TLS Data Processing and Exploration Manual

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Collecting data in the field is only the first step in the complete TLS workflow. This manual will take you through the skills needed to complete assignments for Units 1, 2, and 3. These sections are not linked to specific projects, so you will need to use your own judgment on what portions of the manual you need to use for your given assignment. In addition, you can always use the Help menu in RiScan Pro.

I. Project scan registration and visualization

Loading the project and getting started

1. Project—Open—Navigate to the folder containing the scans from the field; select the "RiSCAN PRO Project" file type (project.rsp). RiScan automatically saves the project, so there is no need to use the "Save as" function at any point.
2. In the RiScan Pro window, the primary components are the Project manager tab in the left panel, the Message List in the bottom panel, and the main visualization panel, which is the center of the screen. The Project manager tab is the panel used most; most functions used in this unit in RiScan Pro can be started from here. The Message list panel indicates whether a function worked correctly or failed and is useful when working with the data. Finally, the large center panel is the area ("Scan view window") where the scan will show up.
3. In the Project manager tab, the "SCANS" folder contains all the scan positions files. In each scan position folder, the file with an orange-colored cloud icon with a grey background is the actual scan point cloud data (note: if scan has already been colored with images this will be a rainbow-colored cloud with grey background). This icon is followed by the date and time of scan collection: e.g., 150623_005743.

Scan Registration

Scans are generally "registered" (aka. tied together) in the field. If the field registration process seems to have errors, or if the scan was registered based on a noncentral scan position, the scans should be re-registered in the lab.

1. Unregister all scans.

   Right-click each scan position and click "unregister." Doing so will enable you to start registration with a clean slate.

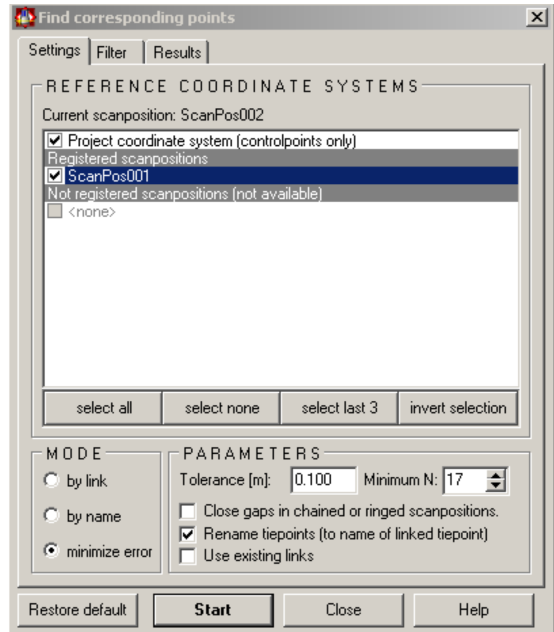
2. Register reference scans.

   Select the scan position to which you want the rest of your scans registered (generally your first position called "ScanPos001"). Right-click on it and select "registered." A green globe will appear to the right of the scan position name.

3. Register remaining scans.

   Double click on a nonregistered scan position (e.g., ScanPos002) and open "TPL (SOCS)."

a. *Use:* Ctrl+A to select all tie points and click “Find corresponding points” (the icon above) on the window menu bar. There should be a minimum of 3–5 tie points in common.



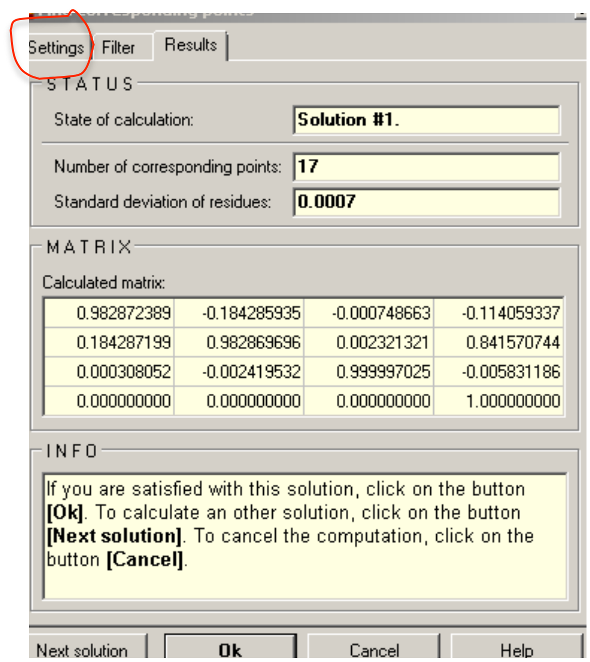
b. *Check:* “Project coordinate system (control points only).”

c. *Check:* The registered scan position(s) in this example will always include previous scans.

d. *Mode:* Select “minimize error.”

e. *Parameters:*
   a. Tolerance should be 0.1 (for metric units).
   b. Minimum # of Targets: 3.
   c. Check “Rename tie points.”
   d. Click “Start.”

f. *Standard Deviation:* Standard deviation should be no greater than 2 cm. If no solution is found or the SD is larger than 2 cm, click “Next Solution.” You can also select “Settings” and increase the “tolerance” and decrease the “minimum # of targets,” **but not below 3.**



- If an acceptable solution is still not found, proceed to **Step 10**. Here you can inspect tie points to determine if any need to be disregarded so an acceptable Standard Deviation can be obtained. Hence, the importance of having as many tie points as possible.
- If an acceptable SD solution is found, click “Ok.”

Data visualization

1. To link the true color of each point to the point, right-click the scan (the orange cloud icon on the grey background, not the scan position folder) and find “color from images” in the dropdown menu. Select all images that apply to that scan position from the dialogue box that appears, then hit enter. It will take a few seconds to work, so be patient.
2. After you have linked the photos, select the scan with the mouse and drag it into the “Scan View” window. You will be prompted with a menu box for options on how the scan should be colored. Choose the true color option (near the bottom on the right-hand side) and choose 3D near the top of the menu. Click “OK,” and the image should appear.

3. Repeat steps 1 and 2 for each of the scans.
4. Here are some useful mouse commands for orienting the data:
   - rollerball (click)—drag/pan
   - rollerball (zoom in/out)
   - left click once—re-centers the rotation
   - shift or control: keeps rotation in vertical or horizontal plane
   - Use the yellow box in the menu bar to re-center the view if the data disappears or you get lost.
5. For a quick look, it is easiest to use the 2D viewing option if you are running on a laptop. However, in lab, the 3D view will show the full scan and is the ideal way to view the data.
6. There are many view types to visualize the scans in RiScan Pro. A list of the types and reasons to use them are below. To visualize the scan, right-click the scan and choose "View," then choose "<new view>." After this step, the following options will be visible.
   a. Amplitude: Also known as the "intensity," the amplitude is a measure of the return strength of the reflected pulse. This view can be used to detect features or as a substitute for the true color.
      i. *Select:* Color range from "Color Table" (gray-scale tends to work best).
      ii. *Select:* "Calculate minimum/maximum" and click "OK."
   b. Reflectance: Reflectance is the reflectivity of each point in the point cloud. This is useful when extracting the targets from the rest of the data, as the targets are generally much more reflective than the surrounding features.
      i. To show the targets, select the black/red color table.
      ii. Then set the minimum to -25 and the maximum to 5; this will highlight the targets in red.
   c. Falsecolor height: This colors the scan based on height using the selected color table between the minimum and maximum values.
   d. Falsecolor range: This shows the distance between the scan position and the collected point.
   e. Single color: One color is selected for all points. This is a good option if the computer is low on memory as well as for viewing alignment between sets of scans.
   f. Truecolor: The color of the point is defined by the true color of the point as determined by the images. Step 1 above describes how to do to this.
7. To view multiple scans in the same space, create a new view.
   a. Drag and drop each scan into the scan view panel.
   b. Each time a scan is dragged in, a dialogue box will appear to choose the view.
   c. Choose a single color for each scan and select a different scan color for each scan position.
8. To save the view as an image, use the small black x (not the red x for the program as a whole) and it will prompt you to save. This can then be accessed through the Riegl Scans project folder in Windows Explorer as well as the Views folder in RiScan Pro. Images are saved as .bmp files.

II. Evaluating tie points and georeferencing

Tie point check

Recall that in the field, we discussed how multiple scans (collected in SOCS, or Scanner's Own Coordinate System) are tied together to produce a coherent scene that can display multiple scanner data (PROCS or PRoject's Own Coordinate System). Later the data is georeferenced to real-world coordinates with GPS data to produce points located in a GLCS (GLobal Coordinate System). Here we are going to evaluate how good our tie points are—the scanner points that we located from each scan position that were used as common points to tie the data into a project reference frame.

1. Open the TPL (SOCS) (Tie Point List [Scanner's Own Coordinate System]) file located in the scan position folder.
2. View each tie point by clicking on it and observing the preview window. If one seems not to be truly represented by the program, examine the point more closely.
3. To do this, double click on the tie point in question in the "TIEPOINTSCANS" folder. Open in 3D view.
4. Rotate the view until you can see the isolated point cloud of the tie point. Zoom in on the point cloud.
5. Drag the "TPL (SOCS)" icon into the viewing window. This will superimpose the primitive onto the scan.
6. Rotate the scan with the overlain primitive. How well does the location of the primitive fit the point cloud?
7. If the fit is poor, open the TPL (SOCS) file again, right-click the point and delete it.

Visualizing tie point vectors

A nice way to visualize the targets used is to visualize the tie point vectors. This creates a figure you can use to show the distribution of targets relative to the scan positions to demonstrate your excellent survey design skills.

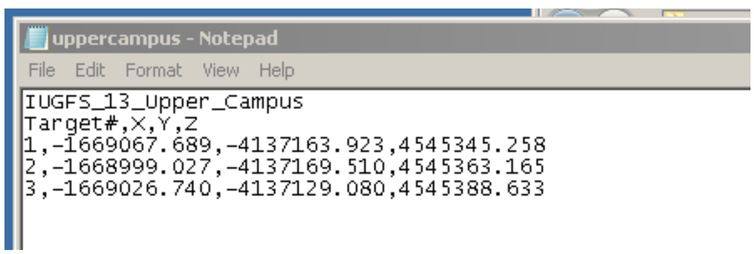
1. Go to the Object Inspector panel or tab. A view of the scan or scans you would like to show tie point vectors for needs to be open.
2. Turn scan view off unless you want to view the scans as well—this can be a messy view. Do this by clicking the orange cloud icon next to each scan. It will turn grey when the scan is not visible.
3. Click the first scan position. The Properties box at the bottom of the object inspector column has a tie point connection dropdown. Click "visible." If you want to see the distance, check that box as well. Finally, make the mode TP SOCS.
4. Do this for each scan position.

Georeferencing point cloud

For the data to link to a global coordinate system (GLCS) instead of the project coordinate system created when scan positions are registered, you need to georeference the data. The steps below outline how to start with GPS data from some or all of the targets in your scan and input the data into RiScan to "georeference" the data.

1. Download data from GPS units. If a UNAVCO employee is present, they will complete this step of the process. If you are using your own GPS system, follow the procedure for your instruments and generate a RINEX file.

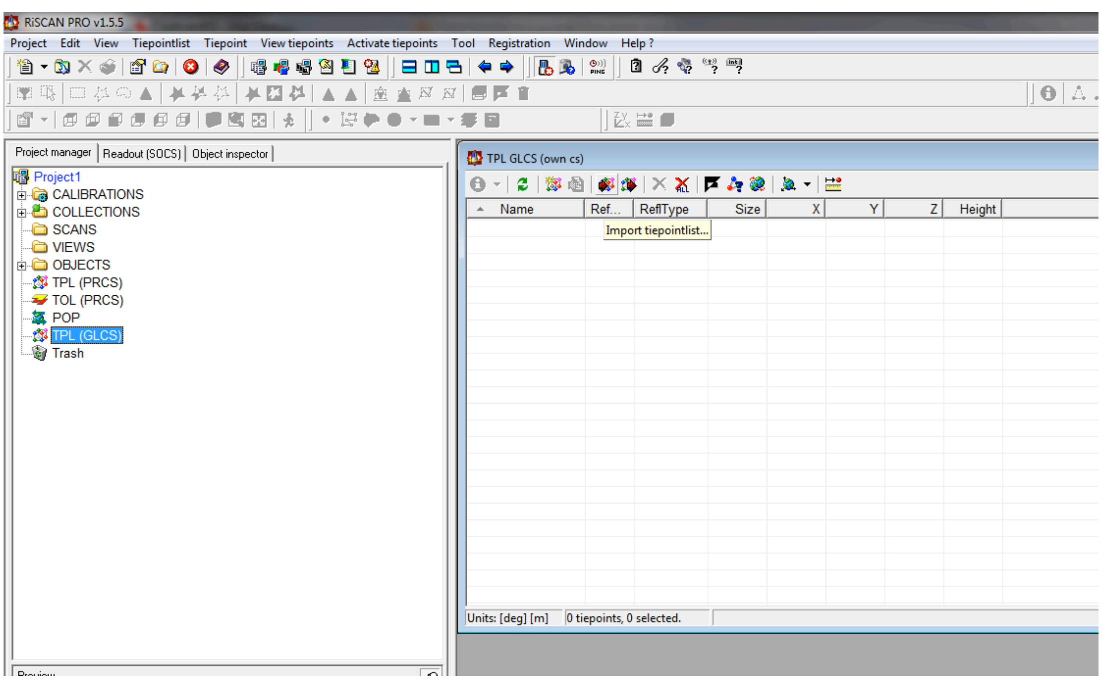
2. Loading to OPUS
    a. **OPUS Website:** Online Positioning User Service
    www.ngs.noaa.gov/OPUS/index.jsp
    b. **Load Data:**
        i. Upload a RINEX file (one at a time).
        ii. Enter vertical offset between the GPS and a reference point.
        iii. Select antenna type that was used.
        iv. Enter your email address.
    c. **Return email:** when you receive the return file back from OPUS, save it in your emails and make an extra copy as a PDF so you have a duplicate.
    d. **Create a control file using Text Editor:** Using any text editor, take the coordinates and elevations from each GPS OPUS solution and enter in the text file. OPUS provides a position in several coordinate systems. Which system you choose is project specific, but in general UNAVCO uses "Earth-centered Earth-fixed" coordinates. Start with a header titling the project, then lines indicating target #, X, Y, and Z (orthometric/elliptical height) on the same line for each GPS position (below). Then save the file in same folder as the rest of your project.



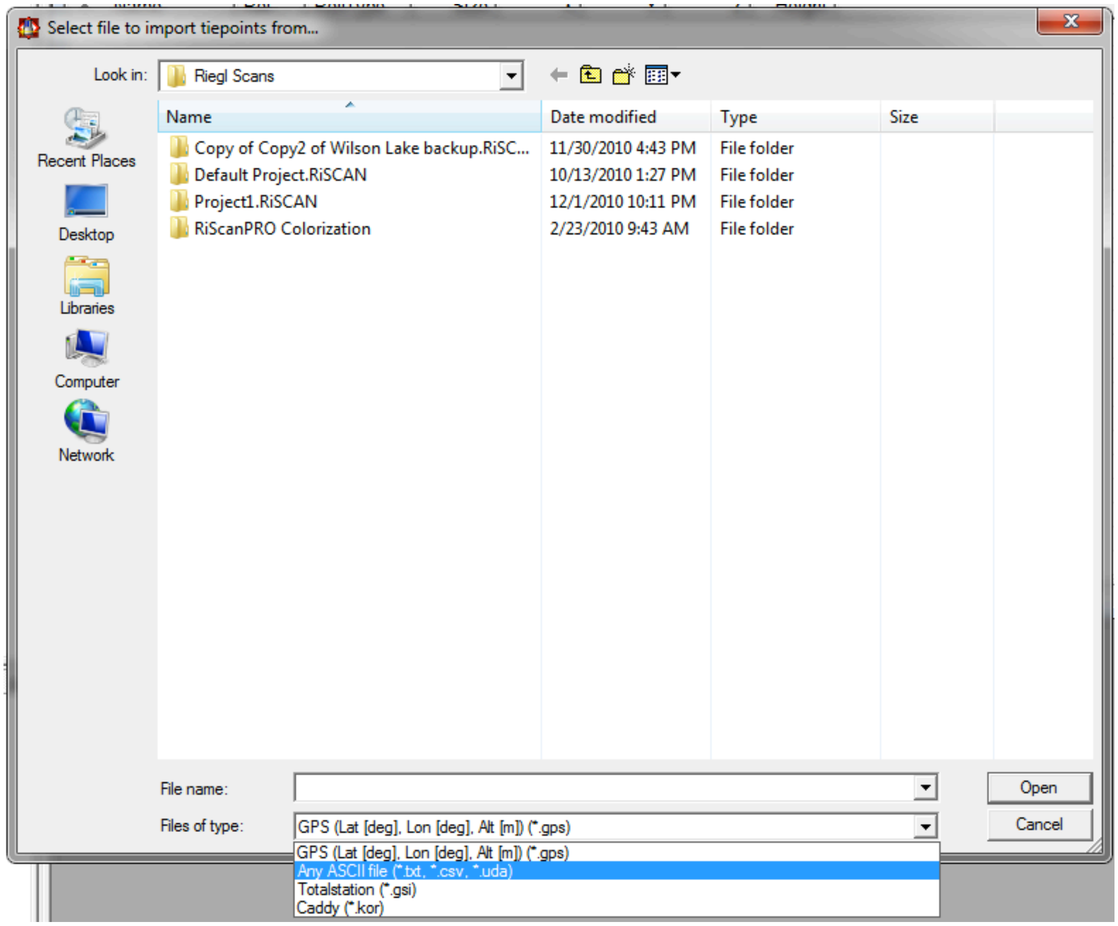

```
IUGFS_13_Upper_Campus
Target#,X,Y,Z
1,-1669067.689,-4137163.923,4545345.258
2,-1668999.027,-4137169.510,4545363.165
3,-1669026.740,-4137129.080,4545388.633
```

An example of how a control file should be formatted.

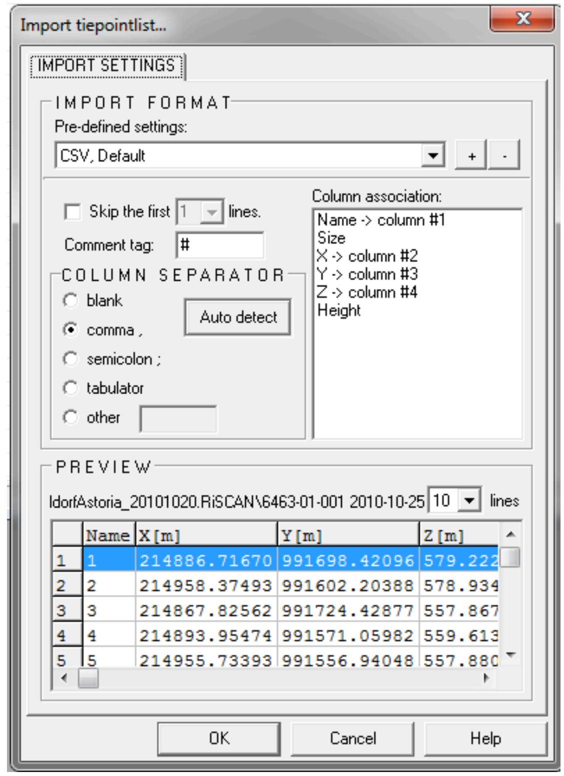
3. Using RiScan Pro
    a. Open TPL GLCS and import the created "control file" using the "Import" icon.



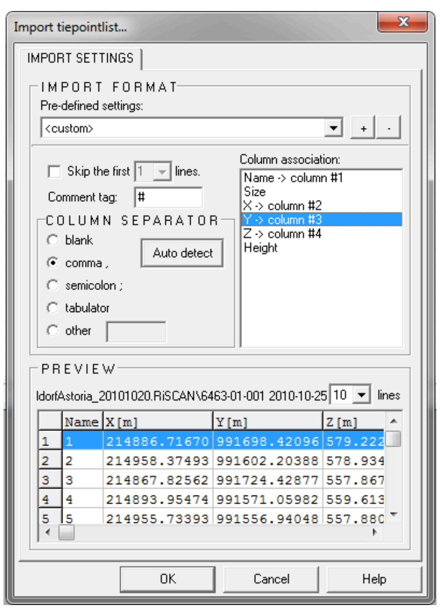
b. In the “Select file to import tiepoints from…” window select “Any ASCII file” from the “Files of type” dropdown menu. Then select the appropriate control file and click “Open.”



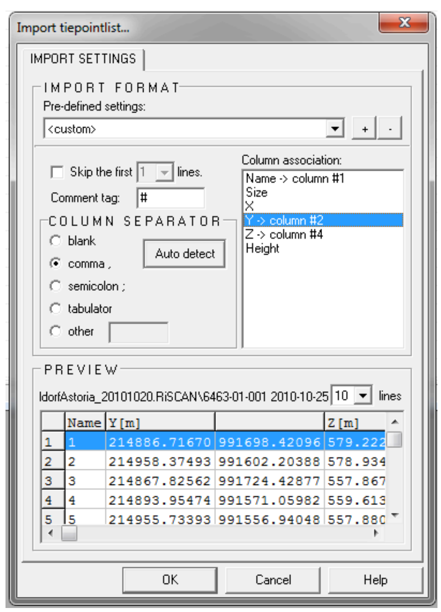
c. The next step is to organize the information and define units for the imported tie points. The image below shows the "Column association" field where you can rearrange the coordinates if necessary. RiScan Pro will assume column organization and units (in meters), which can be changed manually, depending on the survey control being used.



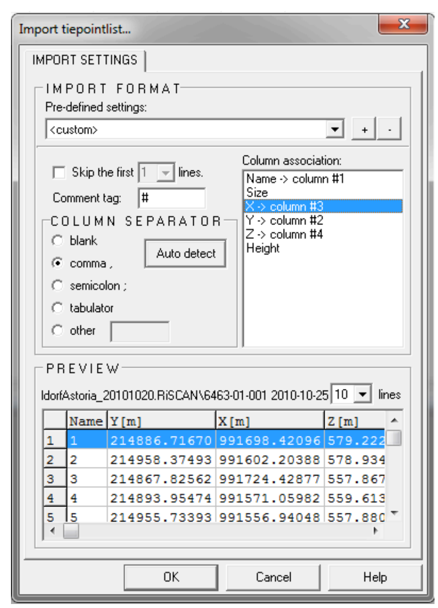
d. **Reorganize Column Headers:** To reorganize columns in the "Preview," click the attribute you want in the "Column Association" field and drag it down to the appropriate header in the "Preview" field. The images below illustrate this.



"Y" is highlighted in "Column Association" window, and ready to be dragged down to the "Preview" field.

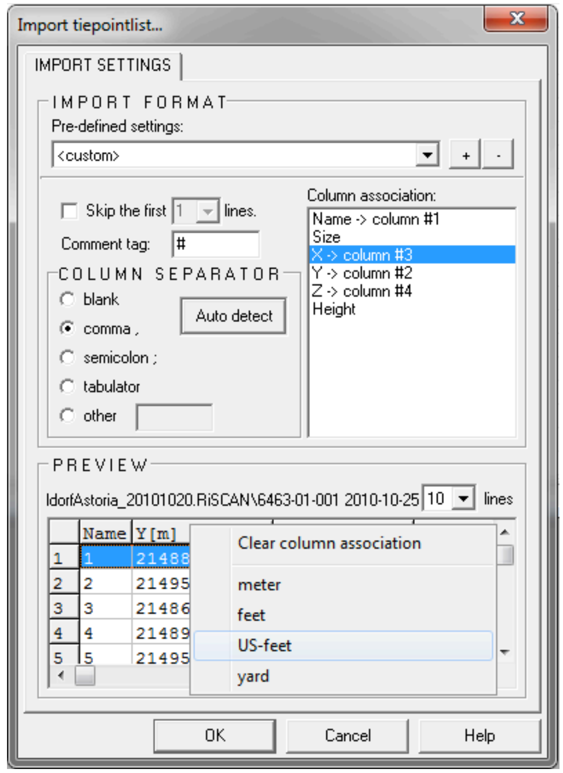


After "Y" is dropped into its new header, "X" disappears.

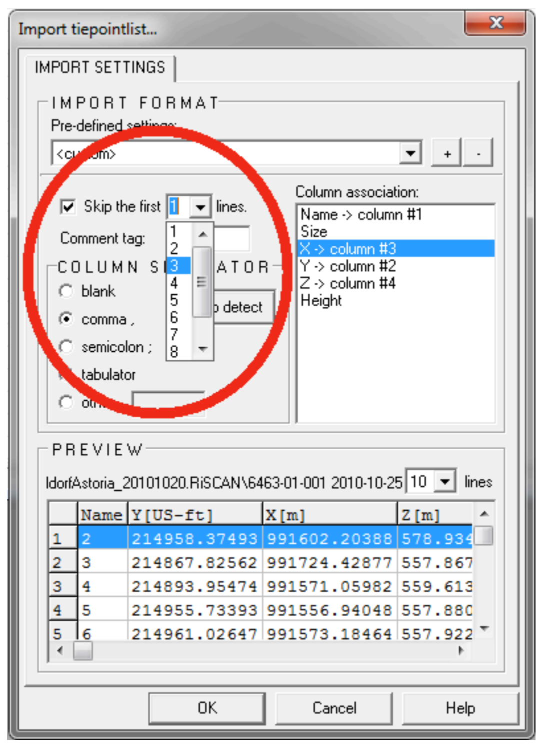


Next, highlight the empty "X" row and drag down to its new column and it will be reassigned.

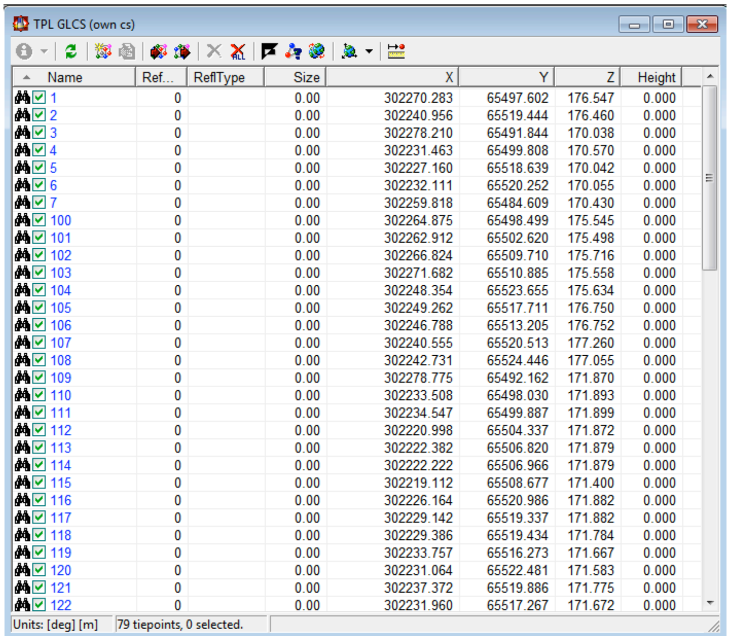
i. *Define Units:* In the "Preview" field right-click on the column headers and chose the appropriate units.



ii. *Eliminate Headers:* If your control file contains headers, they must be eliminated for the file to properly import. Use the "Skip the first ___ line" dropdown to select the number of lines you wish to skip in the "Preview" field. The number of lines you choose to skip should be such that no control points are eliminated from the list.



e. **Import Control Points to GLCS:** If everything is selected and adjusted correctly, click "OK" to import your control points. As the image below illustrates, you should have a nice table of your imported control points in "GLCS."

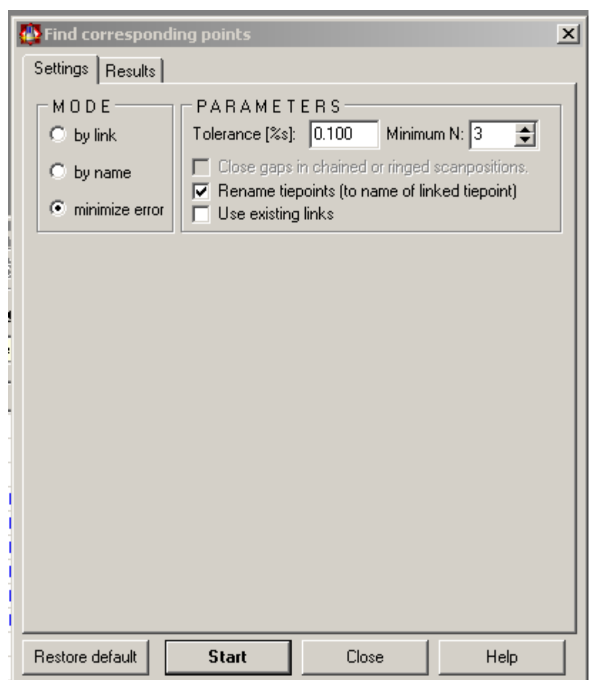

TPL GLCS (own cs)

Name	Ref...	ReflType	Size	X	Y	Z	Height
1	0		0.00	302270.283	65497.602	176.547	0.000
2	0		0.00	302240.956	65519.444	176.460	0.000
3	0		0.00	302278.210	65491.844	170.038	0.000
4	0		0.00	302231.463	65499.808	170.570	0.000
5	0		0.00	302227.160	65518.639	170.042	0.000
6	0		0.00	302232.111	65520.252	170.055	0.000
7	0		0.00	302259.818	65484.609	170.430	0.000
100	0		0.00	302264.875	65498.499	175.545	0.000
101	0		0.00	302262.912	65502.620	175.498	0.000
102	0		0.00	302266.824	65509.710	175.716	0.000
103	0		0.00	302271.682	65510.885	175.558	0.000
104	0		0.00	302248.354	65523.655	175.634	0.000
105	0		0.00	302249.262	65517.711	176.750	0.000
106	0		0.00	302246.788	65513.205	176.752	0.000
107	0		0.00	302240.555	65520.513	177.260	0.000
108	0		0.00	302242.731	65524.446	177.055	0.000
109	0		0.00	302278.775	65492.162	171.870	0.000
110	0		0.00	302233.508	65498.030	171.893	0.000
111	0		0.00	302234.547	65499.887	171.899	0.000
112	0		0.00	302220.998	65504.337	171.872	0.000
113	0		0.00	302222.382	65506.820	171.879	0.000
114	0		0.00	302222.222	65506.966	171.879	0.000
115	0		0.00	302219.112	65508.677	171.400	0.000
116	0		0.00	302226.164	65520.986	171.882	0.000
117	0		0.00	302229.142	65519.337	171.882	0.000
118	0		0.00	302229.386	65519.434	171.784	0.000
119	0		0.00	302233.757	65516.273	171.667	0.000
120	0		0.00	302231.064	65522.481	171.583	0.000
121	0		0.00	302237.372	65519.886	171.775	0.000
122	0		0.00	302231.960	65517.267	171.672	0.000

Units: [deg] [m] 79 tiepoints, 0 selected.

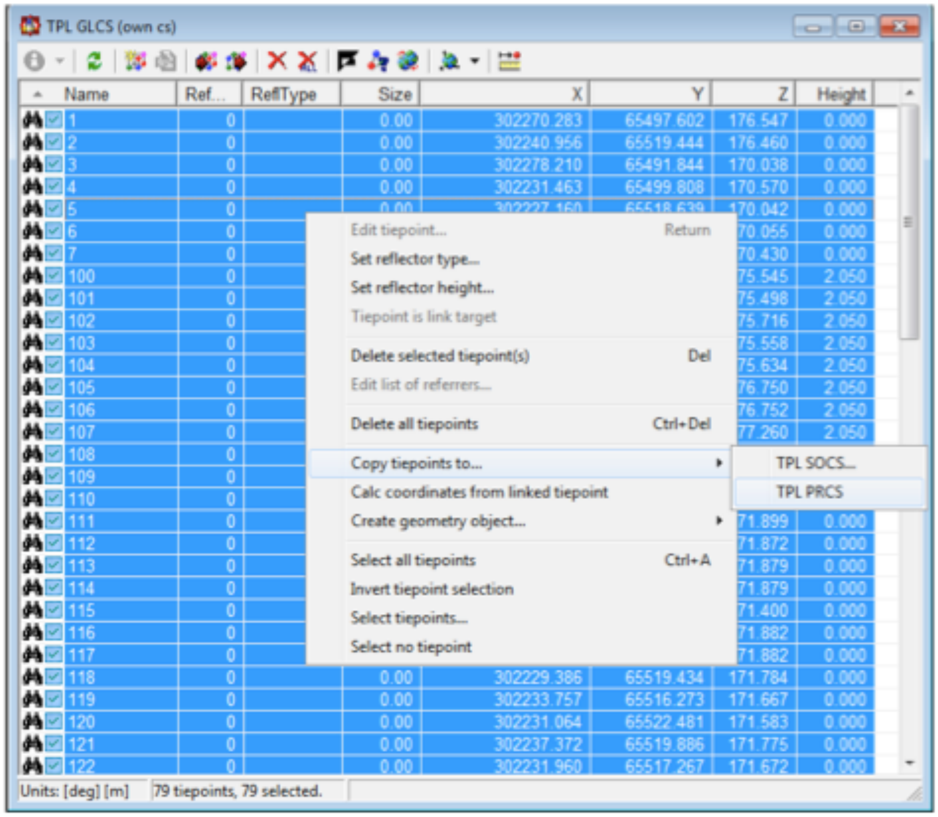
f. **Registration of Scan Data:** Two options exist for registration: "Small Area" and "Large Area." If the total size of the project area is within the scanner range, use "Small Area." But if outside of the maximum range of the scanner, use "Large Area."

i. *Small Area:* If the scans have already been acquired and registered relatively, a simple registration of the "PRCS" to the "GLCS" is all that is needed to fully georeference them. To do so, open "TPL PRCS" and select the "Find Corresponding Points" button. Choose only the number of targets that contain GPS antennas for the "Minimum N." Click "Start," and the entire project will be registered using "PRCS" points accumulated by common reference between two scan positions. You are now finished.

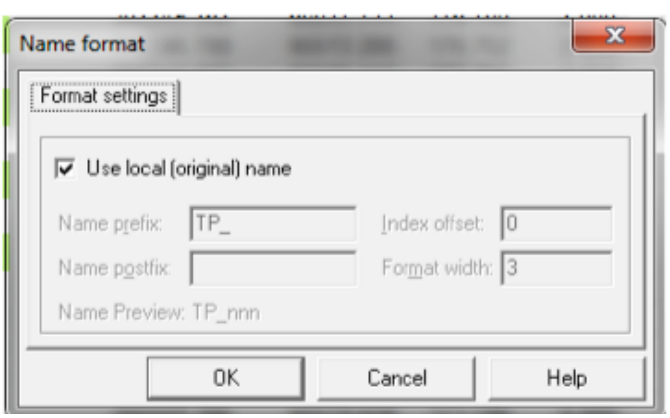


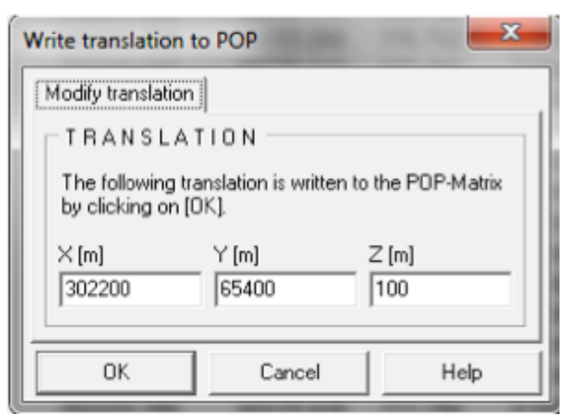
ii. *Large Area:* There are four steps to registering a large scan area.

1. Copy all GLCS to PRCS: To do this, open "TPL GLCS" and select all (Ctrl+A). Next right-click on table and scroll to "Copy Tie points to…" and select "TPL PRCS" (screen shot below).

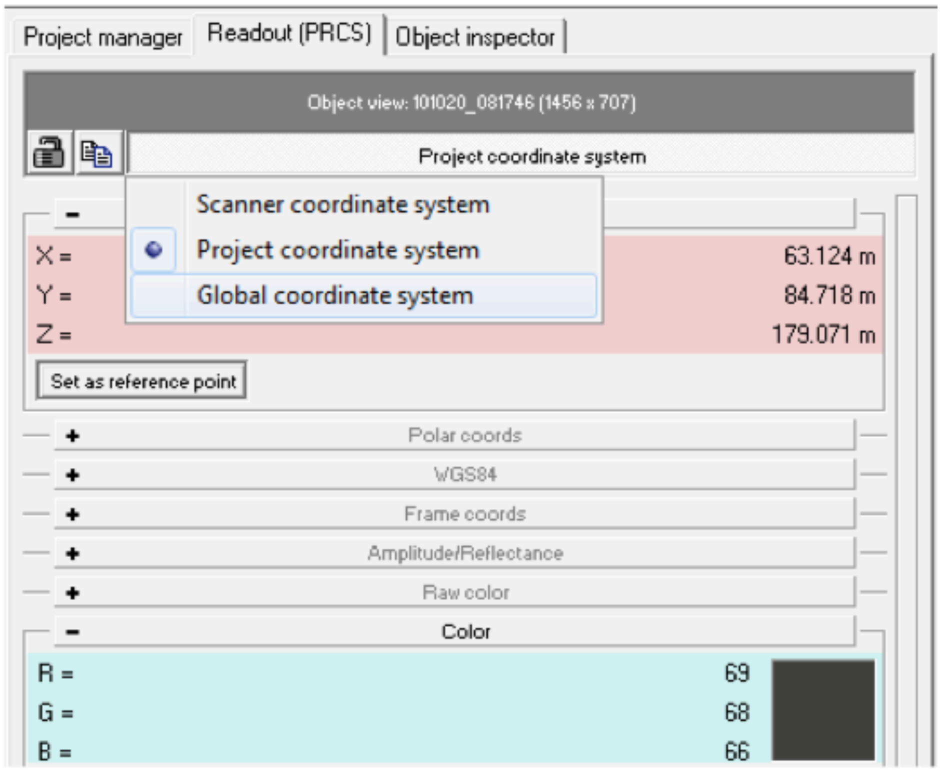


2. Name Format and Write Translation to POP: You will be see the following prompt windows in the order shown. The first window allows you to rename all the control points as they are copied into "PRCS," but this is not necessary. The second window displays the truncation matrix, which will be applied to every coordinate. This means that every point "entering" into the project will be reduced by these values. No need to worry, as these exact values will be added to every single point that is exported from the project such as LAS files, ASCll files, etc.





3. Registration: You can now register any scan position directly to the "PRCS" by using "Find Corresponding Points" at each scan position. Once the scan position has been registered to the "PRCS," it is linked to the registered "GLCS" and therefore tied to real-world coordinates.
4. View Coordinates in 3D: Click on the "Readout" tool next to "Project Manager" and change the coordinate system to "GLCS" by clicking on the current coordinate system at the top. Click "Project Coordinate System" and a dropdown menu will be displayed. Select "Global coordinate system" and run your mouse over the scan data in the 3D or 2D window. The "Readout" window will be populated with all applicable values of each point over which the mouse cursor passes.



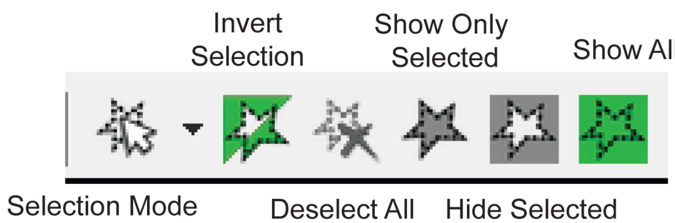
III. Data selection and cleaning

In this next section, you will learn how to isolate particular features in the data set by either selecting them with the mouse or by using filter functions. These techniques can be useful in order to examine smaller-scale features in a large data set, to search for features with common characteristics (like similar material properties), or to "clean" the data set (i.e., remove returns that are not of interest).

Crop data

The series of icons below are for data selection and cropping. To isolate one portion of the data (i.e., the parasequences of interest), use these tools to first select the data and then view just one portion of the data. After selecting the area of interest, right-click to exit the selection tool. To be able to rotate and interact with the data, hit the spacebar.

This tool can also be used to clean data by selecting the area of interest you would like to keep or selecting the portions of data that you would like to delete (e.g., the sky).



Automated filters

You can filter scan-by-scan or on merged scans by right-clicking on the scan data and finding the "Filter data" option. This opens a menu with a number of filtering options. The goal of using these filters is to reduce data density while retaining only the highest-quality laser points.

This section will discuss the range gate, deviation gate, and echo filter options.

1. Range gate: filters by distance from scanner
    - Set the minimum and maximum range based your area of interest. This tool is particularly helpful to eliminate extremely dense data close to the scanner. This is also helpful for eliminating data at long ranges when your scan area is small.
2. Deviation gate: filters based on the quality of the return waveform; this removes complex returns
    - Typically, we recommend a deviation range from 0 to 35.
3. Echo filter: filters based on the return number. The return number refers to the order in which the laser points were received for a given laser shot.
    - For clean data, you should choose singles and firsts. Singles are returns that represent a single return for a single laser shot. Firsts are the first return in a sequence of returned points for a single laser shot.

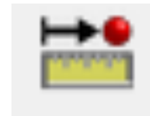
Once a filter has been run, the filtered point will be selected in red. If these points seem unnecessary, you can hit "delete" to remove them from your data.

Terrain filter

The terrain filter does not scale exceptionally well, so we recommend utilizing the preceding data-cleaning steps before using this filter. This filter removes vegetation and other above-ground objects.

Use the button above to activate the terrain filter after selecting your area of interest. You set two parameters: 1. The coordinate system of the plane, and 2. The objects being removed. Use the PRCS coordinate system. Select vegetation. After the filter runs, the vegetation will be selected and you can delete it.

Measuring features



1. To measure the distance between two points, right-click on the scan and select Measure—between two points. This will produce a menu that appears to the left of the screen. Click the mouse into any of the x, y, z fields for the "start point" and make sure that the "closest point" option (rather than "point on surface") option is selected. Next, hold the shift key down when selecting your origin point on the screen. Click back into the x, y, z field for the end point, then shift-click on the image to select the second point. This measure tool is also accessible from the icon below in the toolbar above the scan view panel.

2. To show a measurement grid in the background of the scan view, go to the object inspector panel or tab. Click the camera icon next to GLCamera underneath the GL_CAMERAS heading.

IV. Export data

1. Before you export data, make sure that the scan taken from each scan position has been filtered and cleaned up using the steps above. This will make processing the data in other programs easier as you will have fewer points.
2. Load all scan positions you would like to export into the same view by dragging each scan into the main window.
3. Hit the spacebar and then select your area of interest.
4. Click the icon below to create polydata of the selected area.

5. In the project manager tab/panel, scroll down to POLYDATA and right-click the listed polydata underneath the heading.
6. Select "Export." You want to either export a .las 1.1 or .las 1.2. Name the file and click "OK."
7. The following screen will appear—make sure your options match the ones shown below.