LiDAR Mapping Systems

Post Processing - Workflow with Inertial Explorer and TerraSolid

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NOTE: This manual provides a description and function of the base post-processing workflow for trajectory and LiDAR mapping calibration. The product you purchased may not support certain functions dedicated to specific models, upgrades or customizations.

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1. Introduction

This document covers the essential steps for processing LiDAR and camera data collected with a Phoenix LiDAR Systems mapping system. Be aware that this document should be used as a supplemental outline designed to help users follow-along and perform the data post-processing steps in the correct order. This document is not intended to replace customer training or software specific User's Manuals. Instead, it should serve as introductory material for new users and a reference tool for experienced personnel.

The majority of the workflow outlined in this document has been generalized, however a few mapping system specific key points have been highlighted with distinct colors where relevant:

Key Point Color
Multi-Laser System Specifics *Green*
Riegl System Specifics *Orange*
Mobile System Specifics *Magenta*

Click the links highlighted in blue and underlined to access more detailed documentation and videos .

2. File Setup and Data Preparation

Before we post-process the data, we need to gather and prepare a few essential components.
- Raw data from all sensors (LiDAR, camera, etc.)
- Field notes and other supplemental information that can be used to understand the project and data quality.

2.1 Data Collection and Consolidation

2.1.1 Download Data from Rover Nav Box

Download the folders containing the mission data. Click here for Navbox specific methods.

2.1.2 Download GNSS observations from GNSS Reference Station

The method of downloading the GNSS observation logs may vary from GNSS reference station. The most common way to download the observation logs is through a USB connection established between laptop and GNSS reference station. Just make sure to have the correct GNSS observation logs corresponding to the time and date of your mission.

2.1.3 Download Images from Camera SD Card (if applicable)

When using RAW images taken with a digital camera, you must manually download them from the digital camera's SD card onto your computer. Raw images from Basler cameras are automatically decoded and placed in the corresponding folder within the mission data folder.

2.2 Data Conversion and Refinement

2.2.1 Convert RAW images to JPG

When using RAW images taken with a digital camera, you must convert them to JPG. Raw images from Basler cameras are automatically decoded. SpatialExplorer has a built-in image converter located in the Tools menu bar, Tools → Convert Images to convert raw images only from Basler cameras for your own use (e.g. loading them into Pix4D or PhotoScan).

It is very important that you do not omit or add even a single image, as the association between exposures captured by the navigation system and image files would break, causing mis-projections in the point cloud.

For raw Sony images, it is recommended to use Sony's Imaging Edge software to convert RAW images to JPG.

You must place the converted JPG images in the camX/ folder of the mission data folder. This will ensure that Spatial Explorer is able to properly load the images.

2.2.2 Convert RXP to SDCX with Spatial Explorer

In Spatial Explorer, load your .plp file to reference the raw LiDAR data (.rxp). Under 'Tools' -> 'LiDAR' -> 'Convert Reigl .rxp to .sdcx' and use default settings (MTA zone of 0, reflection: -127db) to create the .sdcx LiDAR file. This resolves MTA ambiguities, increases visualization speeds, and processing speeds in Spatial Explorer. Be sure to store the SDCx files in the

same rover folder as the RXP files. If SDCx files are generated while the PLP file is open, you will need to close and reopen the PLP file for the SDCx files to be recognized and opened within SpatialExplorer.

2.2.3 Extract Panoramic images from Ladybug5

If you have captured image data with the Ladybug5 camera, you will need to extract the panoramic images at the highest resolution available and with the most rigorous stitching method by creating a camera session from data in SpatialExplorer or using LadybugCapPro's utility which can be downloaded under FLIR Software Downloads here.

3. Inertial Explorer Trajectory Processing

Refining the position and orientation of the system through differential corrections and coupling of GNSS and IMU data will increase the accuracy of the data from LiDAR and other sensors.

3.1 Prepare Reference Station Data

3.1.1 Convert Raw to RINEX

- For Stonex reference stations, it is recommended to download Novatel Convert and use it to convert raw static DAT files to Rinex, if you need to refine the reference station coordinates using a free GNSS post-processing service like OPUS or Trimble RTX.

- For CHC reference stations, you can alternatively use CHC RINEX Converter (download here under CHC Software Downloads) to convert ".HCN" files to RINEX files. Simply drag and drop an ".HCN" file into the RINEX Converter and press the green play button. This will generate a "RINEX" folder in the same location as the ".HCN" file, and populate the folder with the various types of RINEX files (observation, navigation, etc.)
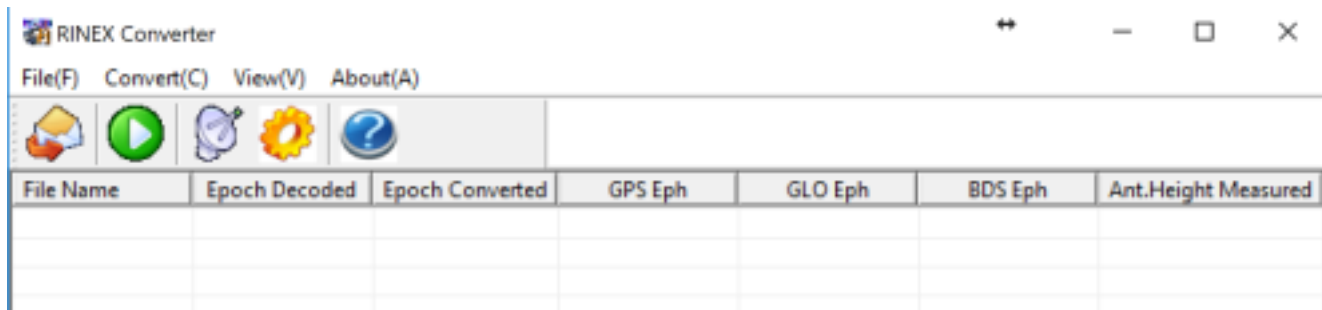
Figure 3.1 CHC RINEX Converter

3.1.2 Refining Reference Station Coordinates

- There are 3 viable options for refining reference station coordinates.
  These options are ranked from 1-Best to 3-Worst:

    Option 1: Setup reference station over a previously surveyed or known coordinate
    ■ Using an established project monument is the easiest way to tie into your project datum

    Option 2: Use OPUS or similar gnss post-processing service, to post process your reference station coordinate. The most accurate OPUS solutions have an overall RMS less than 3 cm.

    ■ Here is a list of some free GNSS online post-processing services:

    OPUS: U.S. National Geodetic Survey

    AUSPOS: Geoscience Australia

    Centerpoint RTX Post Processing: Trimble Navigation Limited

GAPS: University of New Brunswick

APPS: Jet Propulsion Laboratory

CSRS-PPP: Natural Resources Canada

A comparison report of these processing services and detailed description of each service can be found [here.](#)

Option 3: Utilize Precise Point Positioning (PPP) in IE to derive reference station coordinate

- ■ PPP is a positioning technique that removes or models GNSS system errors to provide a high level of position accuracy from a single receiver. A PPP solution depends on GNSS satellite clock and orbit corrections, generated from a network of global reference stations. Once the corrections are calculated, they are delivered to the end user via satellite or over the Internet. These corrections are used by the receiver, resulting in decimeter-level or better (up to 3cm) positioning with no base station required.

3.2 Project Wizard

Start Inertial Explorer and use the [project wizard](#) to input your data into the software

3.2.1 Rover Data

- ● [Input the ".nav" file as Remote (Rover) Data "GNSS Data File"](#)
  - ○ The IMU data file path will automatically populate since the ".nav" file contains GNSS and IMU information.
- ● [Specify your Rover antennae(s) model and height](#)
  - ○ For Phoenix LiDAR Systems' custom GNSS antenna select a "Generic" profile with a measured height of 0.00m, measured to L1 Phase Centre.

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Figure 3.2 PLS custom rover antenna settings

To accurately process the rover trajectory we need all baselines from the Base reference station measured to the rover GNSS Phase Center. Note that Antenna Reference Point (ARP) to phase center measurements vary by antenna model, and selecting an antenna profile applies a Phase Center Offset (PCO) for the selected antenna model.

The ARP to Phase Center offset for Phoenix LiDAR Systems custom GNSS antenna is **0.043m**, and has already been accounted for by the GNSS lever arms in SpatialExplorer during acquisition. See section 7 for more information on the difference between GNSS ARPs and phase centers.
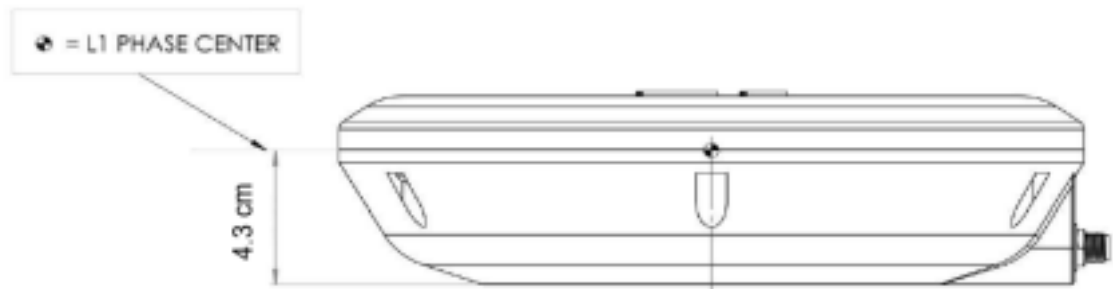
Figure 3.3 Phase center offset (PCO) for Phoenix LiDAR Antenna from ARP to L1 phase center

3.2.2 Base Station Data

- Add the raw base station file(s)
  - Edit the base station details (Very important!)
    - Specify the Antenna model, measured height, and if that height is referencing ARP or L1 Phase Center.
    - Input latitude, longitude, ellipsoidal height, datum and epoch based on the refined coordinates that were determined in section 3.2.1

      NOTE: Inertial Explorer will perform a 7 parameter coordinate transformation from your input

      datum to your processing datum, but will not account for a time dependent transformation between varying epochs. Therefore, you must input your initial reference station coordinate using the appropriate time-dependent coordinate that corresponds to the desired processing epoch.

      RESOURCES:
      1) NOAA's tool for transforming positional coordinates across time and between spatial reference frames: https://www.ngs.noaa.gov/cgi-bin/HTDP/htdp.prl
      2) NOAA's Horizontal Time-Dependent Positioning Toolbox: https://www.ngs.noaa.gov/TOOLS/Htdp/Htdp.shtml
    - **OPTION:** Calculate the reference station coordinates using PPP at this stage only if there is not a better alternative (Coord. Options > compute from PPP) .

- **OPTION:** Add base stations from download
  - Publically available reference station can be utilized for projects without static data from a dedicated base
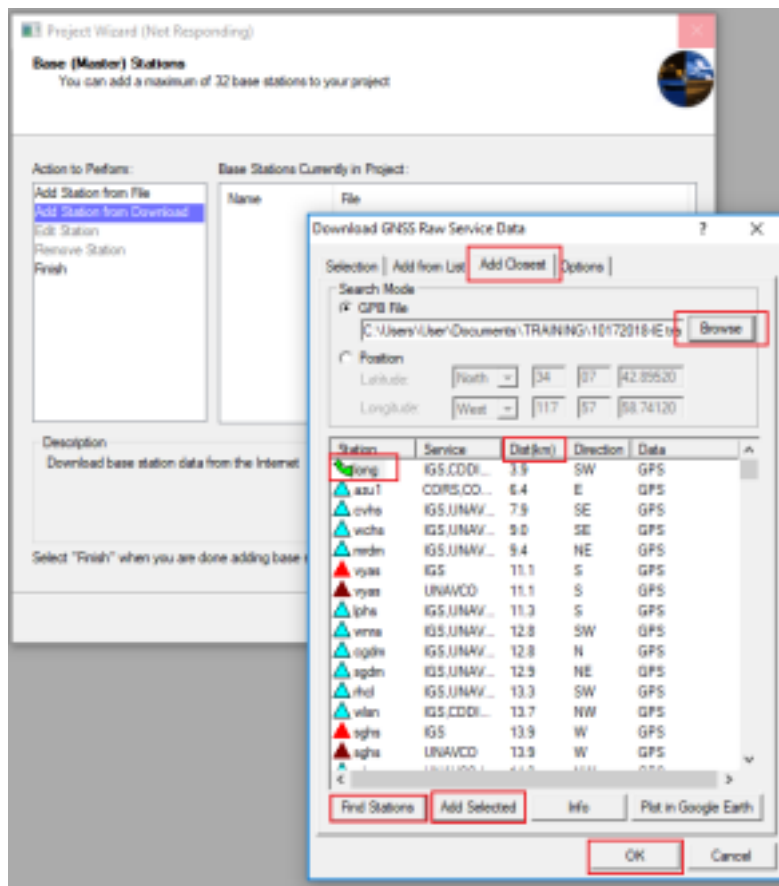
Figure 3.4 Download publically available reference station data from within IE

If you are using CORS data, keep in mind that all coordinates from CORS sites are in NAD83 (2011) epoch 2010.000. If you are processing data using a CORS station, and your desired processing epoch is anything other than epoch 2010.000, you will need to transform the initial positional coordinate for the input reference station

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NOTE: As your baseline increases, accuracy decreases. Due to the nature of RTK/PPK, accuracy degrades linearly at a rate of 1 mm for each km between the base and rover. For this reason, the best trajectory results are produced when using a base station located on site.

3.3 Process GNSS

- Once finished with the Project Wizard, 'Process GNSS'
    - Configure Processing Method
    - Configure Processing Direction
    - Configure Processing Profile
    - Configure Elevation Mask (optional for mobile applications)

3.4 Process Coupled Trajectory

- Process Loosely (LC) and/or Tightly (TC) Coupled to refine the trajectory solution to +/- 0-2 cm in Combined Position separation, and +/- 0-2 arcmin Attitude separation graphs for the time period of data acquisition ○ Configure Processing Direction (check Multi-pass option during TC processing)

- ○ Configure Processing Profile
  - ○ Configure Processing Datum
  - ○ Verify GNSS/IMU lever arm offset
  - ○ Verify Body to IMU Rotation
  - ○ Configure IMU alignment settings (Static/Kinematic/Automatic)

- **Optional:** If your solution is < +/- 4 arcmin Attitude separation, you can use the 'solve lever arm' function in LC to refine\estimate the IMU to GNSS antenna lever arms. Calculate iteratively to refine these values. Once they have coalesced, process your LC/TC again to include the new lever arm values during trajectory processing. **Note:** Use with caution, this option is best suited for verification and is not a replacement for precise measurement of the integrated hardware.
- Output SBET and SMRMSG files with names specifying the exact mission, processing datum, and GPS week ○ SBET will be based on either LC or TC, whichever results are active in IE during output

  *When outputting an SBET/SMRMSG, the default input file will always be the TC solution (if you processed both LC and TC), therefore if you want to output an LC solution, be sure to verify your input file is correct (".cls" = LC and ".cts" = TC).

- Output final graphs by outputting an HTML report

  *Note: Everytime you output an HTML report it writes to an "HTML" folder. If you want to output a separate report for your LC and TC solution be sure to change the name of the "HTML" folder before outputting the second solution.

- Optional: Output a KMZ of your trajectory to reference with Google Earth or to send to your client

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4. SpatialExplorer (version 6.0.X)

In Offline mode SpatialExplorer is used to export raw range data to common point cloud formats, fuse camera data, apply a variety of filters, and project using customizable spatial reference system definitions.

Click here for a detailed overview of the SpatialExplorer Post Processing Workflow

4.1 Opening Data

4.1.1 Phoenix Project File

- Open the *.plp file to load raw data, acquisition settings and sensor configurations into SpatialExplorer.
- Configure the project datum

4.1.2 Trajectory Data

SpatialExlporer allows you to load a variety of trajectory files in order to process data. SpatialExplorer supports the following trajectory file formats:

.nav	Unprocessed, low-rate real-time trajectory data computed during scanning. This trajectory is automatically loaded with .plp
.POF/.POQ	RIEGL"s post-processed high-rate trajectory data that contains absolute time. Manually exported from a NovAtel Inertial Explorer loosely-coupled or tightly-coupled trajectory.

.OUT	SBET (**S**moothed **B**est **E**stimate **T**rajectory) high-rate trajectory data. Manually exported from a loosely-coupled or tightly-coupled trajectory processed by NovAtel Inertial Explorer. Only contains Time-of-Week information, therefore the correct GPS week and time system have to be specified when opening the file.

.cls/.cts Native high-rate post-processed trajectory created by NovAtel Inertial Explorer starting with version 8.70.	**C**ombined **L**oosely-coupled **S**moothed trajectory / **C**ombined **T**ightly-coupled **S**moothed trajectory.. Contains absolute time and does not lead to ambiguities as to which solution (loosely-coupled or tightly-coupled) the file was exported from.

- Open the post processed trajectory that was refined and exported from InertialExplorer.
  - File->Open File-> navigate to the CLS/CTS processed trajectory
  - Multiple trajectory files may be open simultaneously. Click on a trajectory name in the "Navigation" section of the project window, then use the green check mark to select it as the source for use during processing
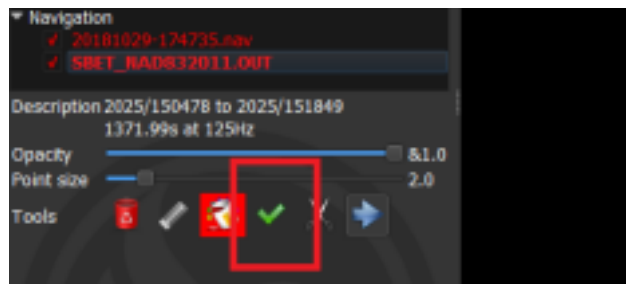
Figure 4.1 Selecting a navigation source

4.2 Produce LAS/LAZ File

4.2.1 Processing Intervals

Time intervals can be set to filter out data from turns, take off/landing, and other off flightline segments of the trajectory during export. There are 2 methods for creating processing intervals in SpatialExplorer:
- With the desired Navigation source highlighted in the Project window, click the Split Trajectory tool (Scissors icon). ○ Utilize the available parameters to automatically search for straight flightlines to use as processing intervals ● **Or,** Use the Positions Measurement tool to mark start and stop locations for each interval you would like to create along the trajectory.
  - Navigate to the Intervals layer of the Project window and click the Eyedropper icon to sample the measurement you have just placed.
  - Assign a name to your intervals.

4.2.2 Finalize Sensor Parameters and Create Cloud

You can choose to refine the final processing parameters for each of your sensors (LiDAR, camera, etc). ● Configuration for each sensor can be accessed from the Project window by clicking on the wrench icon

Figure 4.2

- Configure the numerous processing/calibration parameters associated with the sensors or cameras from this interface.

Create a cloud by clicking on the "Create Cloud" cloud icon , specify the exact intervals desired, filename and path, and click "OK" . Specify the exact intervals desired, filename and path, and click "OK" to generate the CLOUD file.

4.2.3 Export

To export an LAS/LAZ pointcloud from your SpatialExplorer project, click the "Export to LAS" button.
- Specify and output directory and give a name to the file
    - It is recommended to include the coordinate system and datum in the name of your export
- Select the flightline processing intervals from the dropdown list
- Specify the desired output coordinate system
- Select File Type and Version (LAS/LAZ 1.2/1.4)
- Finalize Cloud option
    - If you are going to be post-processing the LAS/LAZ file in TerraSolid, it is recommended to select the Time Format as "GPS time (adjusted)" or "Time of Week (seconds)". This allows for easy matching between the point cloud records time and the time in the SBET trajectory file when calibrating in TerraSolid.
- Set the **User Data**
    - When processing data from a multi-laser LiDAR sensor, it is recommended to set the User Data to "Index of Laser Head (Multilaser)."
    - When processing data from a Riegl sensor, it is recommended to select "Deviation (Riegl)"

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4.3 Produce Image Timing List

In order to use the captured images in Terraphoto, you will need to produce an image timing list.

- For Ladybug Cameras, see workflow here.
- For other cameras, see workflow here.

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5. Spatix and TerraSolid

To load the Terrasolid suite you will need to Install and launch Spatix and load the TerraSolid applications through the IxApps tool.

5.1 TerraScan/Match Setup

5.1.1 Create Project File from Seed File

Launch the Spatix application, and click on "Create new CAD file..". A spatix SPX seed template can be found in the terra64>seed folder on your local drive.

"Execute" all TerraSolid modules to activate them within Spatix.

5.1.2 Manage Trajectories

Open "Manage Trajectories" from the TerraScan main toolbar.

- Click on "Import files" and find the SBET you created in Inertial Explorer.
- Ensure the same coordinate system is applied to the trajectory as you applied to the .las/.laz in Spatial Fuser.
- 'Import accuracy file' and find your SMRMSG file to apply to the SBET
- Isolate individual flightlines
  - Use the "Split at laser gaps" function for the Tools dropdown to automatically detect the processing intervals that were set in SpatialExplorer.
  - **Alternatively**, interactively split flightlines if processing intervals were not set in SpatialExplorer
    - Tools -> 'Draw into Design' to show the trajectory in view 1
      - Use the 'Split' tool to cut the turns out of the trajectory and isolate individual flightlines.
    - Iteratively delete the turns from both the display and the trajectory dialog until you are left with only straight isolated flightlines.
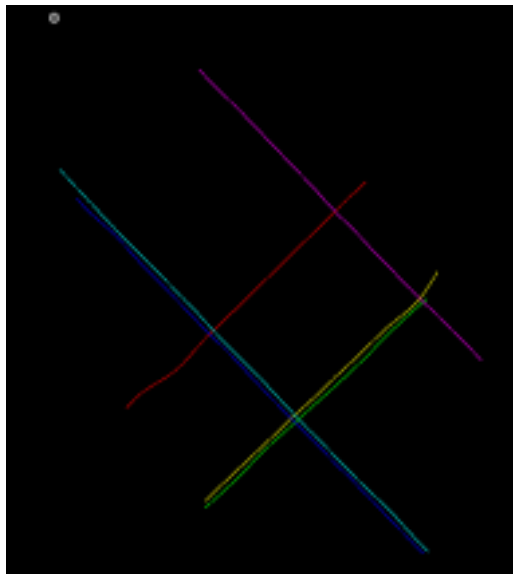

Figure 5.1: Individual, Straight Flightlines

5.1.2 Define Project

To create a new project, you need to open "Define Project" from the main toolbar.
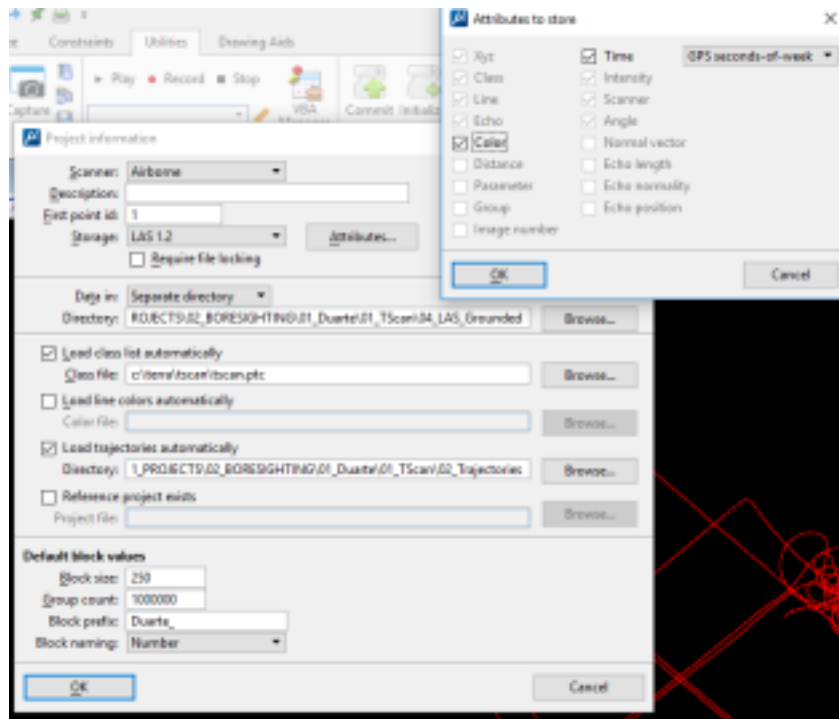
Figure 5.2: Creating a Project

- Ensure the "color" checkbox is selected in the "Attributes" dialog.
  - Utilize ".fbi" format instead of .las/laz as the intermediate storage format in mobile projects
    - Enable the storage of "Normal vector" and "Image numbers"
- You will need to create paths to a "Separate directory" for your project points and for your trajectories.
- Make sure to define the block size based on the point density of your project (typically 100m - 300m). ●
Once you are done, save your project.

5.1.3 Importing Points into Project

- Before reading any points, ensure that the TerraScan "Scan Define Coordinate Setup" origin and resolution is set appropriately for the coordinates of your data.
- In the TerraScan project window: File -> 'Import Points into Project'
  - Leave everything default

5.1.5 Prepare points for calibration

With points imported and flightlines split you will need to prepare the project for calibration

- Run a macro to "Deduce line numbers" for the project points to ensure that they match the trajectory numbers, and "Delete line" 0 to remove turn data if trajectories were manually split.
  - Write over original

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- In project window -> Boundaries -> 'Draw boundaries'
  - Label: Full File Name (optional)
- Run a grounding macro and write the new project points to a 'Grounded' folder
  - Process lines separately
  - Process Scanners separately (optional - takes longer time)
  - Compute normals and classify buildings/wall for mobile data calibration

- ○ Use at least 5m neighbors (more with large buildings/trees)
- ● Edit the project information to point the directory to the 'Grounded' folder
  - ○ Save the project

5.2 Calibration through TerraScan and TerraMatch

Here we will use the functions in TerraScan and TerraMatch to create tie lines and solve for flightline and fluctuating corrections to maximize the relative accuracy.

- ● In the TerraMatch toolbar, run Measure Match to assess relative accuracy
  - ○ Save the report as a baseline
- ● Visually spot check the data

5.2.1 Global Corrections

- ● In TerraMatch toolbar - 'Define Tie Lines'
  - ○ Set Max error of xy and z based on your initial offsets
    - ■ This controls how far apart flightlines can be in order to make observations between them ○ Multi-laser System Check 'Separate scanners'
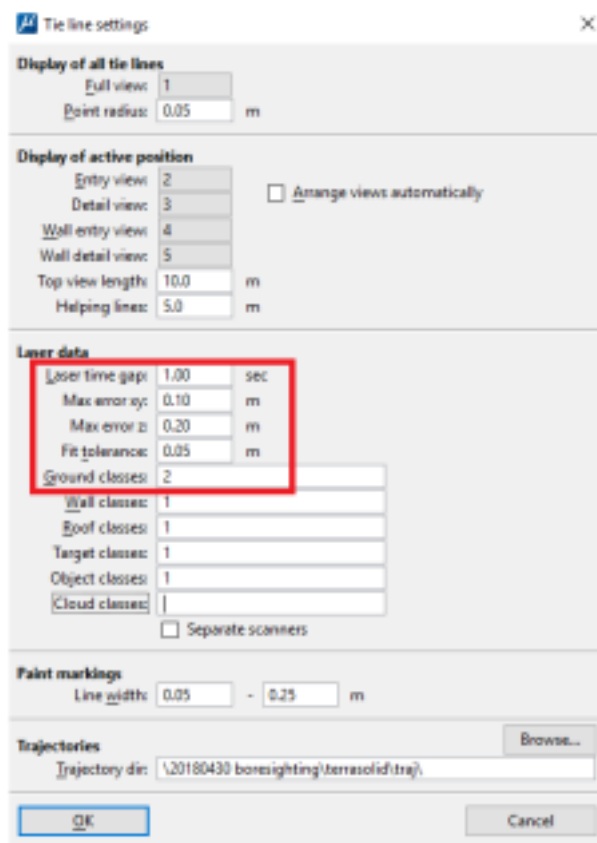 - ○ Mobile projects specify the Wall/Building class for vertical tie line observations

Figure 5.3: Define Tie Lines Settings Dialog Example

- ● In the next window: File -> Search Tie Lines
  - ○ Edit the parameters of the next dialog based on the type of dataset
  - ○ Tip: iteratively try different settings to optimize the number of tie lines found
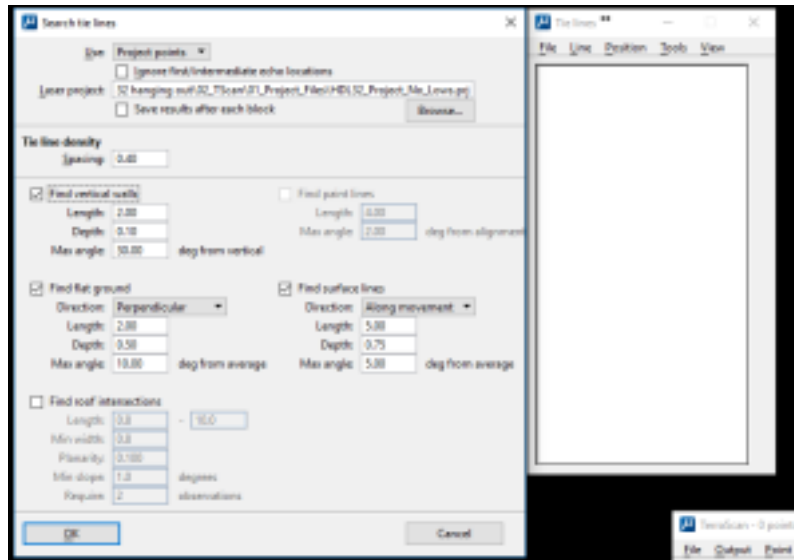
Figure 5.4: Search Tie Lines Dialog (Example from Mobile Mission)

- Save the tie lines found
- In the TerraMatch toolbar -> Find Tie Line Match
    - Solve for whole dataset and solve for Heading, Roll, and Pitch only
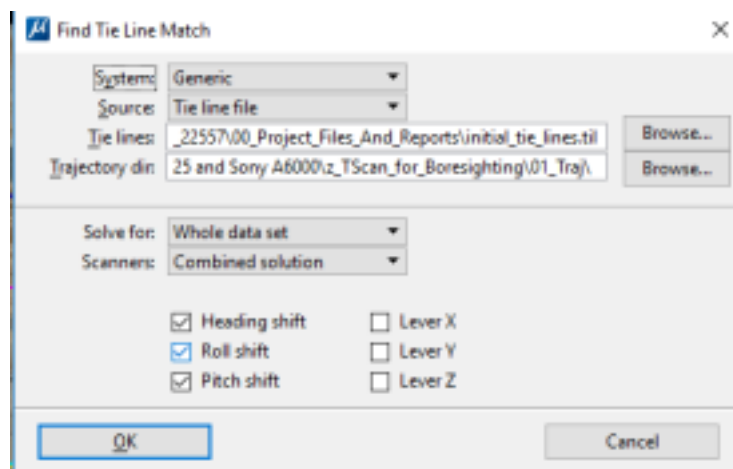
Figure 5.5: Tie Line Match Dialog (Mobile Applications use "Generic" System)

    - Save the corrections found as a .tms and save the report .txt
- Run 'Apply Corrections' from the TerraMatch toolbar
    - Use corrections from above and save to a new folder
- In the 'Define Project' window, set the .las directory to your new folder of corrected .las
    - Save the project
- Run Measure Match with the same setting as previously
    - Save the report

5.2.1.1 Multi-Laser Corrections

- Go through the Define Tie line dialog and search tie lines as you did previously
- Find Tie Line Match same as before, but with only 'mirror scale' checked and a solution per scanner
        - Save corrections and report and 'apply corrections' to a new folder
- Change the directory in your 'define project' to this new folder of corrections

- ○ Save the project
- Run Measure Match with the same settings as before, save report
- Use Define Tie Lines again and search and save a new set of tie lines
- Find Tie Line Match same as before but with Roll, Pitch, Heading checked and a solution per scanner
    - ○ Save corrections and report and 'apply corrections' to a new folder
- Change the directory in your 'define project' to this new folder of corrections
    - ○ Save the project
- Run Measure Match with the same settings as before, save report

5.2.2 Flightline Optimization

5.2.2.1 Flightlines

- Use Define Tie Lines again and search and save a new set of tie lines
- Find Tie Line Match and use 'Individual Lines' instead of 'Whole Data Set' to find individual flightline corrections ○ Save the corrections and report and use 'Apply Corrections' to create a new set of corrected .las

- Change the directory in your 'define project' to this new folder of corrections
    - ○ Save the project
- Run Measure Match with the same settings as before

5.2.2.2 Fluctuating Corrections

- Use Define Tie Lines again and search and save a new set of tie lines
- Use the "Find Tie Line Fluctuations" tool to find fluctuation corrections for the dataset
    - ○ Only solve for Z with a smooth curve and 2*trajectory accuracy
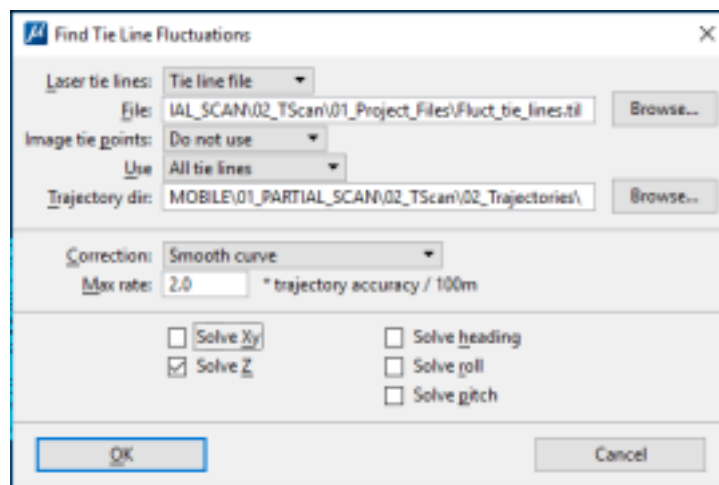
Figure 5.6 Find Tie Line Fluctuations

- Save the corrections found and the report
- Use 'Apply Corrections' to apply the fluctuations corrections and write a new set of .las
- Edit the Project information to point to this new folder and save your project
- Run Measure Match with the same settings as previously and save you report

Now you data has been calibrated and is ready for further classification or creation of derivative products.

5.3 TerraPhoto: Orthomosaic Creation and RGB Extraction

Make sure TerraPhoto is loaded through the MDL applications in Microstation.

5.3.1 TerraPhoto Setup

- In the TerraScan main window, read in all of the ground points for your project area. This will provide TerraPhoto a ground surface to properly rectify and mosaic the imagery
- In the TerraPhoto toolbar, find 'manage camera trajectories' and point the directory to the same folder containing the trimmed trajectories you used with TerraScan and Match.
- In TerraPhoto -> Create a New Mission
    - Create directories for temp, ortho, and mosaic outputs
    - Set up a mission camera
        - Use the most up to date .cal file possible for your specific camera
        - Positions=normal, naming=eagle eye, format=.jpg
        - Specify the image directory of JPGs
    - In TerraPhoto -> Points -> load from TerraScan, specify the ground class *Not necessary for Mobile applications*

- In TerraPhoto -> Images -> Compute list. Use the image timing list .txt created from SpatialExplorer ●
In TerraPhoto -> Utilities -> Create Thumbnails, Shadow maps, and Depth maps
- **Optionally**, With the TerraMatch "Apply Corrections" tool, apply the flightline, and fluctuation corrections used on the point cloud to the image timing list to ensure the two data coincide
- Spot check the initial image accuracy
    - For aerial data In TerraPhoto -> Rectify -> Color Points. This creates an initial orthomosaic to view ■ Assess seamlines and radiometric consistency
        - Check for image misalignment caused by image-timing mismatch
        - Decide if the camera needs additional calibration
    - For Mobile Ladybug Systems: In the TerraPhoto main window -> View -> Camera View
        - In view 7 (or whichever view was specified in 'Camera View') look at a particular image with the LiDAR points loaded and displayed in the same area to assess how well the imagery coincides with the LiDAR data. If you see slight offsets between the two data go through camera calibration refinement below. If you see large differences, check the image timing list and your raw photos for obvious skipped events and recongsile in your image timing list

5.3.2 Tie Point Adjustments

- For aerial missions in TerraPhoto -> Image -> Define Tie Points
    - Cycle through the image list that is created and find an image with well defined, identifiable features on the ground surface (not above ground objects).
    - Using one image, use 'Point' → 'Add Ground' to select a feature in view 1, then the same refined location in view 3.
    - In view 4 a series of other images that contain the same feature are shown. Select the same location on the feature as you did in view 2.
    - Quality is paramount over quantity, although you need at least 5 points to provide a decent initial camera calibration.
    - If you can find an image with minimal above ground features, you can try automated tie points using File

-> Search Tie Points. With this method be diligent to delete points that are on above ground features.

Figure 5.8: Example of automatic image tie points

- If using a mobile system with a Ladybug camera, use these steps for Image Tie Points:
    - Cycle through the image list created in this dialog and find an image with well defined, identifiable features on vertical surfaces near the drive lines that can be seen from multiple angles.
    - Using one image, use 'Point' -> 'Add Air Point' to select a feature in view 1, then the same refined location in view 2.

    - In View 3, a series of other images that contain the same feature are shown. Select the same location as in view 2.
    - Quality is paramount over quantity, although you'll need at least 5 points to provide a decent camera calibration.
- Save these tie points and go to File -> Output Report
    - Note the starting and final misalignment values at the bottom of the report and ensure that they are getting better.
    - Within this dialog: Tools -> Apply Misalignment. Save this report as well.
    - This will change the extrinsic values in the camera calibration file (.cal).
- Open Camera Definition from the TerraPhoto toolbar
    - The new extrinsic values now appear here.
    - Tools -> Solve Parameters (re-calculates intrinsic values based on tie points and using new extrinsic).
    - Solve for all three intrinsics and save the camera definition.
    - Click 'Apply' to apply these new values to the calculations that created the initial image timing list and refines the image positions and orientations.
- Rectify -> Define Color Points to check your calibration through assessing the on-the-fly orthomosaic. ○ For Mobile Ladybug Systems assess this calibration quality with the "create view" tool under "view" ● Repeat the tie point and intrinsic/extrinsic calibration process until the orthomosaic created through 'Define Color Points' has acceptable image alignment.
    - For Mobile Ladybug Systems assess this through the "create view" tool under "view"

5.3.3 Color Points

- In the TerraPhoto toolbar, find the color points toolbox and open it separately.

5.3.3.1 Color Balance

- Start with an automatic search for color points using the color points main window → file → search points. ● Then use the color points toolbox to place or delete color points, and overcome any existing radiometric issues with the orthomosaic. Save these points when done.

5.3.3.2 Seamlines

- Start with an automatic search for selection shapes using the color points main window → image → search seamlines. Search between all images.
- Then use the seam line editing tools on the right side of color points toolbox (either selection shape or brush) to edit the seam lines and minimize any parallax issues.

5.3.3.3 Seamlines for Mobile Applications and RGB extraction

- For seamline edits to be used in RGB extraction or in Mobile application, the LiDAR file format needs to be changed to Fast Binary (.fbi) either in 'define project' or in the loaded points in TerraScan.
- Compute normal vectors for the entire project/file (towards trajectory)
- Use Tools -> Extract color from Images and ensure image numbers are computed and stored ● After extraction: Use Rectify -> Define Color points to start the seamline editing process (mode: Point cloud) ● Use the selection shapes tool(s) as described in the Aerial post processing workflow
    - After each selection shape is place, manually choose the best image to provide RGB information

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- After finishing selection shapes, use Tools -> Extract Color From Images to permanently store edits
    - Select "Used Stored" as the image number, the rest default
- Complete any radiometric alteration using 'Color Points' in the same process as with aerial projects. ● Now the image number prioritization applied through the selection shapes process is written into each point ○ Use 'extract color from images' and ensure the image numbers are set to 'Use Stored' and to load the color points to keep the selection shape seamline and radiometric edits in the RGB extraction process.

5.3.4 Orthomosaic Output

To Output an Orthomosaic: *Not applicable to Mobile Ladybug Systems*

- Create an AOI for your mosaic to be clipped to, or use the bin boundaries from your LiDAR project to tile the mosaic output.
- Rectify → Rectify Mosaic
    - Specify your desired output resolution (pixel size) and use 3*8 bit color
    - Specify your coordinate system ensure a proper georeference, and generate .tfw/.ecw file.
    - Use the color points and selection shapes from the seam line and radiometric editing.

5.3.5 RGB Extraction

To Extract RGB information into the Point Cloud:

- In your TerraScan Project Window → Tools → Extract color from Images
    - Use raw images and specify the color points you saved from earlier steps.
    - Use closest in 3D for the geometry of colorization, although feel free to try other methods. Project and platform type can make other methods preferrable.
    - *Use Closest in Time for Mobile Ladybug Systems to extract RGB information to the point cloud*
    - Use Depth Maps and a minimal footprint (~1-2 cm).

5.4 Ground Control and Assessing Absolute Accuracies

If you do not have ground control for a specific project or area, this section should be skipped. Use the relative accuracy from the last measure match report as the reportable accuracy, but clearly communicate that this is relative accuracy of line to line ground surfaces, not absolute accuracy of the point cloud to a real life surface.

- Open your GCP file and format it into a tab delimited .txt file without headers and ordered Northing, Easting, Z, without any descriptor columns. Ensure the coordinate system used by the GCP's is the exact system that your point cloud is in, otherwise re-project the points. You should also have a subset of withheld GCP's for a final accuracy report.
- In the TerraScan Project window -> Tools -> Output control report (and save)

Number	Easting	Northing	Known Z	Laser Z	Dz
1	410861.368	3776930.990	111.232	109.880	-1.352
2	410884.749	3776901.630	112.121	109.810	-2.311
3	410964.360	3776947.828	111.690	109.800	-1.890

Average dz	-1.851
Minimum dz	-2.311
Maximum dz	-1.352
Average magnitude	1.851
Root mean square	1.892
Std deviation	0.481

Figure 5.7 Sample Control Report

- Note the average Dz. This will be your vertical shift applied to the point cloud to shift the data up or down to the relative elevation of the GCP's. This will correct any error applied to the base station height or other raw inputs with incorrect elevations.
- Create a macro to 'transform points' by the Dz noted above, then run this macro on the project. ● Change the project directory to reflect this new set of .las/.laz and re-run the control report against these new points with the GCP file of withheld points.
- Save this report as the final accuracy report. The RMS value is your reportable absolute accuracy, with the standard deviation as a good reference to the 'tightness' of the accuracy.

6. Mobile Data Processing Tips

When processing Mobile datasets, a few considerations should be kept in mind. The processing is largely the same, with some nuanced differences:

- Convert .prg streams to panoramic images with the rigorous processing setting and an appropriate stitching sphere size.
- Ensure all of the image events were converted to panoramics, to ensure no corruption of the .prg streams.
- Walk through all images to check for color issues or potential dropouts or duplicates.
- Trim image timing list as you see fit related to the above issues.
- Try using the TerraPhoto tool "Delete Closeby Images" in the 'images' dropdown to remove duplicate images from stops.

● Creating depth maps: set the depth resolution to 1mm if processing time allows, otherwise 1-2cm. ● Compute normal vectors: This aids the RGB extraction process for mobile applications, although not necessary.

6.0.1 Create Mask for Panoramic Image RGB Extraction

- To create a mask to exclude the car and antennae from the RGB extraction process:
  - ○ Open a .dgn that has Easting and Northing origins set to zero in 'Photo Define Coordinate Setup'.
  - ○ Start 'Manage Raster References' from the TerraPhoto toolbar.
  - ○ Attach one raw image (for example ladybug_panoramic_000001.jpg).
  - ○ Select this image in the reference list and start 'Edit / Modify attachment' menu command.
  - ○ Click OK. Image gets positioning where lower left corner is at 0,0 and pixel size is 1.0 master unit.
  - ○ Start 'Display / Fit / All' and click in view 1.
  - ○ Draw polygon for bad image area.
  - ○ Start 'Define Camera'.
  - ○ Use 'File / Open' to open ladybug.cal.
  - ○ Select polygon drawn in step 7.
  - ○ Start 'Tools / Assign bad polygons'.
  - ○ Save camera calibration.

7. Frequently Asked Questions

1. **How can I contact Phoenix LiDAR Systems for support?**
   If you need help, we offer a number of options for customer support. The preferred method of communication for support is through our ticketing system. Send an email to support@phoenixlidar.com with the subject line as the title of your question and include your question in the body of the email.

2. **What is the difference between an ellipsoid and a geoid?**
   Ellipsoid comes from the word "ellipse," which is simply a generalization of a circle. Ellipsoids are generalizations of spheres. The Earth is not a true sphere, it is an ellipsoid, as Earth is slightly wider than it is tall. Although other models exist, the ellipsoid is the best fit to Earth's true shape.

   Like the ellipsoid, the geoid is a model of the Earth's surface. According to the University of Oklahoma, "the geoid is a representation of the surface of the earth that it would assume, if the sea covered the earth." This representation is also called the "surface of equal gravitational potential," and essentially represents the "mean sea level." The geoid model is not an exact representation of sea level surface. Dynamic effects, such as waves and tides, are excluded in the geoid model.

   Unlike the geoid, the ellipsoid assumes that Earth's surface is smooth. Additionally, it assumes that the planet is completely homogeneous. If this were true, Earth could have no mountains or trenches. Further, the mean sea level would coincide with the ellipsoid surface. This is not true, however. Vertical distance exists between the geoid and the ellipsoid as a result of the geoid taking into account mountains and trenches as an Earth model. This difference is known as the "geoid height." The differences between the ellipsoid and geoid can be significant, as the ellipsoid is merely a baseline for measuring topographic elevation. It assumes that the Earth's surface is smooth, where the geoid does not.

3. **What is the difference between Antenna Reference Point (ARP) and Antenna Phase Center?** All GNSS measurements are referred to the antenna phase center, where the antenna phase center is defined as the apparent source of radiation. The position of the antenna phase center is not necessarily the geometric center of the antenna. The actual antenna phase centers for L1 and L2 frequencies are points in space, and cannot be measured physically.

Since the Antenna Phase Center cannot be measured physically, the Antenna Reference Point (ARP) is used as a physical measurement point, and the known Phase Center Offset (PCO) is applied to the ARP measurement to yield the true Phase Center measurement. The ARP on a GNSS antenna is typically the point on the centerline of the antenna at the mounting surface.

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If you have any questions about this document, please contact Phoenix LiDAR Systems by sending a message to support@phoenixlidar.com.