.02 degrees

1 dependent on type of DGPS solution (float vs fixed integer carrier phase)

* all values RMS per axis

POS/LV System Overview

System Overview

POS/LV 420 includes:

- POS computer system (PCS)
- Inertial measurement unit (IMU)
- Distance Measurement Indicator (DMI)
- 2 GPS receivers
- Windows Controller software

POS/LV 420 modes of operation:

Standby

- No navigation solution output
- Only raw sensor data

Navigate

- Normal mode of operation
- Navigation solution output

POS Computer System

• **Size**	350 x 445 x 111 mm 2.5U, 19” rack mount compatible
• **Power**	120/220 VAC, 60/50Hz, 110W max.
• **Weight**	9.4 kg
• **Temperature**	0º to +50º C
• **Humidity**	5% to 95% RH non-condensing
• **Components**	Power supplies Communication processor Navigation processor Serial interface module Ethernet interface Timing and synchronization hardware GPS receivers (L1 and L1/L2)

Inertial Measurement Unit

• **Gyros**	fiber optic gyros
• **Accelerometers**	silicon accelerometers
• **Data Output**	Incremental velocities and angles (ΔV, $\Delta\theta$)
• **Data Rate**	200 Hz
• **Data Interface**	Serial digital
• **Size**	204 x 204 x 168 mm
• **Weight**	3.5 kg
• **Temperature**	-40º to +60º C
• **Power**	From POS computer system

GPS Receivers

POS/LV contains one each of the following embedded GPS receivers:

L1/L2 GPS receiver

- dual frequency
- 12 channel
- RT-2 option available (narrow lane RTK)

High Performance L1 GPS receiver

- single frequency receiver
- 12 channels
- very accurate code and phase tracking

Distance Measurement Indicator (DMI)

- **Size** 153 mm diameter x 97mm (not including collets or restraint rod)
- **Weight** 2.7 kg
- **Temperature** -40º to +80º C
- **Humidity** 0 to 100%

High resistance to shock

Summary

POS/LV

- **Complete source of real-time or post-processed position and orientation data**
- **Replaces**
  - roll/pitch sensor (vertical gyro)
  - heading sensor (directional gyro)
  - GPS receiver
  - distance measuring instrument (DMI)
  - data integration, collation and recording computer
- **Provides excellent performance in a high dynamic environment**
- **Provides data continuity during GPS outages**
- **Provides highly accurate solution when used with POSPac**

Generating Navigation Data using POS/LV

Generating Navigation Data using POS/LV

<u>Five Steps</u>:

1) Plan Mission
2) Drive Mission: Collect raw data using POS/LV
3) Extract Data: PosPac Extraction Utility
4) Generate differential GPS solution: PosGPS
5) Generate SBET navigation solution: PosProc

Step 1

Plan Mission

Step 1: Mission Planning

Plan as for a standard DGPS survey:

- Minimize baseline length(<30 km)
- Minimize multipath
- Minimize DOP
- Multiple base stations

Minimize Baseline Length

Carrier Phase DGPS Accuracy Limitations

- Receiver Noise (~2 cm)
- Multipath
- Baseline Effect (Atmospheric Delays)

Baseline Effects

- 1 to 2 ppm (1-2mm per km)
- Up to 5 ppm during peak of solar cycle

Baseline <30 km for robustness

Use multiple base stations for redundancy

Minimize Multipath

Multipath

- Caused by reflections of GPS signals
- Error can be as large as 1-2 m

Base Stations away from and above reflective surfaces

Use Choke Rings on antennas

Minimize DOP

DOP (dilution of precision)

- Reduced accuracy due to satellite position
- Acts as scale factor for position error

  (e.g. if DOP = 7 , 5 cm error becomes 35 cm)

Plan mission to run during maximum satellite coverage to obtain best data

Multiple Base Stations

Redundancy

Step 2

Drive Mission

Step 2: Drive Mission

Using POS/LV effectively:

- Proper installation
- Proper handling

Installation Parameters

Installation Data input into POS via LV-POSView

Entered once and saved into memory

Three types of parameters

- Lever Arms
- Misalignment Angles
- GAMS Orientation

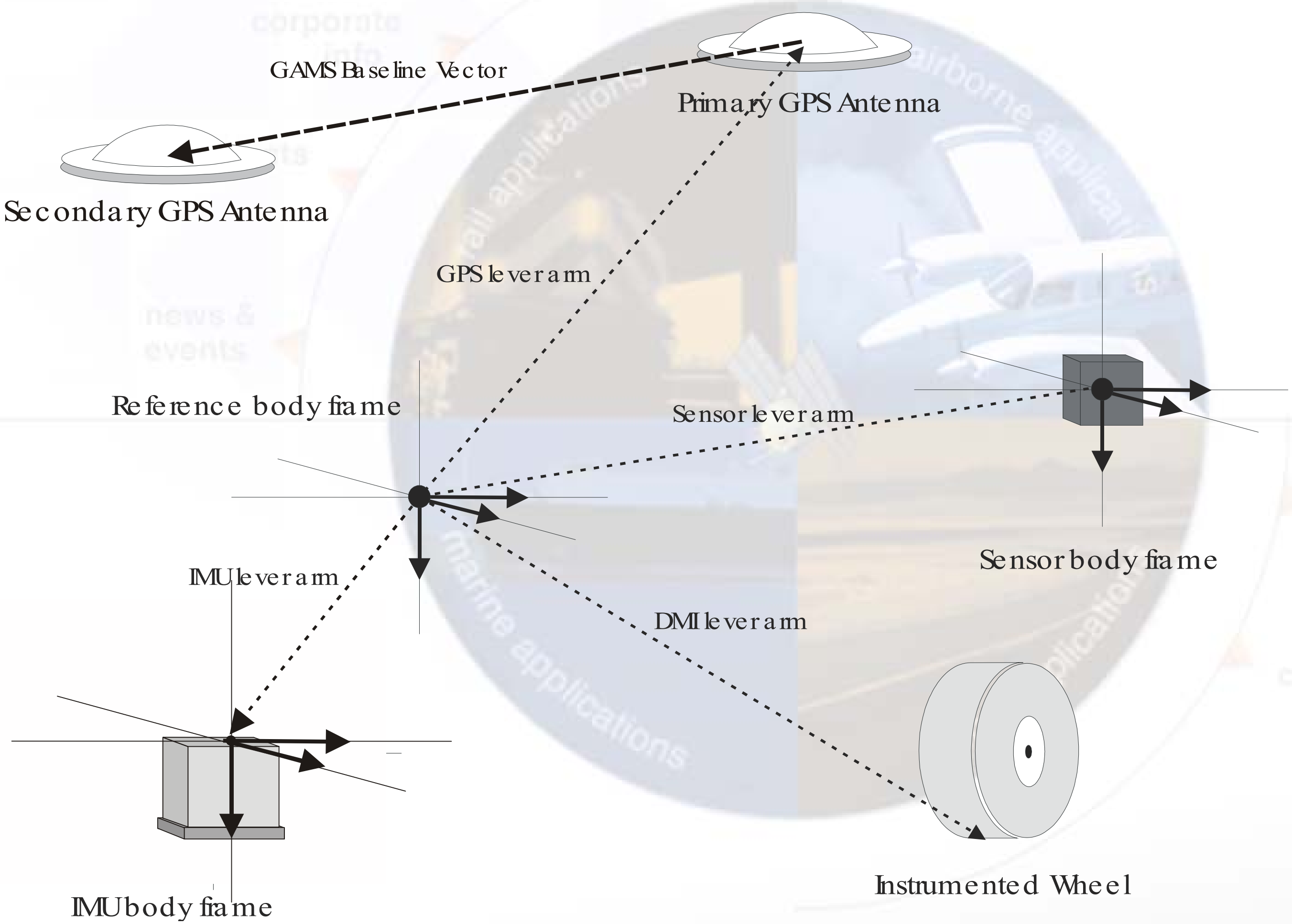
Lever Arms

X, Y, Z distances between two body frames

For Lever Arm measurements:

- X is positive towards front of vehicle
- Y is positive towards right side of vehicle
- Z is positive down through bottom of vehicle

Lever Arms


GAMS Baseline Vector
Primary GPS Antenna
Secondary GPS Antenna
GPS lever arm
Reference body frame
Sensor lever arm
Sensor body frame
IMU lever arm
DMI lever arm
IMU body frame
Instrumented Wheel

Lever Arms

- **Reference to GPS**

  To translate GPS position and velocity data to centre of Reference frame

- **Reference to IMU**

  To translate IMU position and velocity data to centre of Reference frame

- **Reference to DMI**

  To translate DMI distance data to centre of Reference frame

All POS position and velocity outputs are valid at centre of Reference frame

Lever Arms

Real-time Accuracy: 10 - 20cm

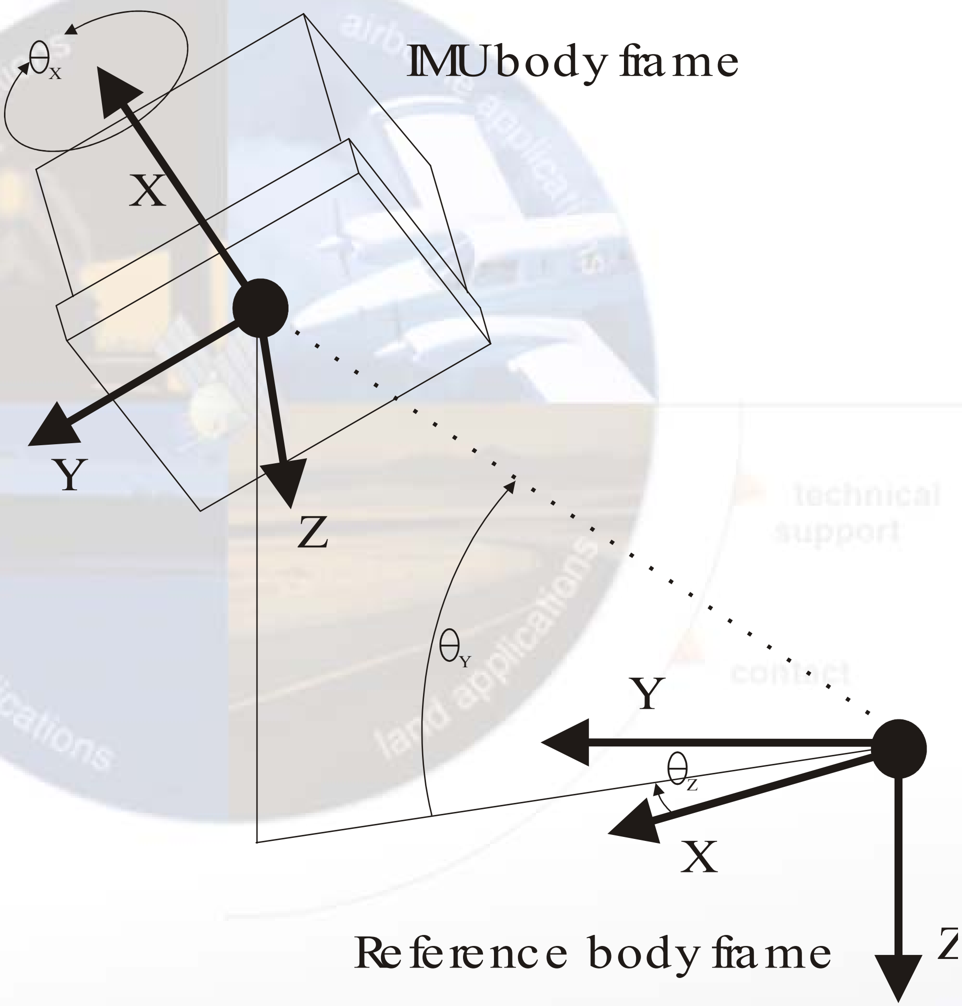
Post-processed: User to GPS: 10 - 20 cm*

User to IMU: 1 - 3 cm

* are refined by PosProc

Misalignment Angles

- **Sequence of rotations to align one body frame with another**
- **e.g. IMU body frame with respect to Reference body frame**



Misalignment Angles

- **Reference to IMU**

  To translate IMU attitude data to centre of Reference frame

- **Vehicle to Reference**

  To translate data from Reference to Vehicle frame (usually 0 – frames aligned)

Misalignment Angles

Reference to IMU

- Angles determined during installation
- Dependant upon IMU type, IMU location and sensor type

Vehicle to Reference

- Angles usually set to zero

Misalignment Angles

Real-time Accuracy: 10 deg

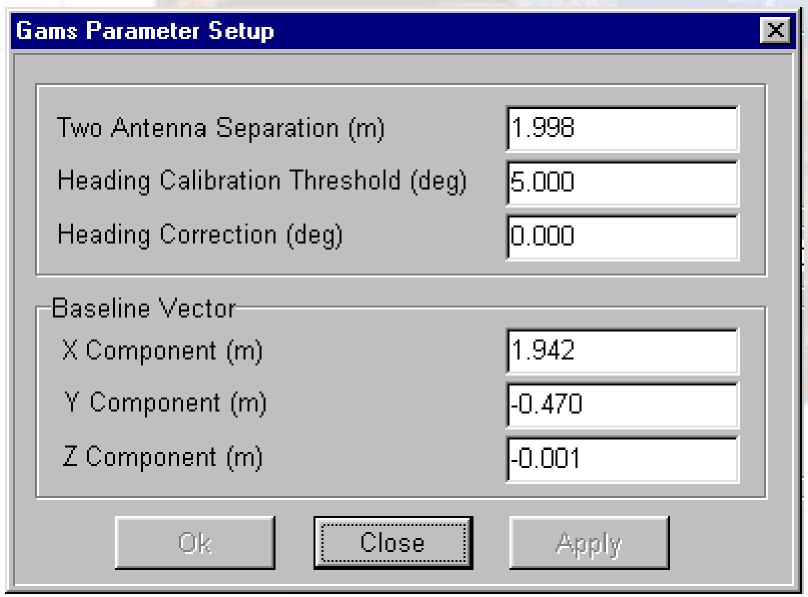
Post-processed: User to IMU: 10 deg*

Vehicle to User: 10 deg*

* Refined by boresighting program PosBST

GAMS Orientation

POS/LV will determine antenna separation vector automatically during GAMS configuration



Mission Checklists

Data Storage Considerations

- To maximize storage space, you can reduce the real-time output to 10 Hz; raw data rate (200 Hz IMU and 2 Hz GPS) are unaffected by this change!
- A 1GB PC Card will hold approximately 4 hours of data.
- Quick-Format PC Cards before the mission to erase all files (incl. Recycle Bin)

Mission Preparation

- Bring several PC Cards and store them appropriately until use
- Check laptop PC battery for good charge
- Enter mission data in POS/LV Mission Profile Form (see Operation Guide)
- Check all cables for secure connections
- Check Event cable for connection if Event timing is being used

Mission Start Checklist

- Power on all equipment – verify that no errors present
- Park vehicle away from buildings and other multipath reflection sources
- Switch POS/LV to *Navigate* mode – wait for GPS Status:OK and Coarse Leveling to finish
- Insert PC Card in drive
- Click *Start Logging* in *PC Card Logging* window
- If using Events, trigger sensor – verify increasing event count
- Ensure that DGPS Base Station is on
- Log 5-10 minutes of data
- Start mission. Watch for POS LED to turn solid green within 5 minutes

During Mission Checklist

Stand Alone Mode

- ❑ Monitor POS/LV using PCS status LEDs
- ❑ Use DATA LOG button to start/stop data logging to PC Card

Controller Monitor Mode

- ❑ Monitor LV-POSView Main Window displays – compare to vehicle motion
- ❑ Monitor LV-POSView Faults Window
- ❑ Monitor Events count in LV-POSView Main Window – compare to sensor

During Mission Restart

- Stop vehicle away from buildings and Stop logging data
- Power off PCS – wait 10 seconds – Power on PCS
- After initialization, log 5-10 minutes of data
- Drive an abrupt S-turn or any two accelerating arcs
- When PCS LED turns solid green, continue mission

Post Mission Checklist

- ❑ Stop vehicle away from buildings
- ❑ Continue logging data for 5-10 minutes
- ❑ Stop data logging and remove PC Card
- ❑ Power off all POS/LV equipment

Step 3

Data Extraction

Data Extraction

Use the PosPac data extractor to:

- Extract raw data
- Check raw data for gaps (GPS, IMU, and DMI)
- Plot real-time solution

Step 4

Generate Differential GPS Solution: POSGPS

GPS Raw Data Conversion

Choose appropriate GPS Receiver Converter

Vehicle Data

- Make all epochs kinematic (*Options* menu)
- Re-calculate Position and Time (*Options* menu)

Base Station Data

- Verify kinematic flag is off (*Options* menu)
- Re-calculate Position and Time (*Options* menu)

View GPB-File

- Note GPS time of First and Last Epoch
- Check Epoch Interval (0.25 sec, 1 sec, etc.)
- Check for L1 only or L1/L2 phase measurements
- Verify there is a valid position computed by the Receiver
- Verify Static flag for Base Station Receiver data
- Verify Kinematic flag for Vehicle Receiver data

Configuration Set-up

- Enter correct WGS84 coordinates and antenna offset for *Master GPS*
- Enter 0.0 for antenna height offset of *Remote GPS* (all lever arms will be removed in PosProc)
- Save Project

Computation

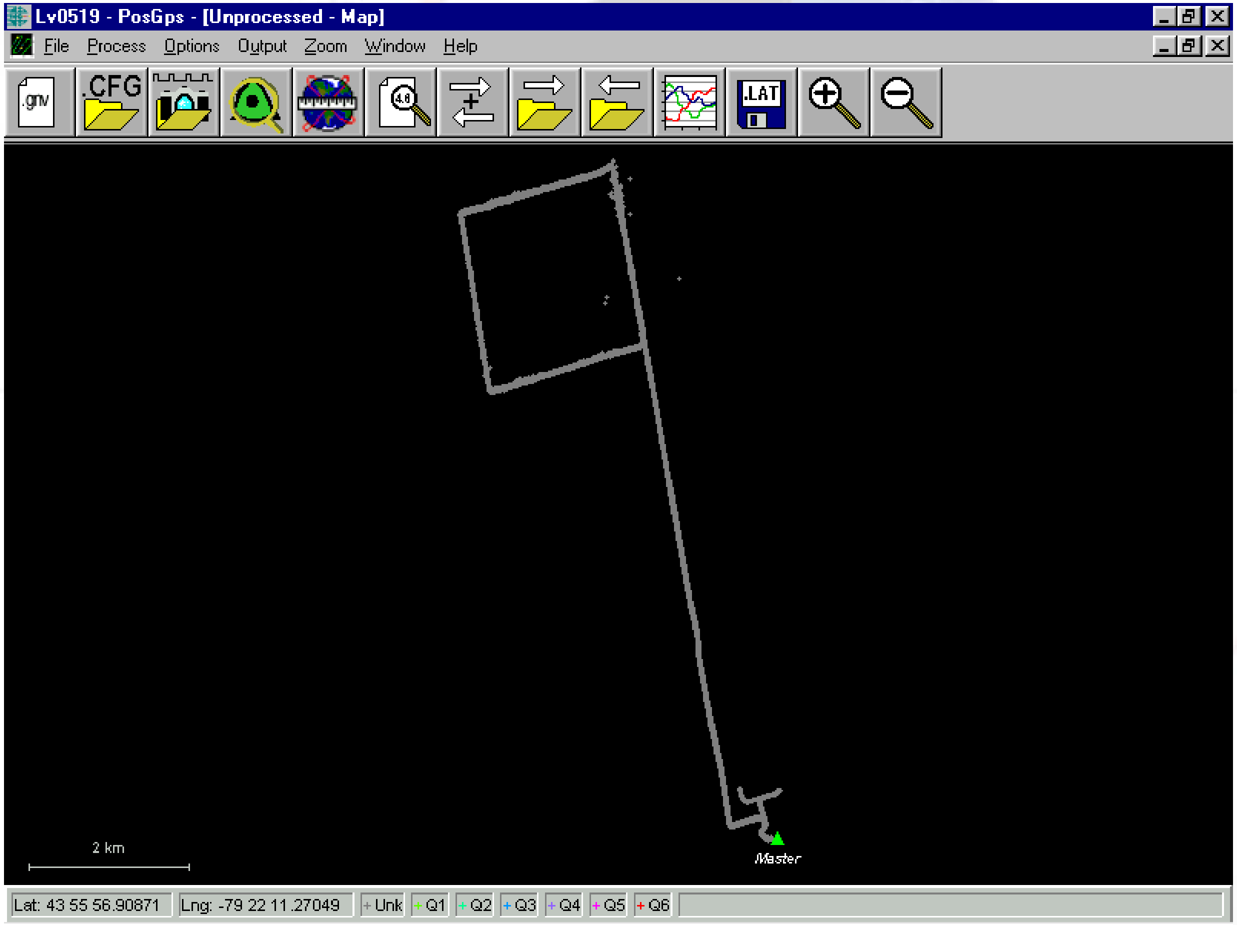
Options > General

- Verify Start and End times for processing
- Verify processing interval (common epoch interval)

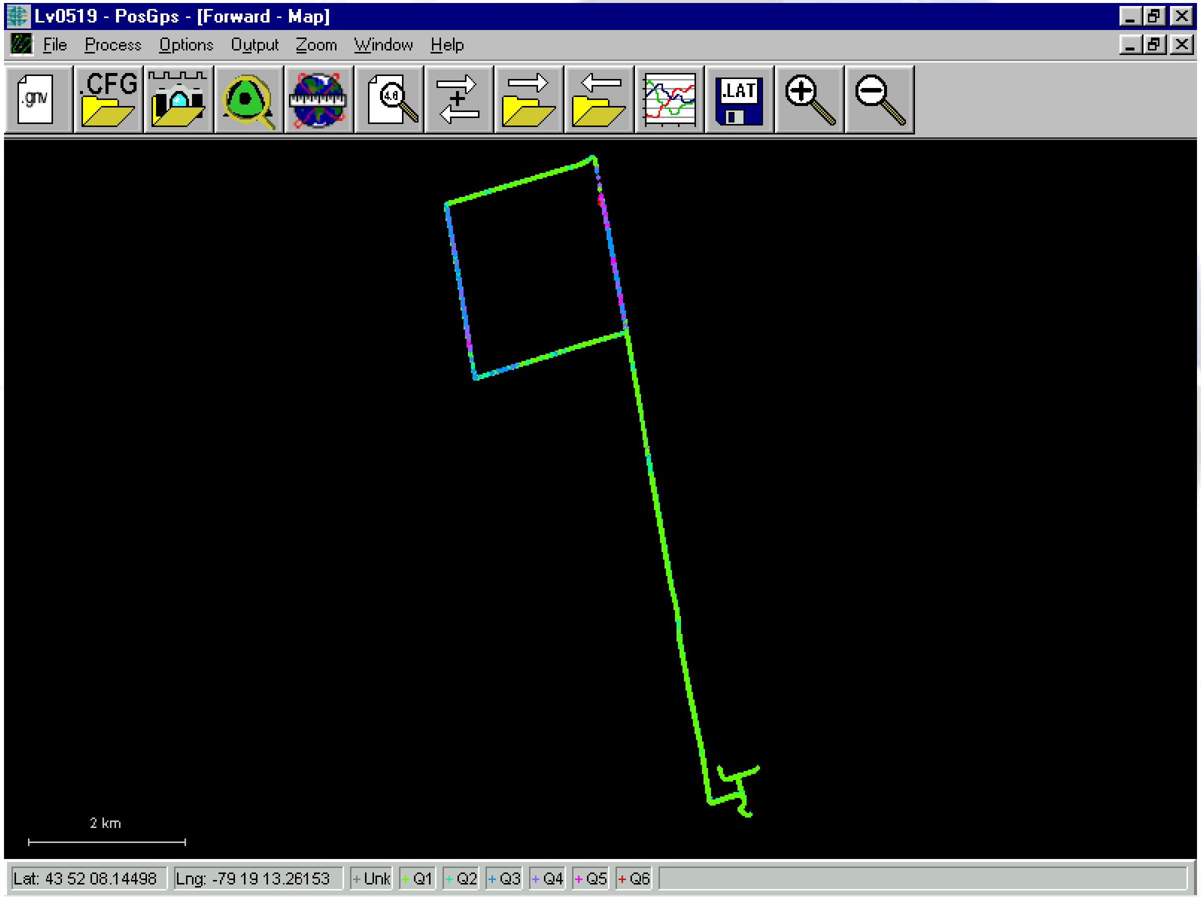
Options > Standard Deviations

- Set C/A Code standard deviation to 1.5m
- Set L1 Phase standard deviation to 0.02m
- Set L1 Phase rejection tolerance to 0.1m

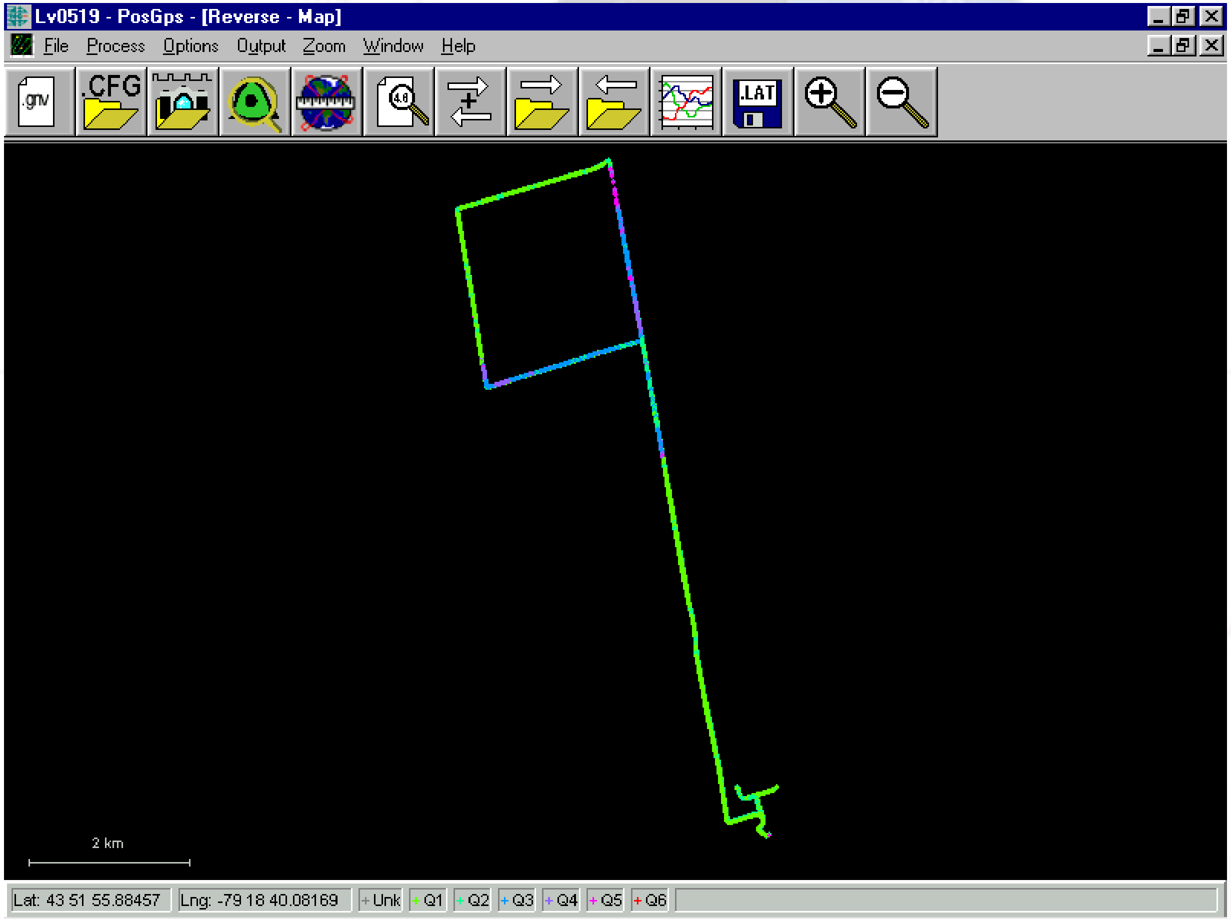
Example: Base Station in Project Area



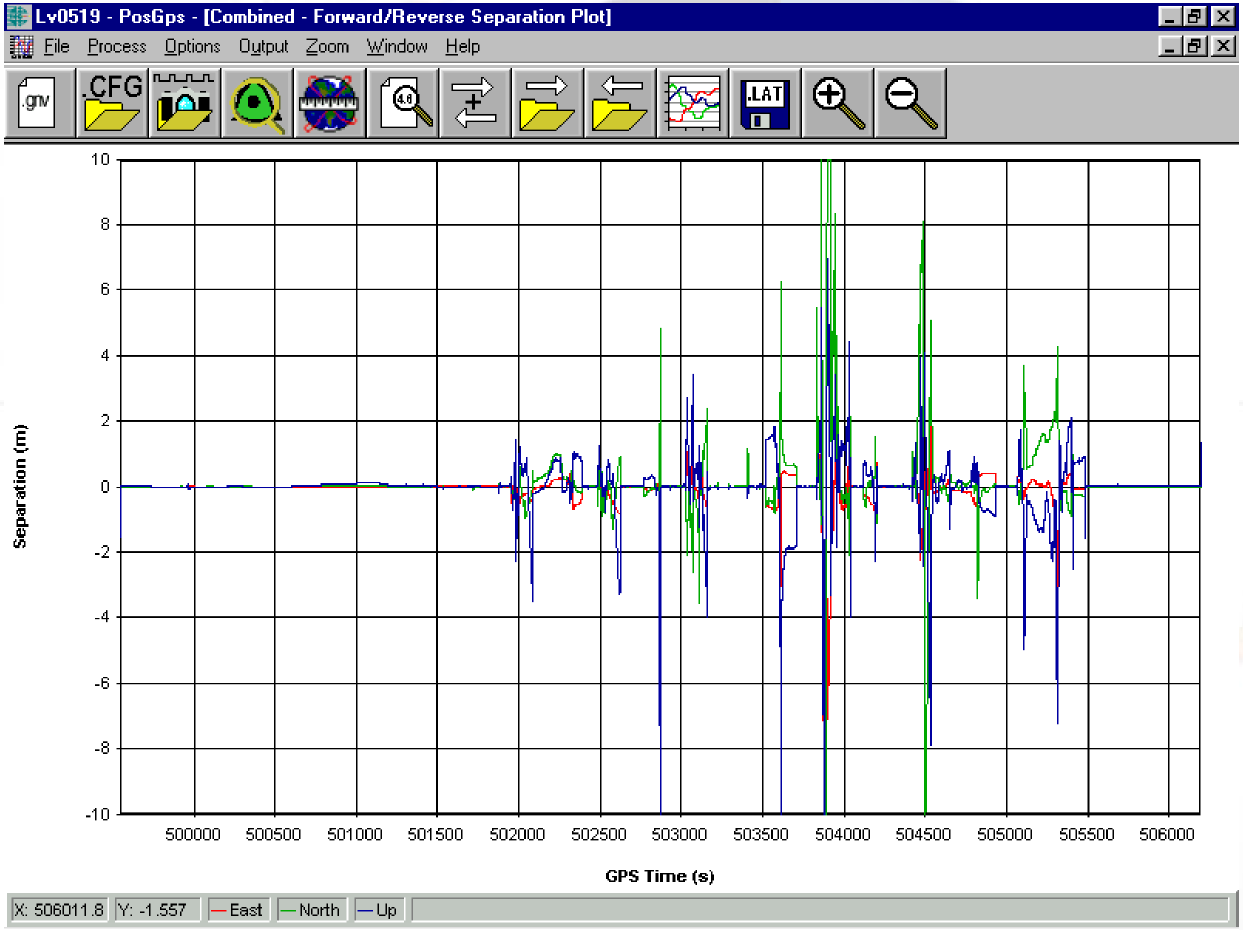
Specify start time near base for FWD processing



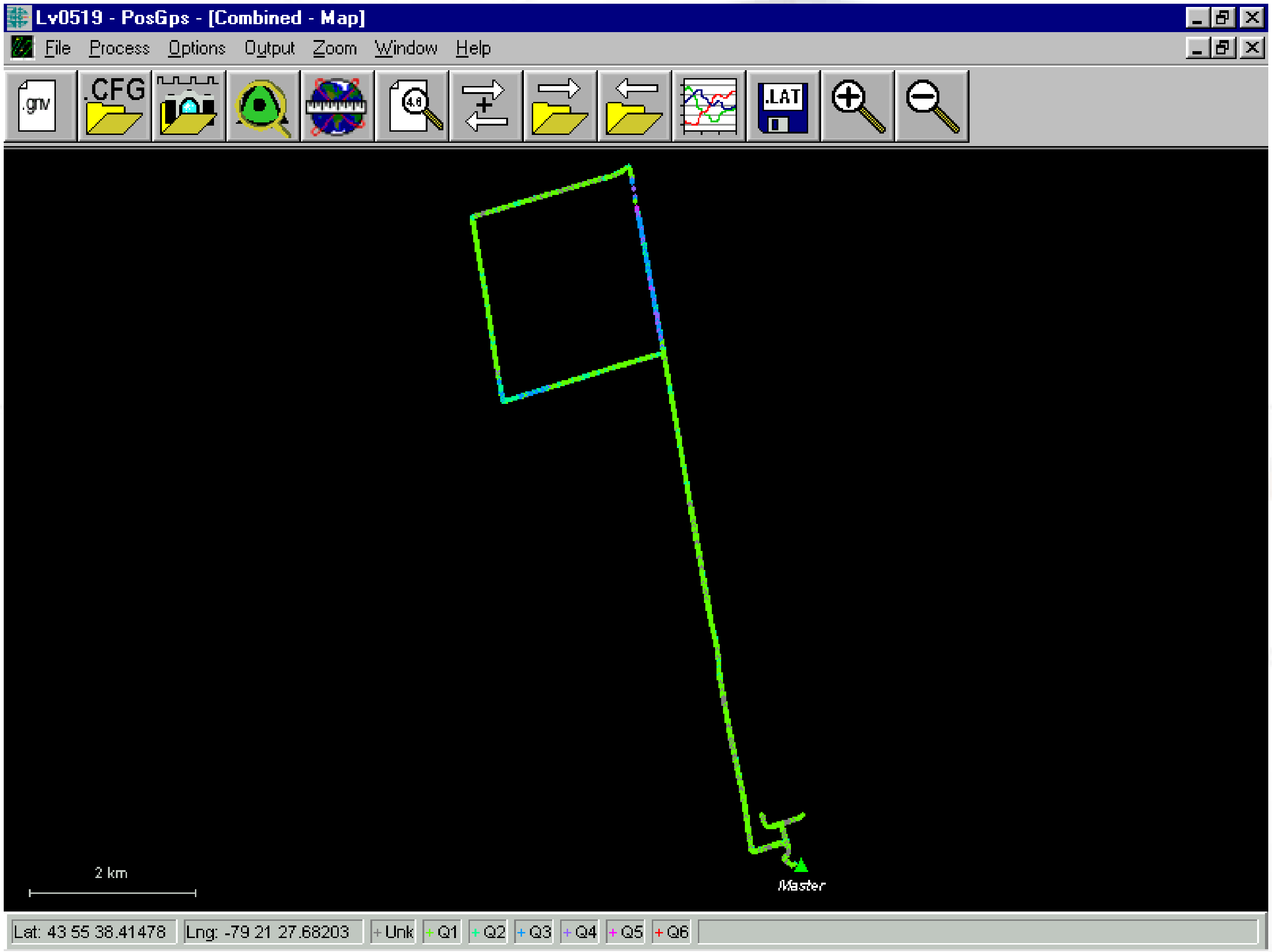
Specify start time near base for REV processing



Combine solutions and review separation



Final GPS trajectory



Step 5

Generate SBET Solution: POSProc

Configuration File

Choose the proper configuration file for your IMU (AIMU, LN200, Phalanx, LR86)

GPS Solution

- Integer Carrier Phase (IDGPS)
- Float (FDGPS)
- RTCM (DGPS)
- (Code only) (GPS)

RESULTS
Sensor Errors and RMS

Accelerometer Drift

- Stable and smooth curve within RMS bounds (1σ)
- Should be less than 400μg for LR86 and Phalanx
- Should be less than 1500μg for LN200
- Z drift is lower than X and Y drift
- Low frequency drift is caused by temperature

Accelerometer Scale Factor

- Should be less than 400ppm for LR86 and Phalanx
- Should be less than 1000ppm for LN200

Sensor Errors and RMS (cont'd)

Gyro Drift

- Curve will "wander around" because of short-term variations
- Should be around 1°/hour or less
- Z-Gyro drift affects heading
- Low frequency drift is caused by temperature

- **Gyro Scale Factor**
  - Stable and smooth curve
  - Should be less than 300ppm

Sensor Errors and RMS (cont'd)

Gyro Bias

- Stable and smooth curve
- Phalanx should be around 1°/hour (or less)
- LR86 should be around 3°/hour (or less)
- LN200 should be around 1°/hour or 3°/hour

S/D Misalignment

- Should be less than 0.3' for pitch and roll
- Should be less than 0.8' for heading

Summary

<u>Five Steps</u>:

1) Plan Mission
2) Drive Mission: Collect raw data using POS/LV
3) Extract Data: POSPac Extraction Utility
4) Generate differential GPS solution: POSGPS
5) Generate SBET navigation solution: POSProc