Riegl TLS Validation Manual and Workflow

UNAVCO
Boulder, CO

2013

This manual was developed by UNAVCO staff to document our best-practices for validation of Riegl VZ series terrestrial laser scanners. This document is for a tie-point based workflow.

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Introduction

UNAVCO, Inc. maintains a pool of 5 Riegl terrestrial laser scanners (TLS) consisting of three VZ-400s, one VZ-1000, and one Z620. As a matter of protocol, UNAVCO regularly validates each of these scanners which allows UNAVCO to determine whether an instrument's performance has failed to meet specifications and whether an internal re-calibration must be performed.

The purpose of this manual is to give the user a step-by-step guide to the validation process of UNAVCO's Riegl scanners. Explanations of the equipment and setup procedures are given along with details of how to collect and process the data as it relates to the validation process.

Validation Range

The validation range at UNAVCO's Boulder, CO, facility was designed and built with guidance from Riegl to test the calibration of UNAVCO's scanners in a manner similar to the validation array used by Riegl at their factory in Austria. The array consists of twenty-one reflective targets which are affixed to permanent structures (buildings, street lamps, etc.) and placed at different ranges, scan angles, and heights in a 100m radius on the SE side of the UNAVCO building. Two mounting locations for the instrument have been designated on an old satellite dish mount on the SE side of the UNAVCO building, and a detailed scan is performed from each mount. Figures 1-9 show the dual position TLS mount and the location of the targets.

Figure 1 This is the dual position TLS mount. Scans are performed from ScanPosition001 and then ScanPostion002.

Figure 2 Targets T01-T12 are located on the southeast side of the UNAVCO building and northeast of the TLS mount.

Figure 3 Target T13 is located on a light pole in the east UNAVCO parking lot.

Figure 4 Target 14 is affixed to the light pole at the east entrance to the UNAVCO parking lot.

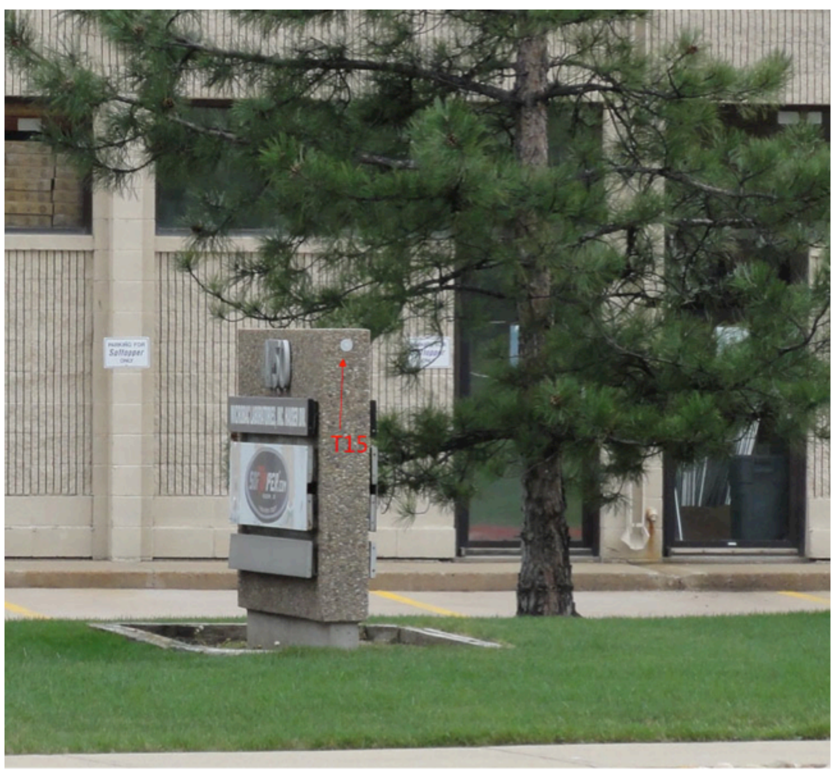


Figure 5 Target T15 is affixed to the sign across the street to the east.

Figure 6 Target T16 is located on the street sign of 4725 Nautilus Drive to the south of the dual mount.

Figure 7 Target T17 is located on a power box almost due south of the dual TLS mount.

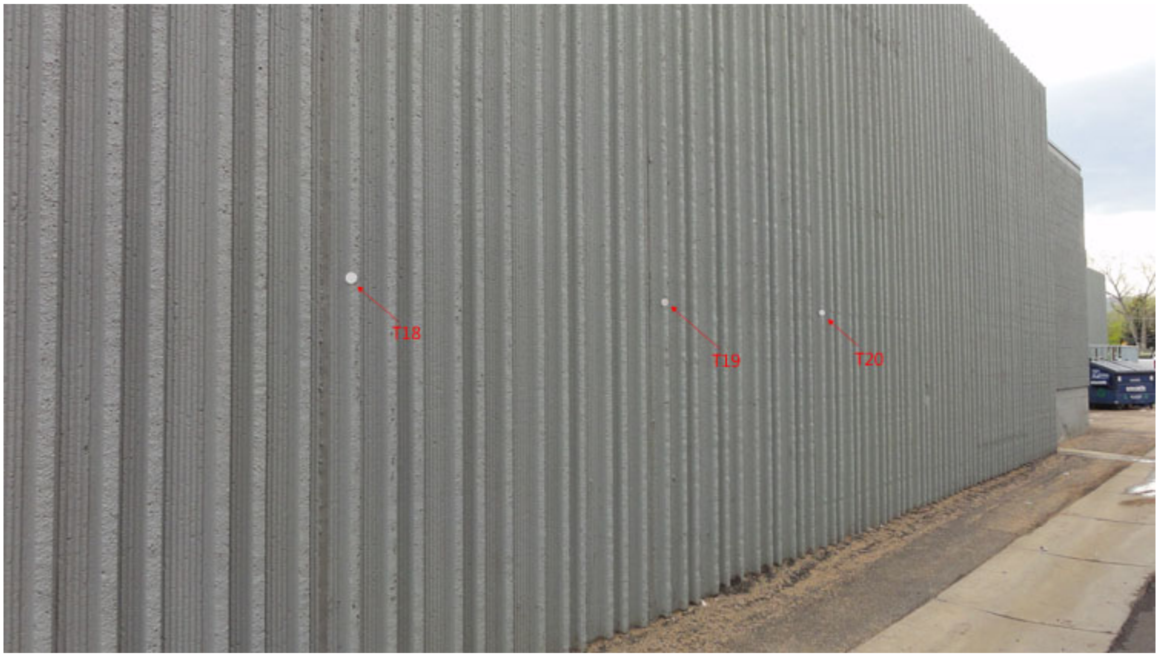


Figure 8 Targets T18-T20 are located on North wall of 4725 Nautilus Drive, which is the building next door to the South of the UNAVCO building.

Figure 9 Target T21 is located across the street from the 6350 Nautilus building.

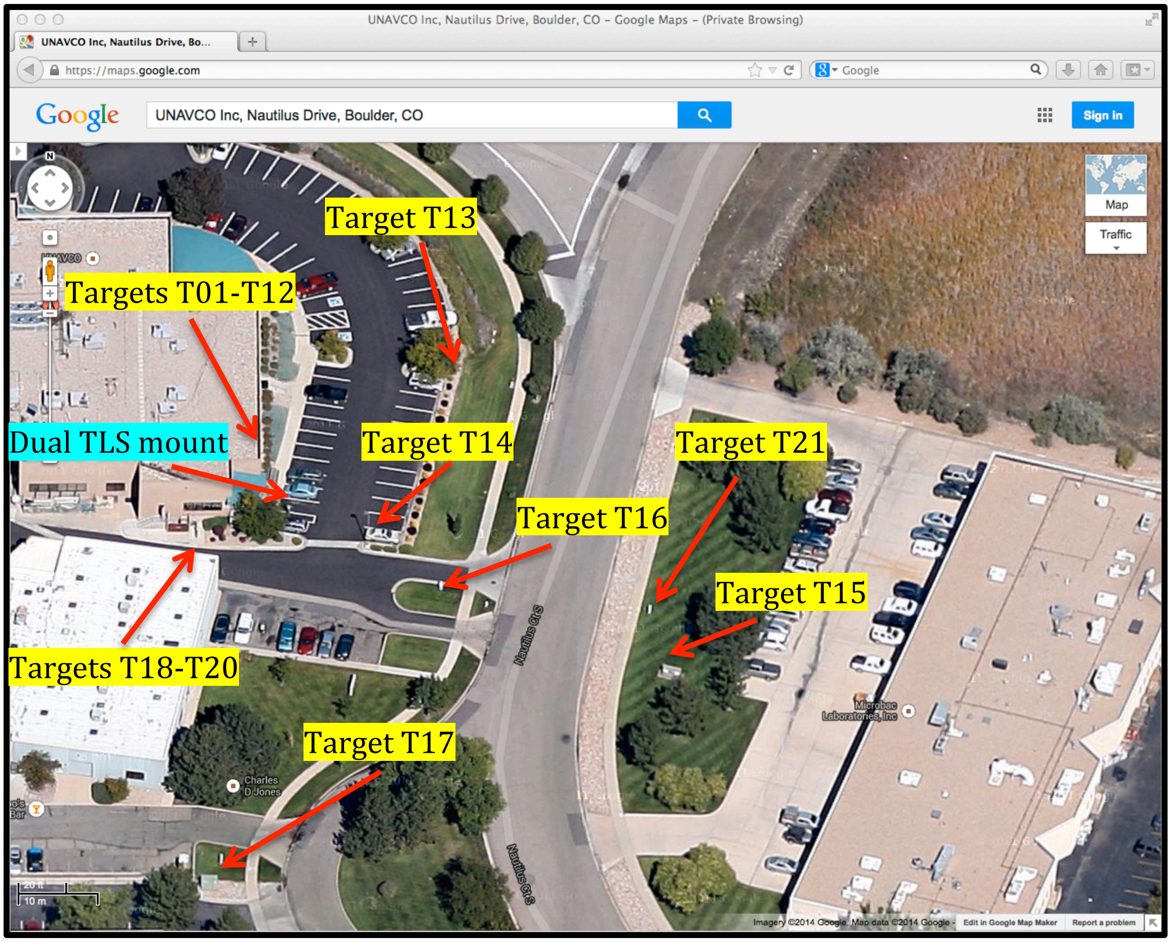


Figure 10 Aerial view of the Riegl validation course at UNAVCO's Boulder office.

As seen in Figure 10, the targets are arranged clockwise from T01-T20 starting at the SE corner of the UNAVCO building. The exception to this is target T21 which was added to the array after its construction. Table 1 gives the physical description of each target along with the range to target from each scan position.

Target Name	Size (cm)	Color	Range to Target ScanPos001 (m)	Range to Target ScanPos002 (m)
T01	5.0	Red	7.003	7.003
T02	5.0	Red	9.294	9.295
T03	5.0	Red	9.229	9.230
T04	5.0	Red	11.164	11.166
T05	5.0	Red	11.525	11.527
T06	5.0	Red	12.971	12.971
T07	5.0	Red	13.812	13.811
T08	5.0	Red	15.014	15.016
T09	5.0	Red	16.187	16.188
T10	5.0	Red	17.384	17.383
T11	5.0	Red	18.571	18.570
T12	5.0	Red	19.616	19.617
T13	5.0	Red	30.619	30.620
T14	5.0	Red	11.771	11.771
T15	5.0	White	56.177	56.178
T16	5.0	White	31.221	31.221
T17	5.0	White	67.134	67.135
T18	5.0	White	18.450	18.450
T19	5.0	White	20.022	20.023
T20	5.0	White	21.737	21.736
T21	10.0	Red	49.617	49.614

Table 1 Table showing physical properties of each target and their approximate distance from both scan positions. Distances are truncated to three decimal places and were collected with the Riegl VZ_______. The range values will vary slightly between scanners as the position of each scanner's laser source, or coordinate system origin, relative to the scanner mount is unique.

The distances given in the table above are the distances of the 3-dimensional vectors from the scan origin (laser source) to the target. RiSCAN Pro automatically calculates these distances.

The next section details the process of setting up the scanner and computer for validation.

Equipment and Setup

Setting up the scanner is a straightforward task. The following section describes the equipment you will need to complete the validation process.

Equipment

- **TLS mounting hardware**. This brass coupler is threaded onto the bottom of the scanner. The Allen wrench is used to tighten two screws on the mount which secures the coupler.

- **Battery box**.

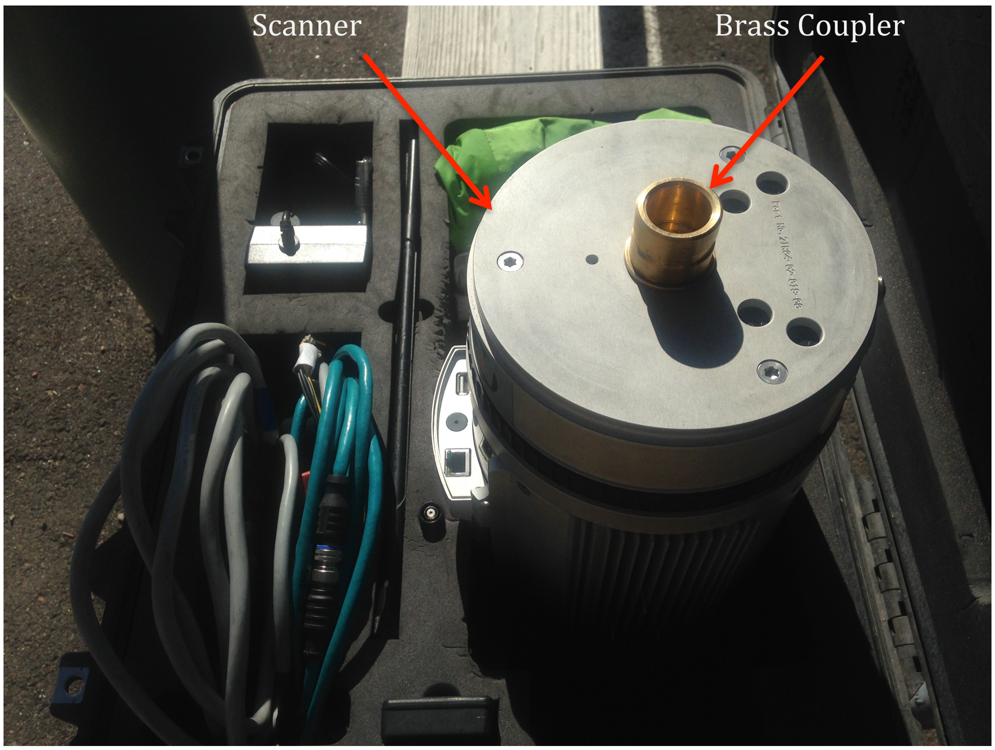
- **Scanner**.
- **Computer**.
- **Kestrel weather meter**.

Equipment Setup

As mentioned earlier, the validation course is set up on the South East corner of the UNAVCO building in Boulder, CO. An old satellite dish mount has been repurposed as the dual TLS mount from which both scans are taken (see Figure 1 in section above titled "Validation Range"). The following steps illustrate how to set up the scanner for validation.

Step 1

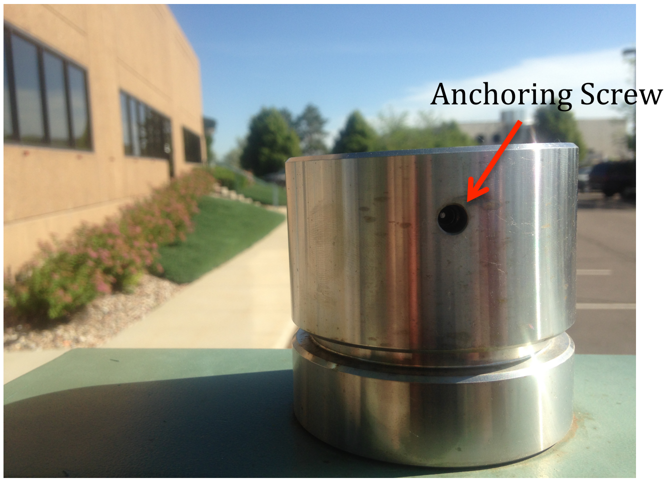
First, thread the coupler to the bottom of scanner as shown.



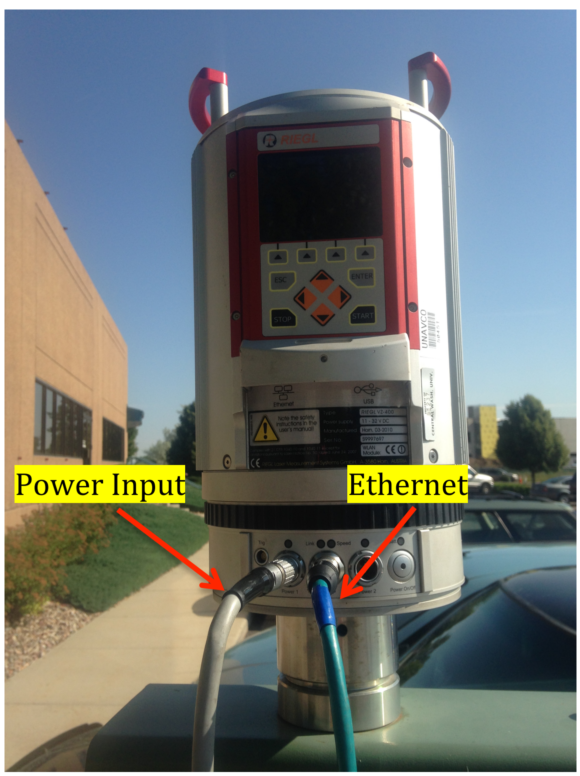
Make sure that it is secured tightly. If it is not, the torque due to the rotation of the scanning head will cause the coupler to loosen causing the scanner to be unstable on the mount.

Step 2

Next, secure the scanner to the dual TLS mount via the coupler. The image below shows the female portion of the coupler, which is affixed to the mount.



Use the Allen wrench to tighten the anchoring screws and secure the scanner to the TLS mount. Once the scanner is set up, plug in the power and Ethernet cables to the back of the scanner. The following picture illustrates how the scanner should look when properly mounted.



Step 3

Connect the Ethernet cable to the scanner's ToughBook and turn on computer. At this point you should hang the Kestrel 4000 from the TLS mount and turn it on as well.

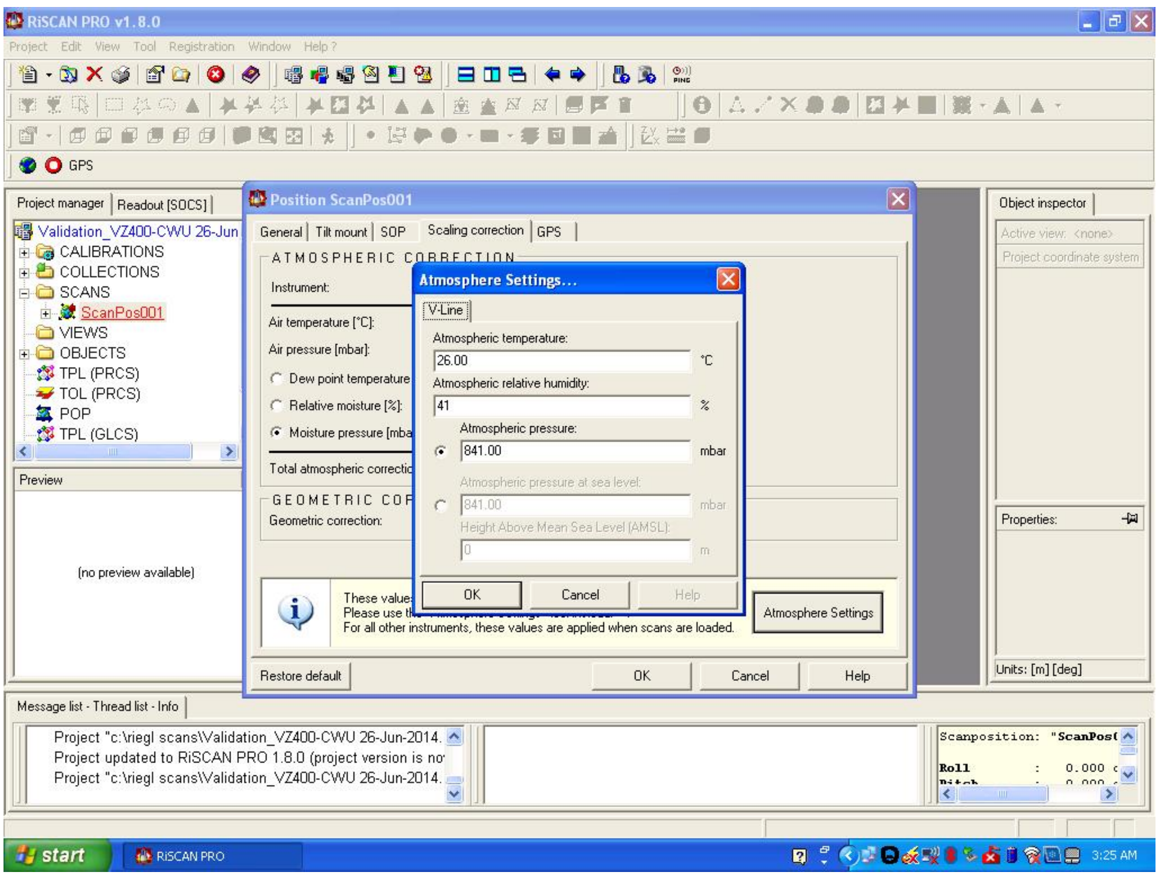
Step 4

Start RiSCAN Pro. Once the program has fully loaded, connect the scanner to the batteries. The scanner will automatically turn on and go through its initialization process. As it does, the scanner head will go through a full 360° rotation and stop. At this point the scanner is ready to collect data.

Data Collection

Users familiar with the Riegl instruments should follow the steps outlined below, which presume basic knowledge of the target-based workflow approach to scanning. Users with less experience should refer to Appendix A, which describes the scanning process in step-by-step detail.

1. Create a new project in RiSCAN Pro with the following naming convention:
   "yyyy-mm-dd_Validation_VZxxxx"
2. Connect to the scanner.
3. Set up a new scan position and be sure to enter the atmospheric conditions as collected by the Kestrel in the "Scaling correction" tab of the scan position Attributes window.



4. Collect a new single panorama scan. We recommend setting the angular resolution to 0.050 deg. You may choose whether or not you wish to collect images.
5. Once the instrument has finished, identify the 21 targets in the scene and finescan them. The targets should be named T01-T21 so that Excel will properly sort them and to keep consistent with our conventions. Please also make sure that each finescan "looks" good by checking the scan image and checking that the target diameter is reasonable (within a few millimeters of

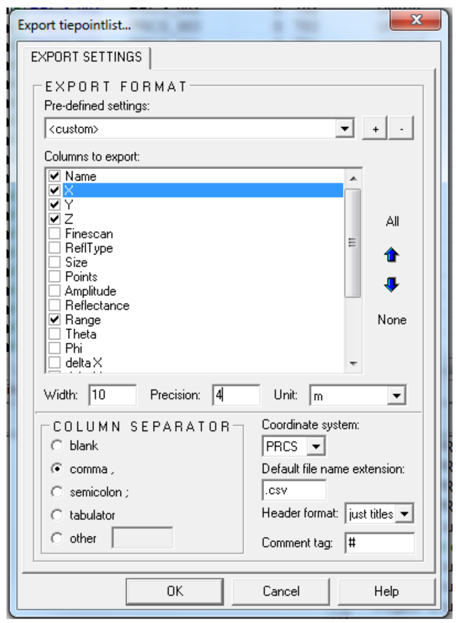
its true diameter). If needed, repeat finescans of any targets that don't meet these requirements.

6. Repeat 3-5 for Scan Position 2.
7. Before taking the equipment down, register the two scans to each other to confirm the scanning was successful. The software should find a solution with all 21 targets whose standard deviation is less than 1cm. If this isn't the case, identify problem targets and rescan.

   At this point, you are done scanning and may return the equipment to the instrument lab.

Exporting Data

1. Make sure you make a backup copy of the project on an external drive that you should keep until the project has been properly archived on the TLS data archive.
2. Open up the project and export each tiepoint list to a .csv file. You will want to export the Name, X, Y, Z and Range information for each tiepoint. Make sure the coordinate system is "PRCS", and that the precision of the X, Y, Z coordinates is 4 decimals.



Processing the Data

The x, y, and z coordinates given for each target are the coordinates of their respective centers as calculated by the scanner from the given scan position. The number in which you are interested is the distance between the two calculated centers of each target. This distance is called the "residual". It is calculated using the 3-dimensional distance formula

$$d_{x,y,z} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

where (x_1, y_1, z_1) are the coordinates of the target's center calculated from ScanPos001 and (x_2, y_2, z_2) are the coordinates of the target's center calculated from ScanPos002.

Ideally, the residual for each target should not exceed 0.003m for the scanner to be considered within factory specifications. If the residual is greater than 0.004m for a majority of the targets, then more frequent testing is in order to track the extent of the laser's "drift". If the residuals continue to grow with each test, contact Riegl.

The steps below will guide you through the process of calculating and recording the residuals for each tiepoint.

1) Open up the ScanPos001.csv and ScanPos002.csv files in Microsoft Excel.
2) Select all information below the first row and use the "Sort A-Z" function to sort the data from T01-T21. (Note: This is why it is important to name tiepoints 1-9, T01-T09. If you name them T1-T9, Excel will not sort them numerically.)
3) After sorting the data in each file, save it.
4) In the "Riegl Scanner Validations" folder, open the file named ValidationResiduals_VZXXX-x_DD-Month-YYYY.xlsx
5) Save this file with the appropriate information (i.e. ValidationResiduals_VZ400-1_02-May-2022) in the same folder as the TPL files.
6) Go back to the ScanPos001.csv and press Ctl+A to select all of the information in this table.
7) Right click on the selected information and click "Copy".
8) Go back to the ValidationResiduals file and right click on the cell that says "Paste" under the heading ScanPos001 and past the information you copied from the ScanPos001 spreadsheet.
9) Go to the ScanPos002.csv file and press Ctl+A.
10) Copy the information to the ValdiationResiduals file under the ScanPos002 heading in the cell that says "Paste".

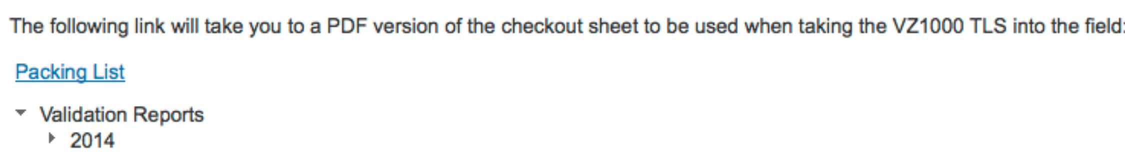
At this point the ValidationResiduals spreadsheet will calculate the residual, in millimeters, for each target. Look at the residuals to ensure that most of them are within the 3.0 mm tolerance specified by Riegl.

Wrap Up

The last step of the validation process is to fill out the Validation Report located in the main "Riegl Scanner Validations" folder. The file name is "ValidationReport_VZXXX-X_DD-Month-YYYY.docx". Open the file and "Save As" a new file with this format in the appropriate folder. Then fill out the information in the report and save it.

All materials should be archived as follows:

- Original RiSCAN project: Zip up project and place in staging folder on thump2 server. Notify the archivist, who will move the project to the validation archive. Instructions for staging material on thump2 can be found in the document entitled "*Archiving TLS Data – stfp upload with FileZilla.pdf*", which is available on the UNAVCO TLS wiki.
- Report and Residual Calculation Spreadsheet: Create PDF versions of the report and spreadsheet, and upload to the corresponding TLS instrument Wiki page. Each instrument page has a section with an expandable table entitled "Validation Reports"; create an entry for the validation you with to report.



The report and residual calculation spreadsheet should also be staged on thump2 for archiving.

The validation process is now complete.

Appendix A: Data Collection

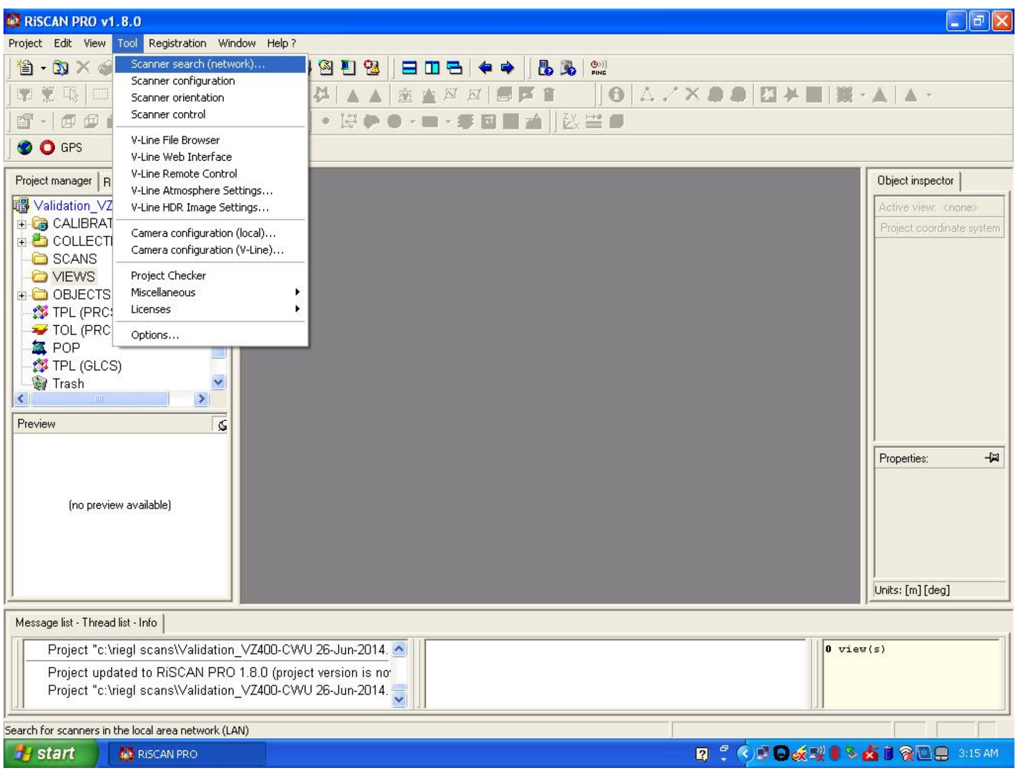
Now that the scanner and computer are set up you are ready to collect data. The steps below will walk you through the scanning process.

Step 1

In RiSCAN Pro, click the "File" tab at the top left of the screen and click "Open". Next open the "Scanner Validation" folder and select the "ValidationDefalut.RiSCAN" folder. This will open a project with various defaults already set. Next click "File" then "Save as". Save the project with the file name format "yyyy-mm-dd_Validation_VZxxxx" (eg. 2014-07-14_Validation_VZ400-1). Click "Save".

Step 2

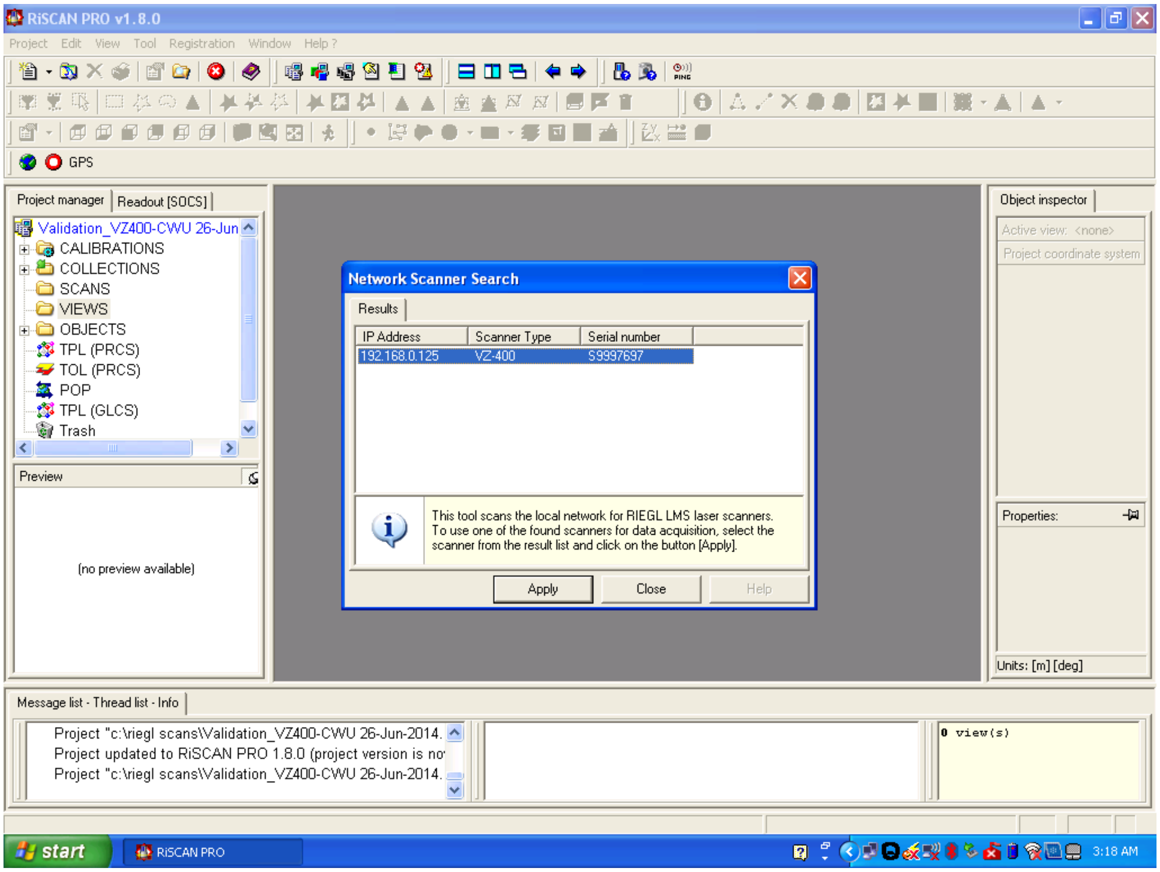
Next click on the "Tool" tab at the top. A dropdown menu will appear. Select "Scanner search (network)" as shown below.



This will automatically search for the scanner being validated and bring up its IP address, model number, and serial number.

Step 3

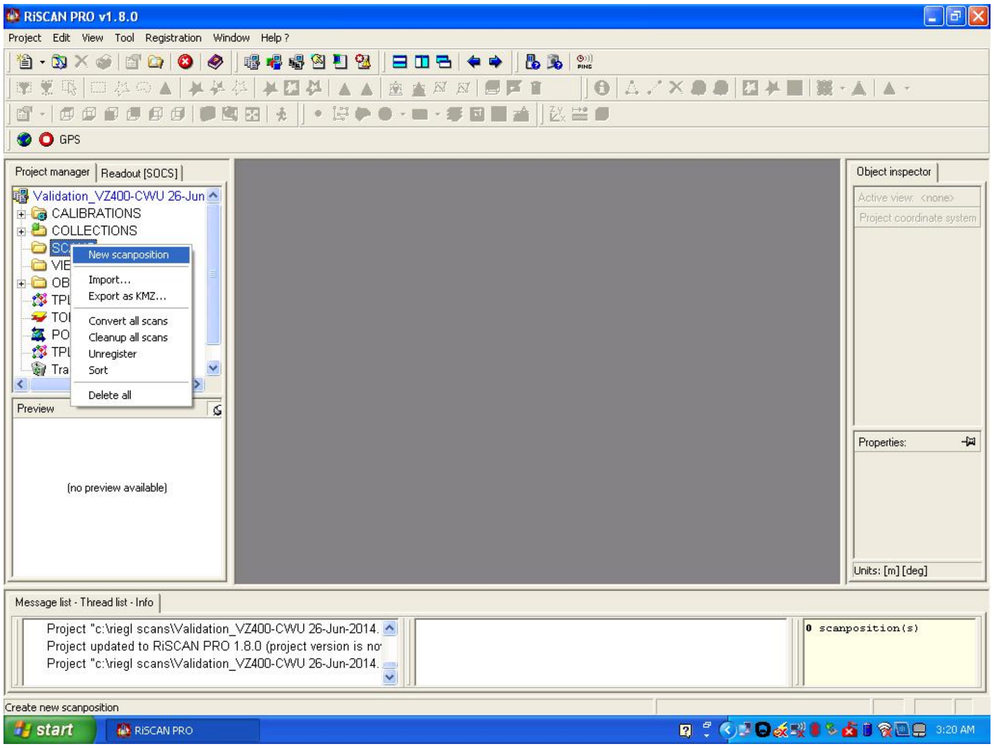
A popup screen will appear indicating that RiSCAN is searching for the scanner. Once it has recognized the scanner the screen will display the information seen in the window below.



Click "Apply".

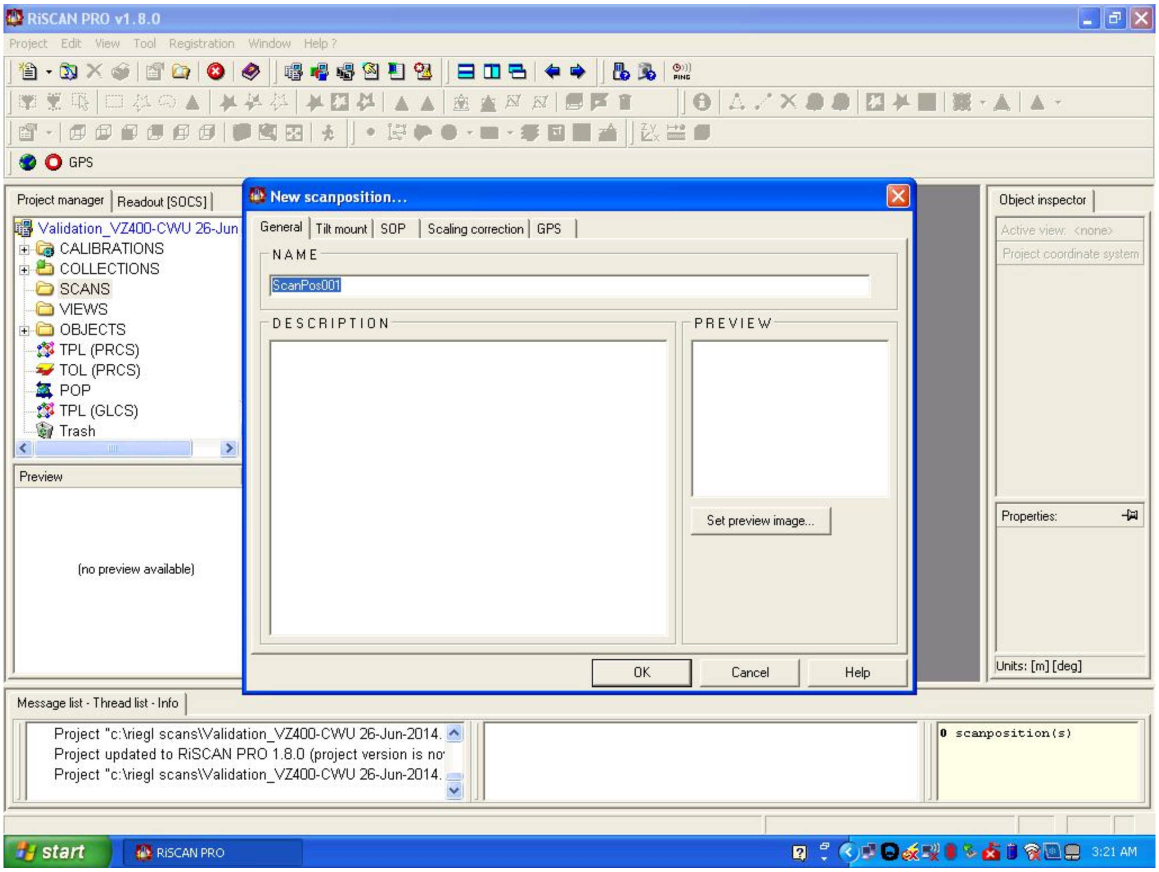
Step 4

Once the scanner has been associated with the project you can start setting up your first scan position. To do this, right click on the "SCANS" folder in the "Project manager window" on the left of the screen as shown. A popup menu will appear. Click the first option on the menu called "New scanposition".



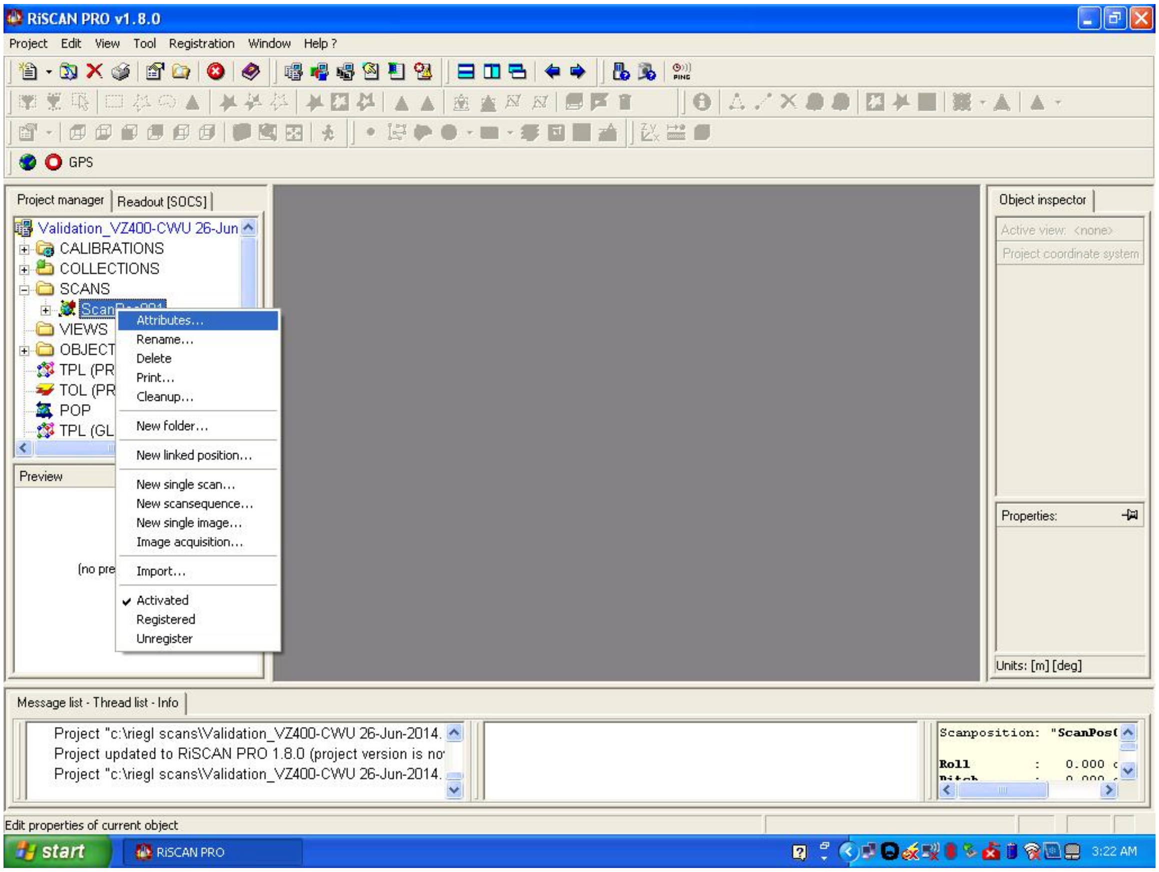
Step 5

A new window will come up on the screen called "New scanposition". The default name in this window is "ScanPos001". Leave this default name and click "OK".



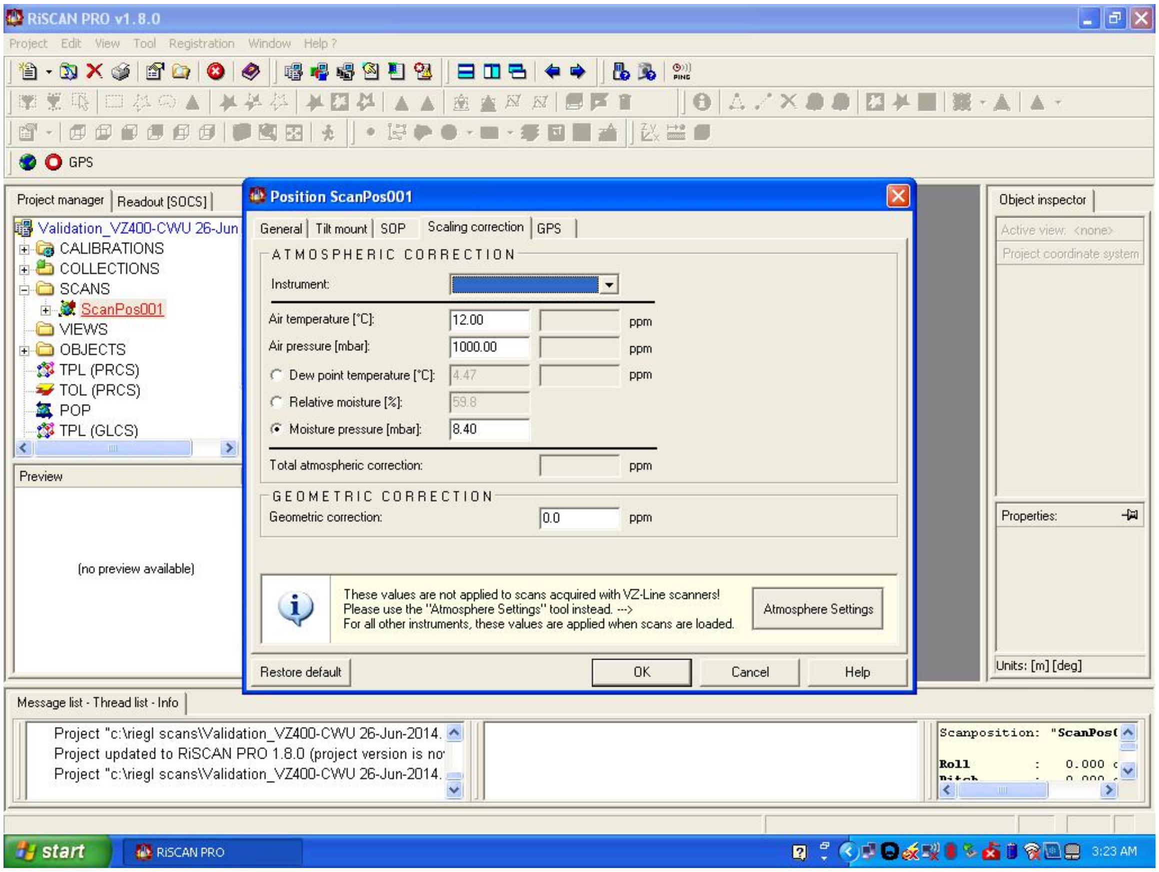
This will create a new scan position in the "SCANS" folder.

Step 6
Right click on ScanPos001 and select "Attributes" at the top of the menu.



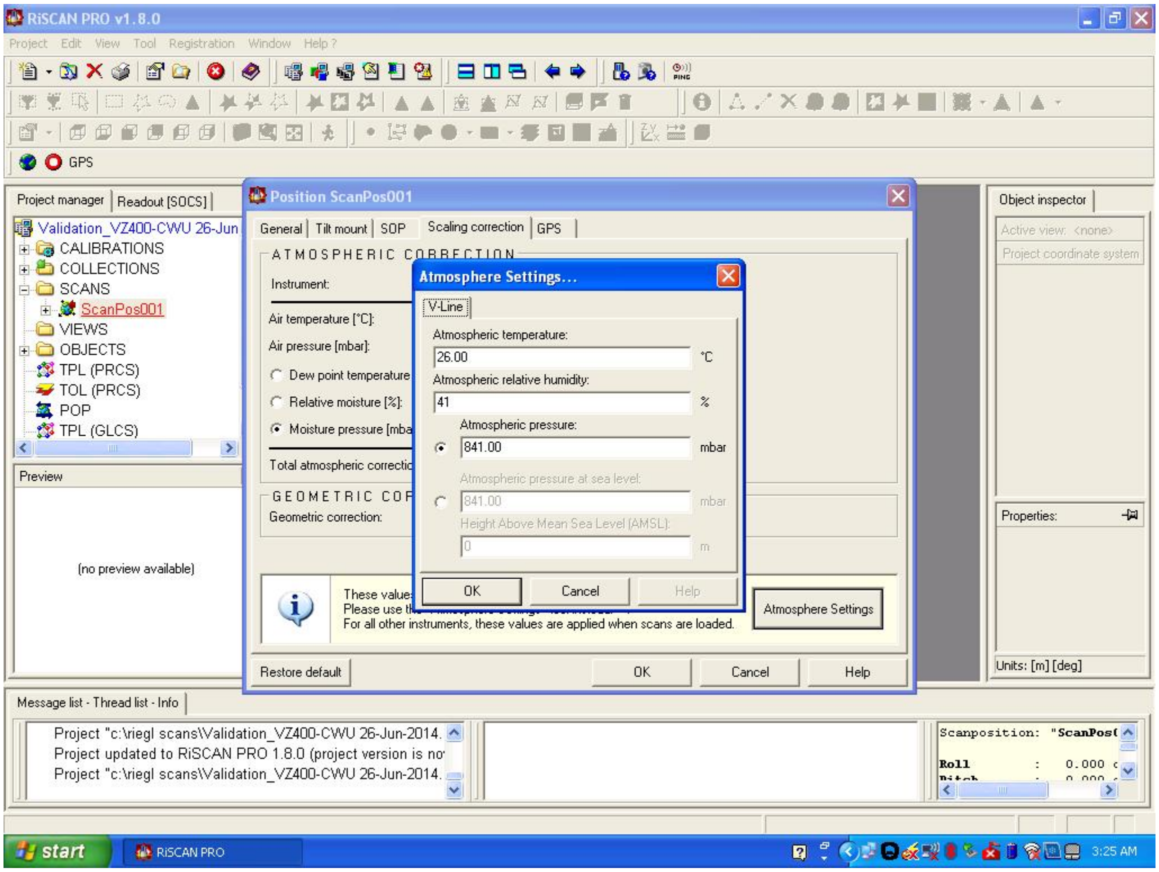
Step 7

You will see another popup window called "Position ScanPos001". Click on the "Scaling correction" tab at the top. Next click the "Atmospheric Settings" button at the bottom of the window.



Step 8

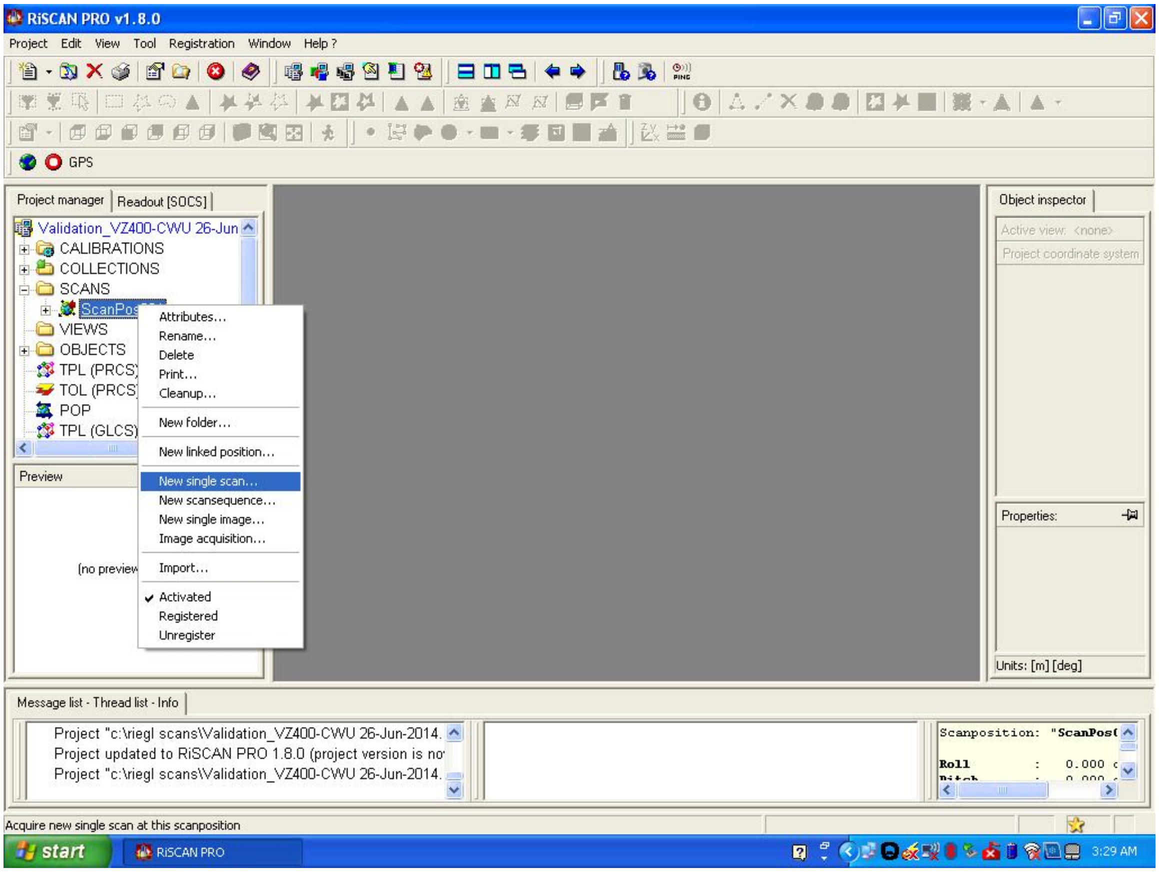
After you click the "Atmospheric Settings" button a smaller popup window will appear called "Atmospheric Settings". Here you will enter the current temp in °C, atmospheric pressure in mbar, and % humidity. This data is all collected from the Kestrel 4000 weather station.



Once you have entered this data, click "OK". You are now ready to set up the scan.

Step 9

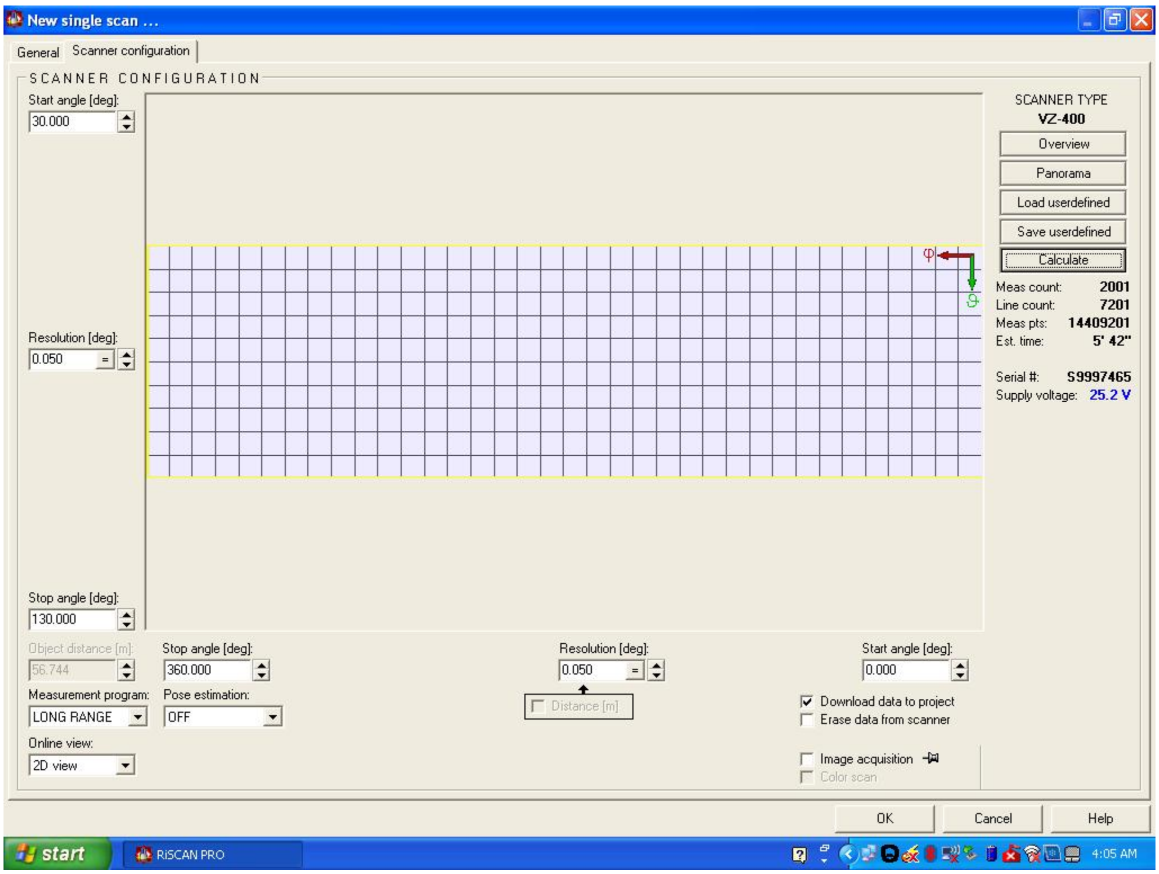
Now that you have created a new scan position, ScanPos001, right click on it as shown. From the menu click "New single scan". A new window will pop up on the screen.



Step 10

In the window shown below you will first click “Panorama” at the right of the screen under “SCANNER TYPE”. Then you will choose the angular resolution of your scan. To accomplish this, enter the resolution you want in the field to the left where it says “Resolution [deg]”. Then click the “=” button to the right.

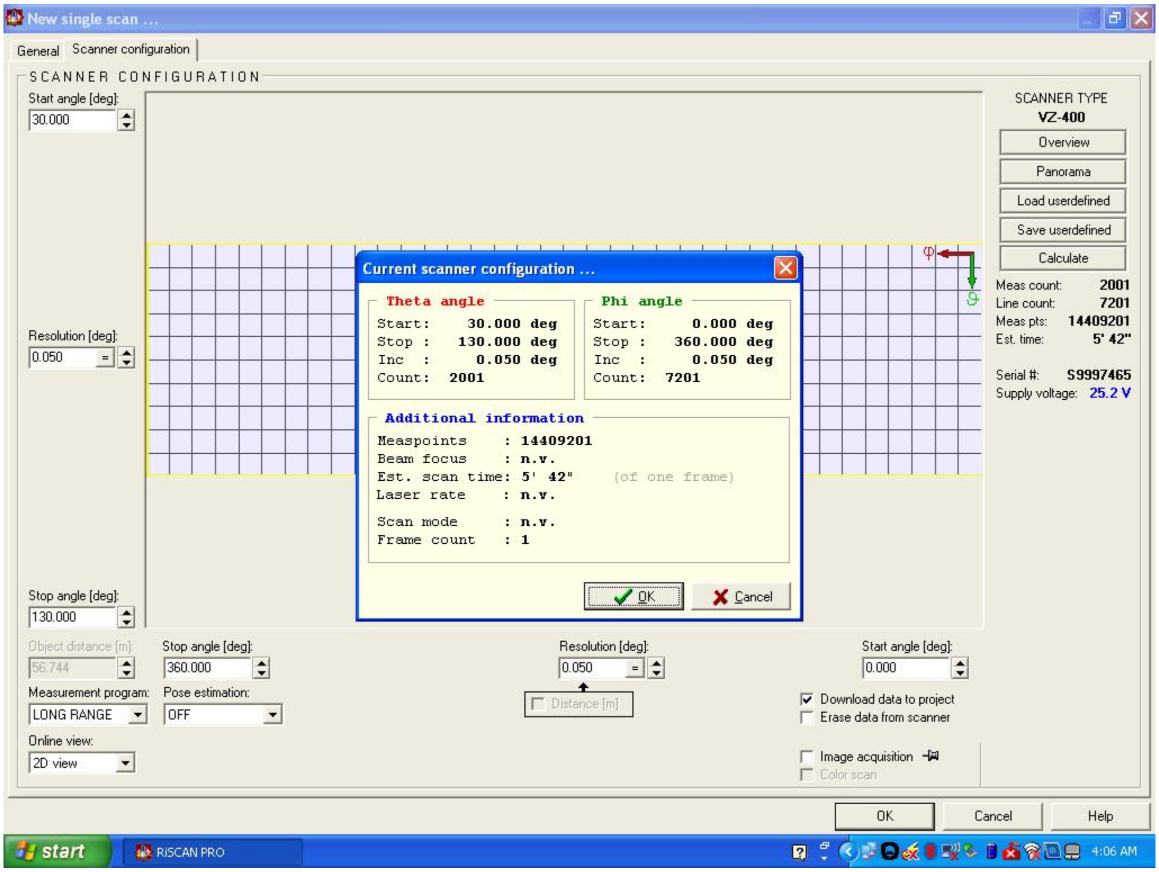
NOTE: The lower the number, the longer the scan will take. So, for example, a scan with a resolution of 0.02 degrees will take longer than a scan with a resolution 0.08 degrees. For the purposes of validation we recommend setting the angular resolution at 0.05 degrees.



In the lower left portion of this window you will see a field called “Measurement program”. From the dropdown menu select “LONG RANGE” and then click “OK”.

Step 11

Once you have done this, the "Current scanner configuration" window will pop up. This window is just a check for you to make sure the scanner settings are what you want. If they are, then click "OK".



Your first scan will now begin.

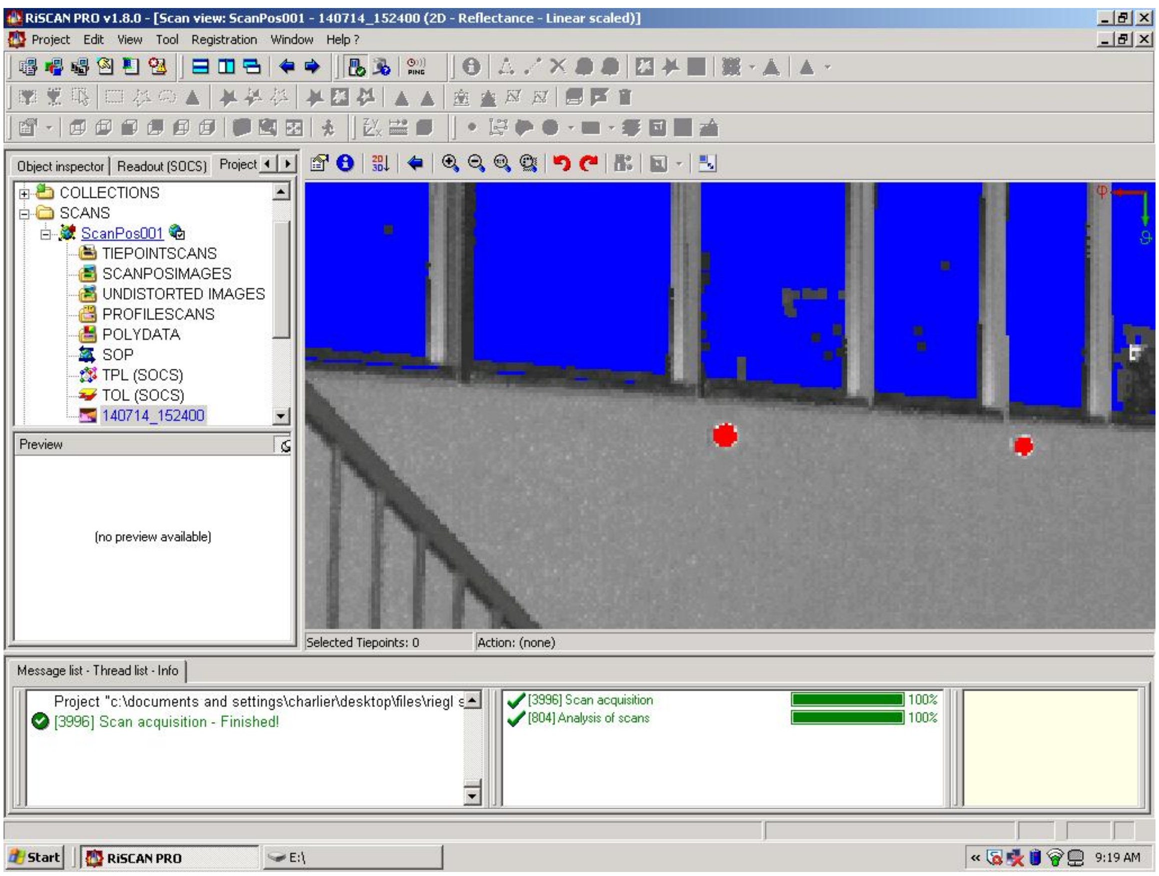
Appendix B: Creating Tie Points and Finescanning Targets

After the scan is complete, the next step is to label and finescan all of the targets. Please refer to the images in the "Validation Range" section for proper naming of targets. The information in Table 1 of this section will also be needed. The steps outlined below will walk you through the process of creating tie points and finescanning the targets.

Creating Tiepoints

Step 1

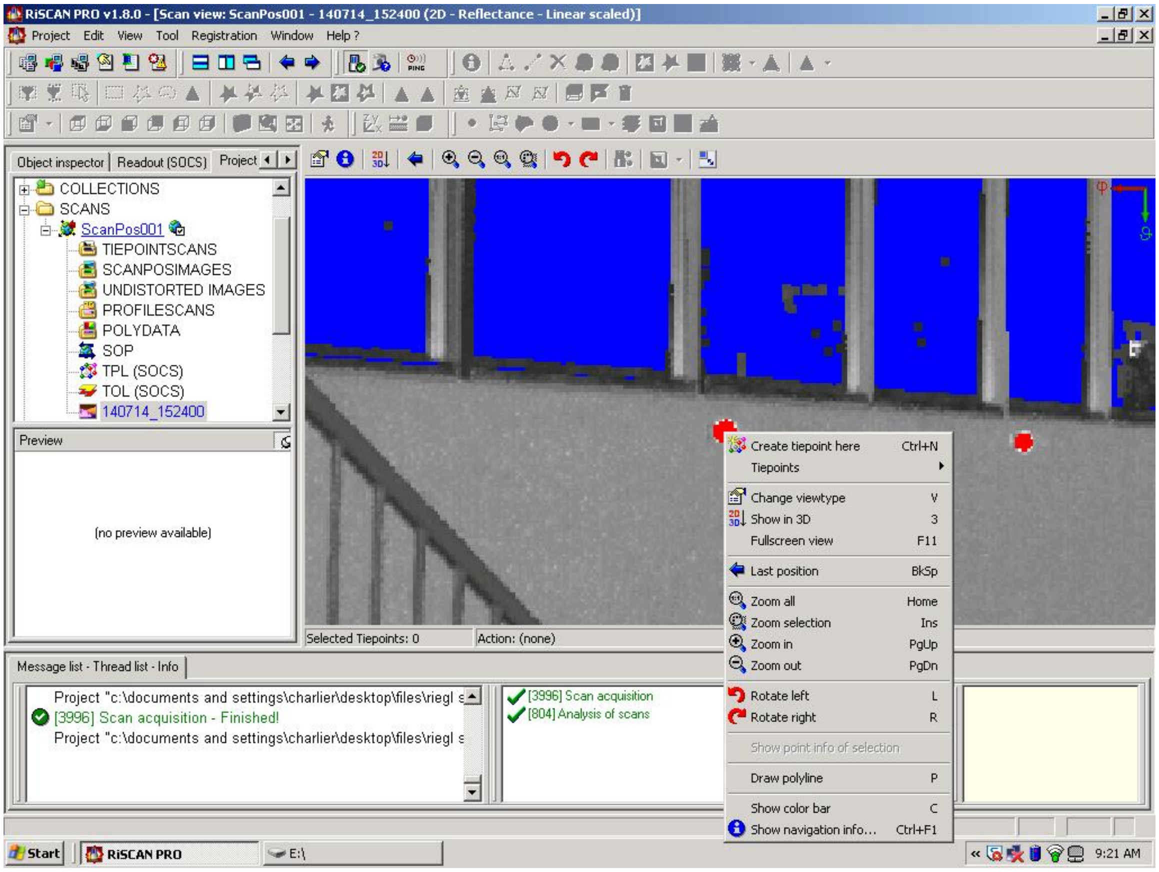
The most expedient way to create tie point for finescanning is to locate the first target and zoom in on it by using the cursor to draw a box around the target. Doing so will zoom in on the target as shown below.



This image shows targets T01 and T03 which are affixed to the southeast side of the UNAVCO building at 6350 Nautilus Drive in Boulder, CO.

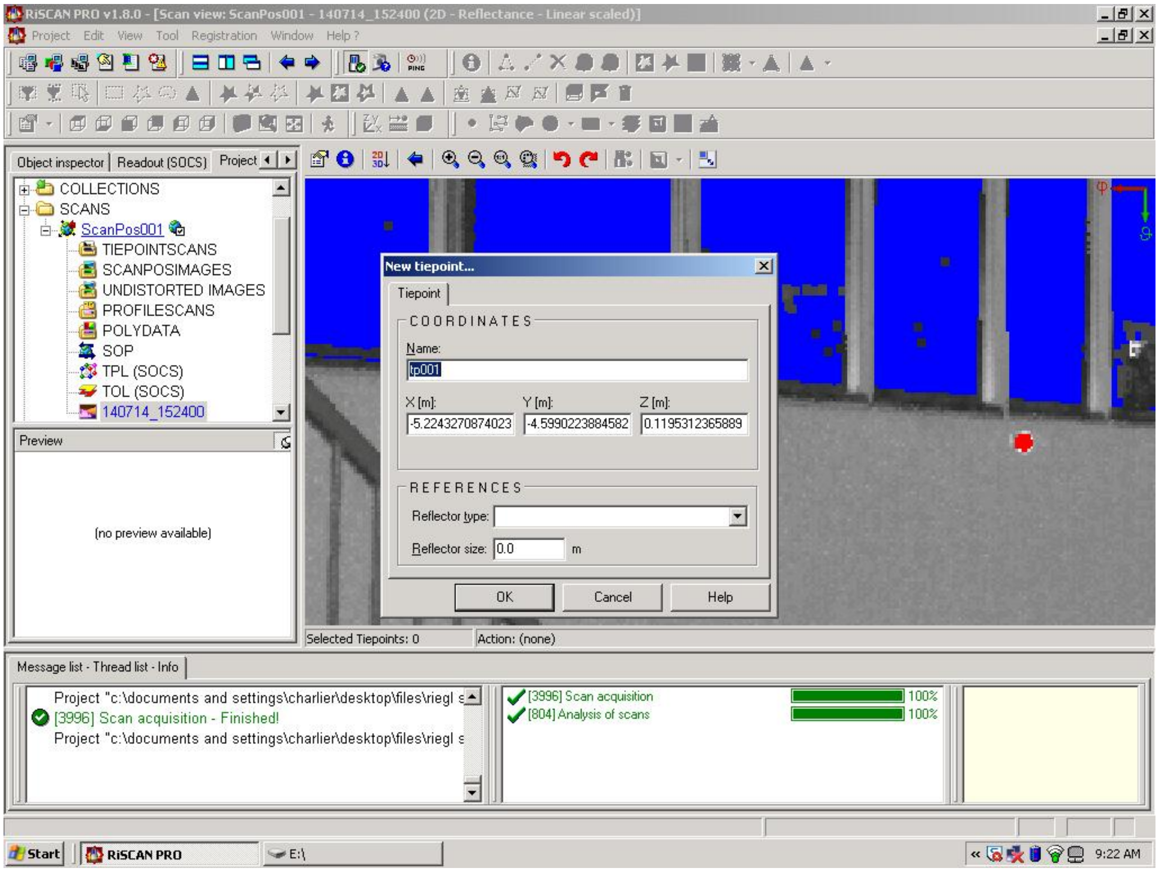
Step 2

Once you have located the first target, place the cursor in the center of the target and right-click it. A popup menu will appear as shown.



Step 3

From the menu select the first option “Create tiepoint here”.

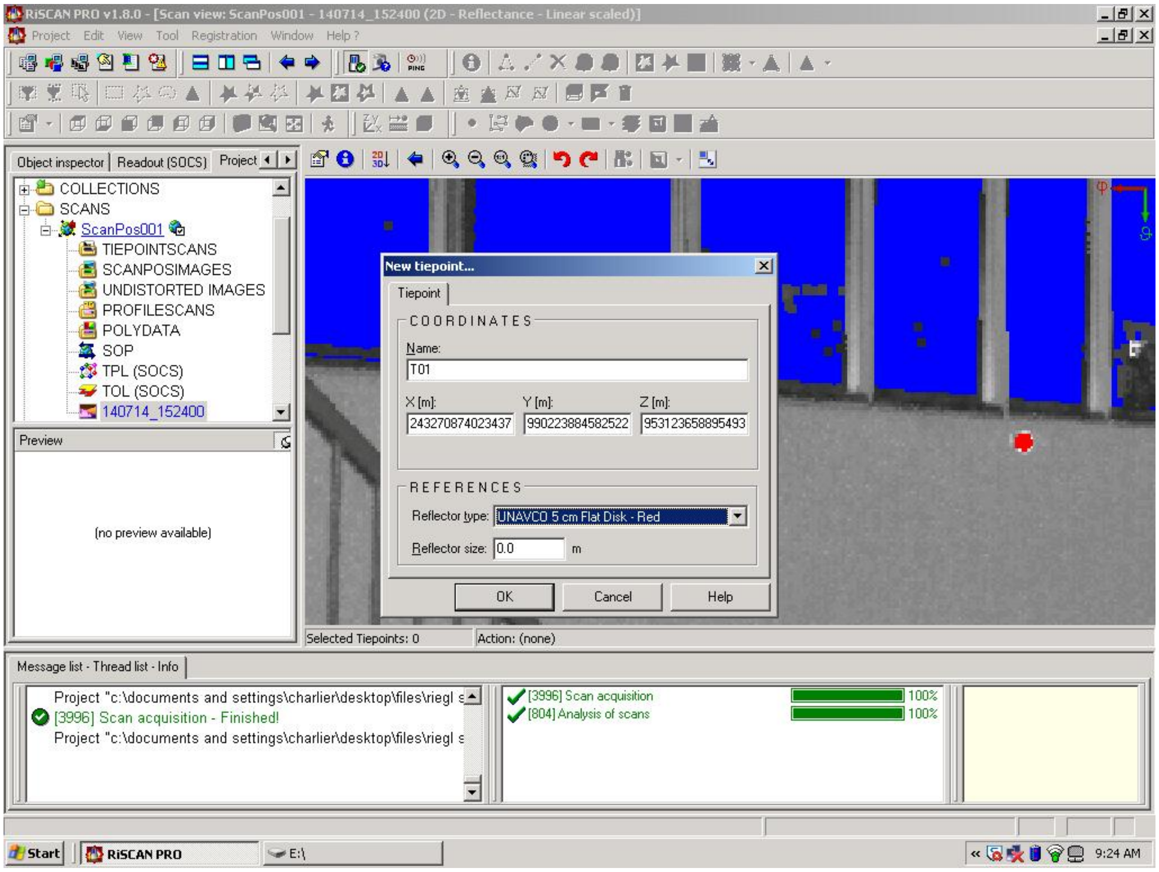


In the field labeled “Name”, rename the tiepoint “TP01”.

NOTE: In Figure 2, targets 1-9 are labeled T1-T9. When labeling the targets in this step they should be named T01-T09. This is done so that Excel will properly sort the data when it comes time to calculate the divergence between ScanPos001 and ScanPos002.

Step 4

Under "REFERENCES" click "Reflector type". A dropdown menu will appear. Select the appropriate target type. Table 1 gives a list of all the targets in the range along with their physical descriptions. Use this for a reference if necessary.



Click "OK". Repeat this process for the remaining twenty targets.

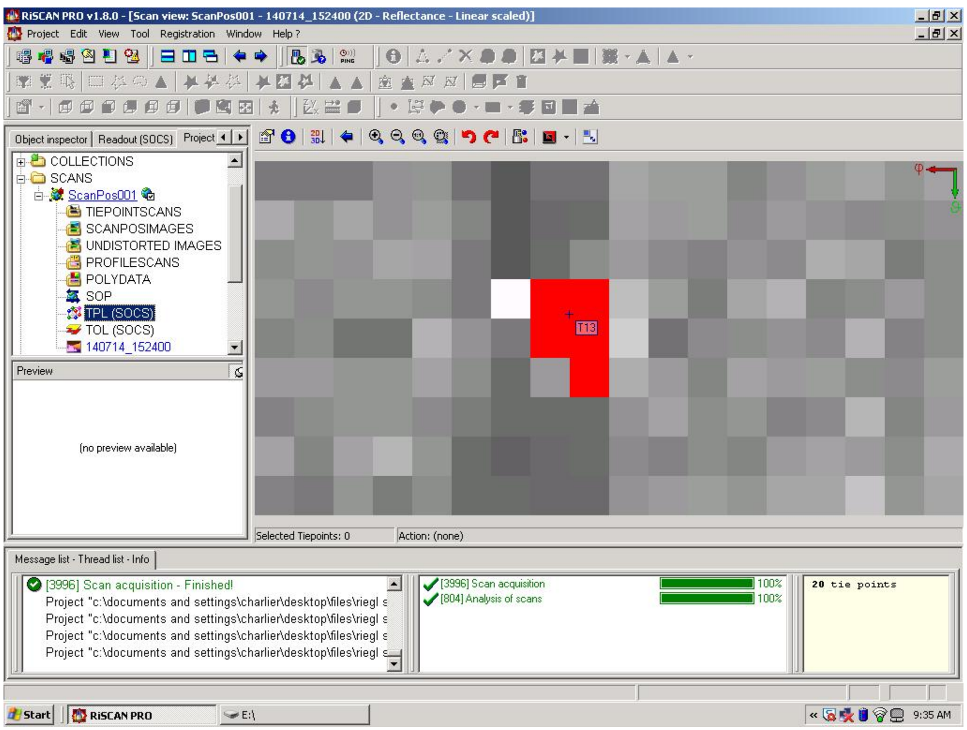
NOTE: If there are targets that are obstructed or did not scan well, do not label them as tiepoints in either scan position. For example if target T17 is obstructed in ScanPos001 but not ScanPos002, do not label it in either of the scans. This will mean that you have twenty tiepoints instead of twenty-one. This is perfectly acceptable.

Finescanning Tiepoints

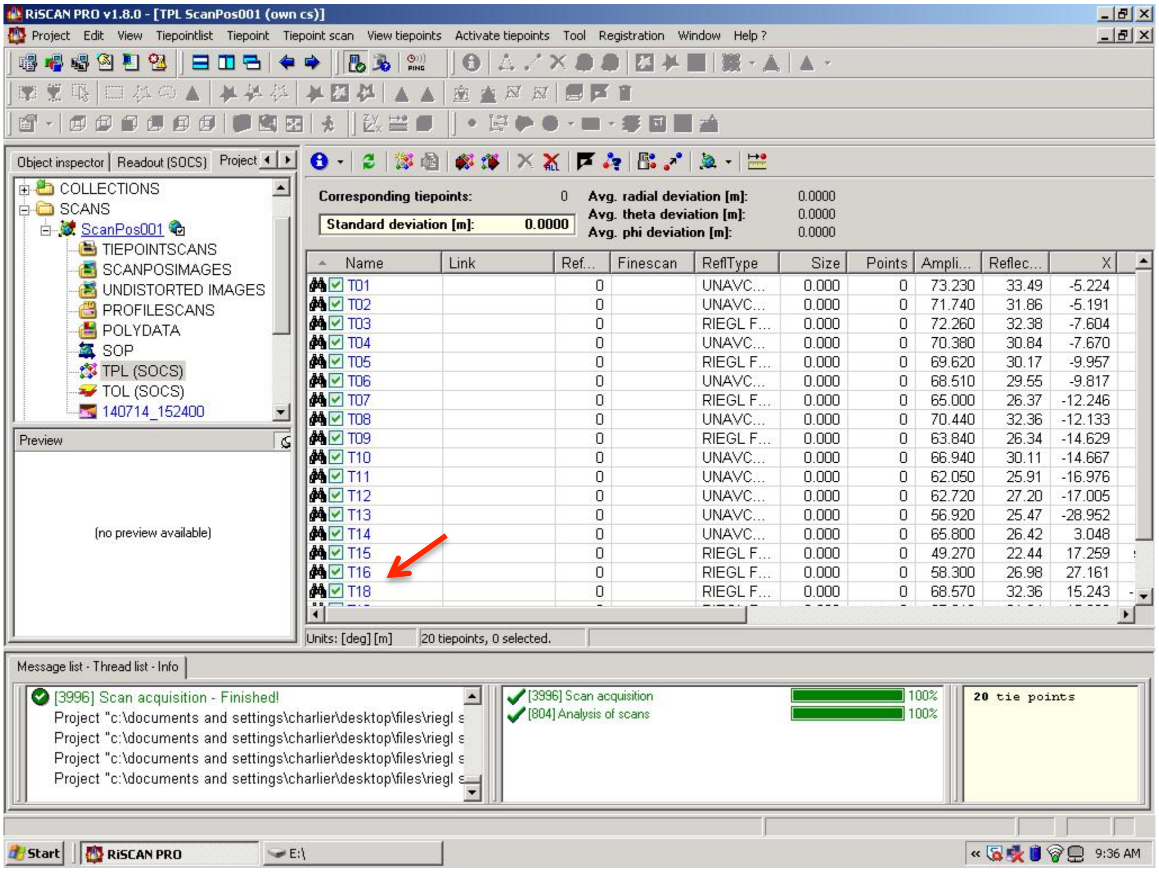
Once you have located all targets and used them to create tiepoints, you are ready to finescan them. This means that the scanner will locate and perform a high density scan of each target. The information obtained from this scan includes: *x*, *y*, and *z* coordinates, range to target, and target size. The *x*, *y*, and *z* coordinates will be used later to calculate the divergence between ScanPos001 and ScanPos002 for each target. The steps below will guide you through the finescanning process.

Step 1

Double-click on the "TPL (SOCS)" option in the "Project manager" list to the left of the screen as shown.



This will bring up the entire list of tiepoints that you have created as seen in the next image.

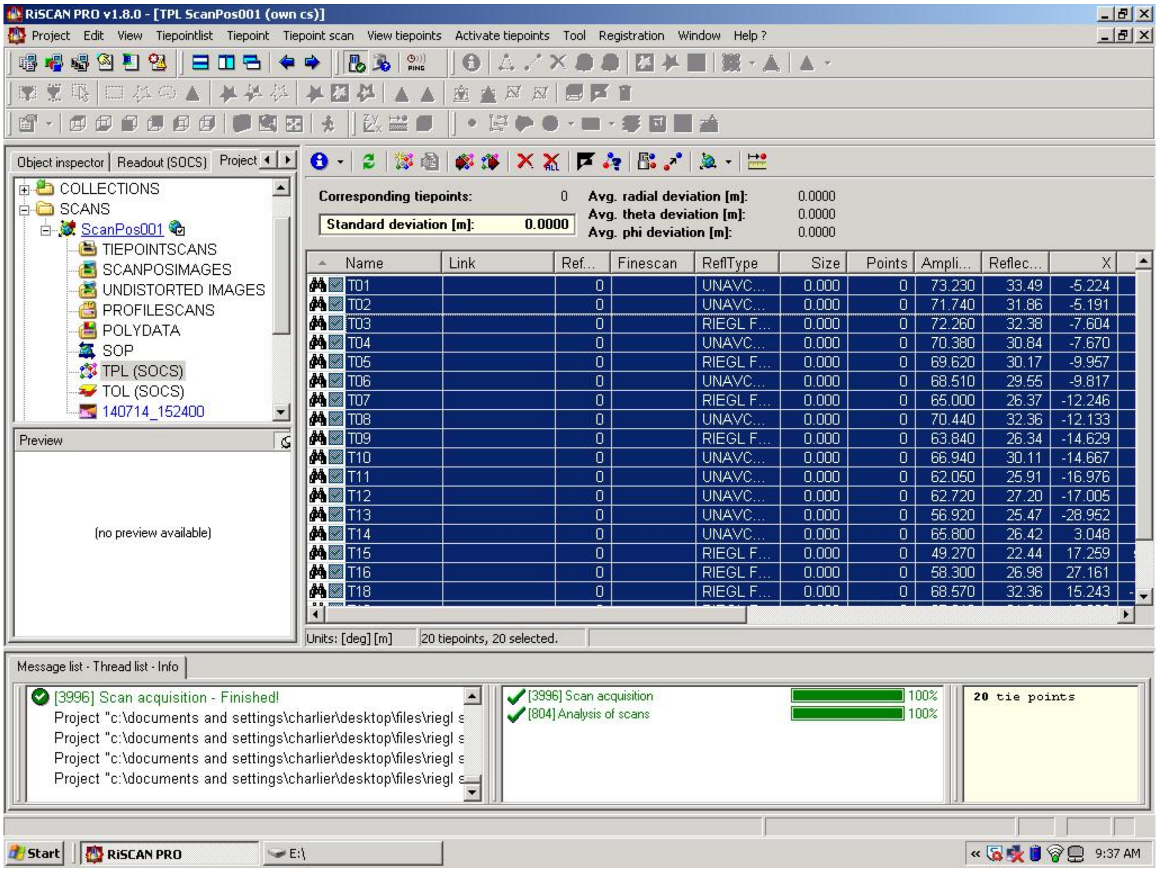


As noted earlier, there may be targets that become obstructed from the scanner's view and, therefore, cannot be used as a tiepoint. In the TiePoint List (TPL) above you will notice that target T17 is missing. This is due to the fact that it was not visible to the scanner from ScanPos001 during the time of validation.

Even though it was visible from ScanPos002, target T17, was not used as a tiepoint for this position either. This was to ensure that both scanpositions had the same number of tiepoints.

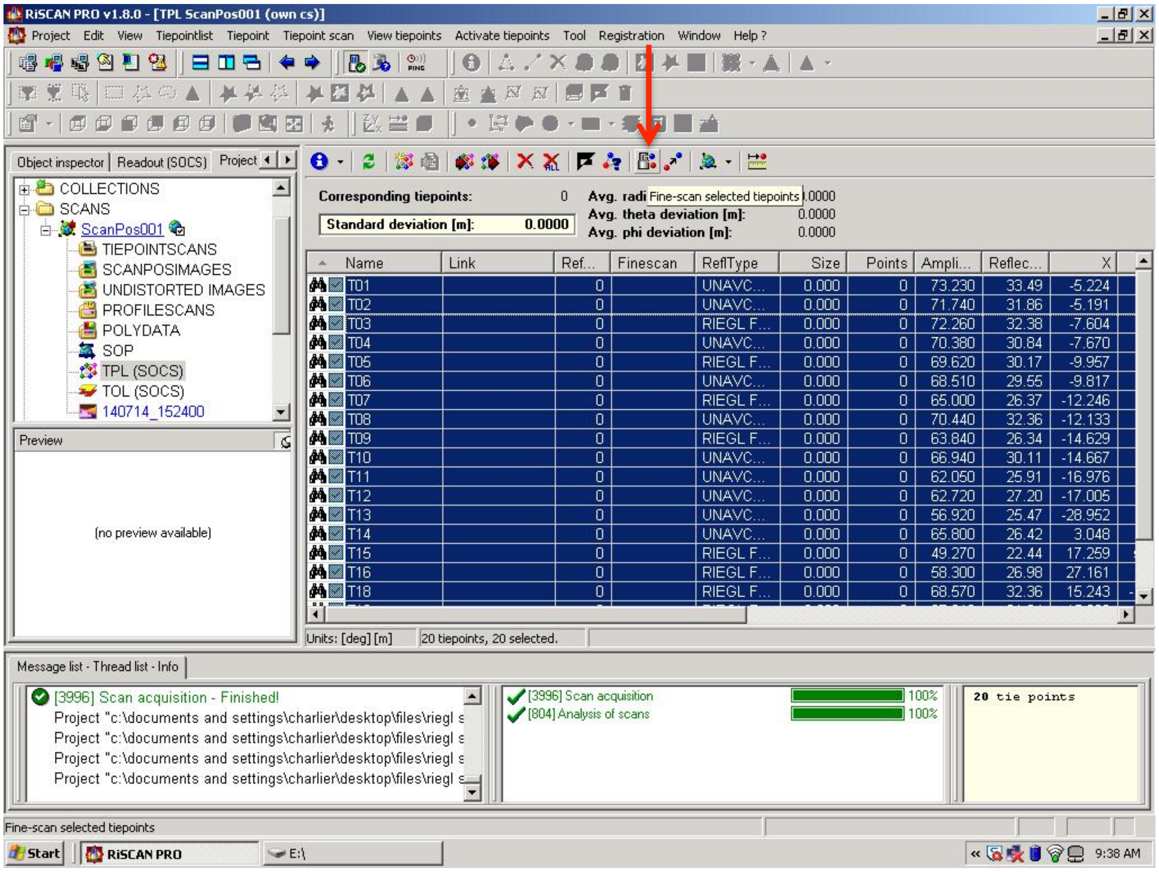
Step 3

Click on one of the tiepoints and then press Ctl+A on the keyboard to select all tiepoints.



Step 4

To initiate the finescan of the targets click the icon indicated by the red arrow in the image below.

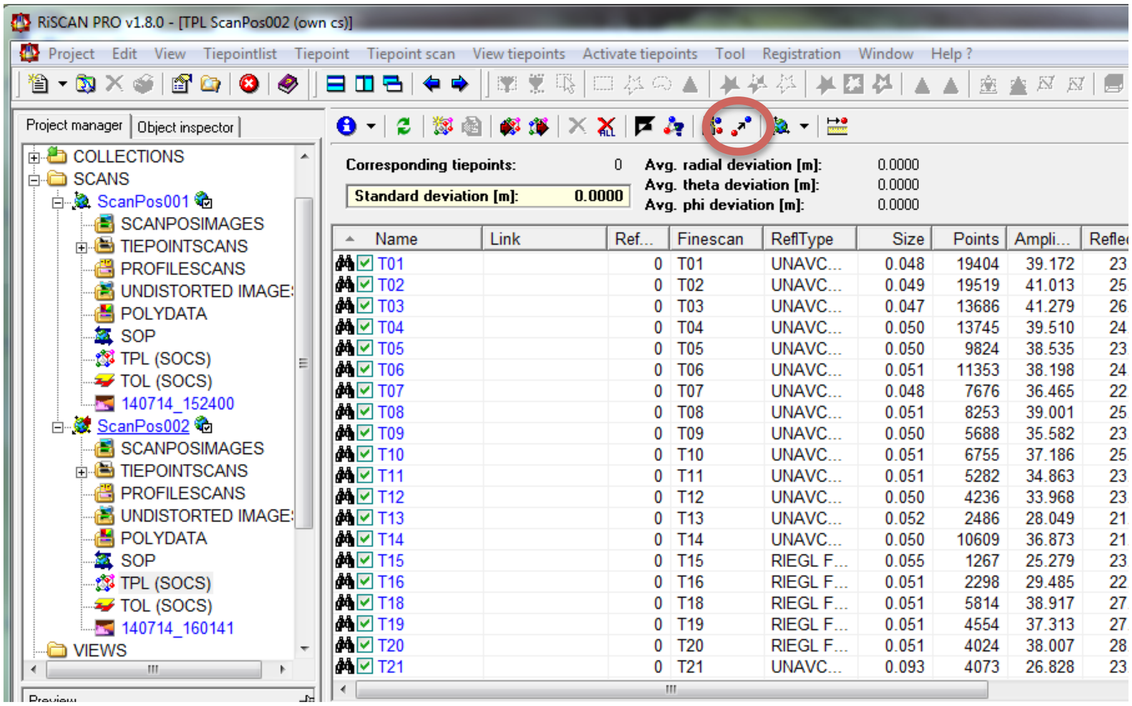


Once the scanner has completed the finescan process you will see the "Size" column updated with the size of each target. At this point it is a good idea to check each finescan. Look at each image to make sure it is roughly the right shape (i.e. circular) and size. Each target should be within +/- 0.3 mm of the actual size. Once you have done this, you are finished collecting data from ScanPos001.

Now move the scanner to ScanPos002. Once you have secured the scanner to the second scan position simply repeat the scanning, tiepoint creation, and finescanning processes outlined in the preceding sections.

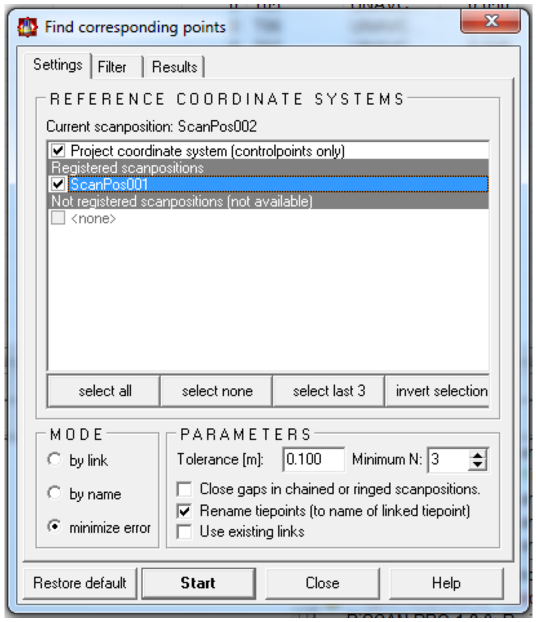
Step 5

Once the Scan Position 2 tiepoints have all been fine scanned, the scans from each scan position should be registered to each other so that will be in the same coordinate system. To register Scan Position 2 to Scan Position 1, open the Scan Position Tie-Point List (TPL (SOCS)). Click on the icon showing an arrow connecting a red ball to a blue ball:

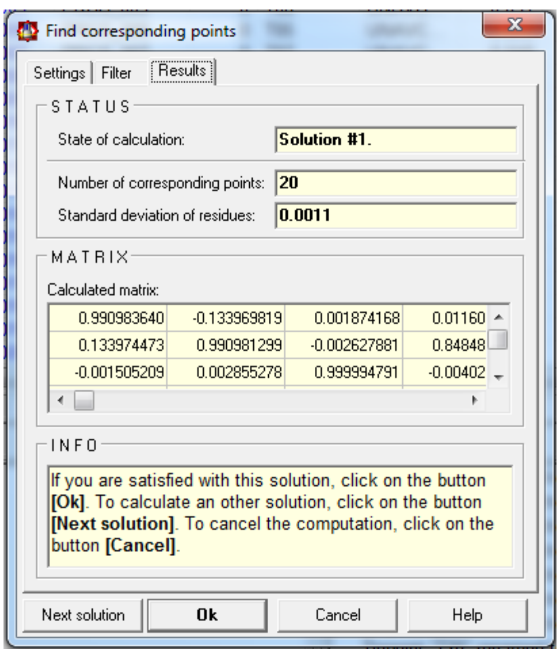


A window will open, and the following parameters should be set:

- Check both “Project coordinate system” and “ScanPos001” boxes
- MODE : minimize error
- Tolerance [m]: Ultimately, we would like for the tolerance to be less than 1cm. However, you may leave the default value of 0.100m and adjust as necessary.
- Minimum N: Designates the minimum number of points used for the registration. Ideally, the program should use all 21 tiepoints. This is another variable you can change as needed.



Press “Start” to being the registration. The software will produce several solutions, but generally the first solution should be the best. In the example below, only 20 tiepoints were visible. The algorithm determined the best solution used all 20 points and returned a standard deviation of residues of 0.0011m.



If the first solution generated is not satisfactory, press “next solution” until you find the solution you believe is the most accurate, using the most points and reporting the lowest standard deviation. Generally, however, the first solution should be the most accurate.

Press OK when you have found a satisfactory solution. Your data is now registered and both scan positions now share a common coordinate system (PRCS).

After all data has been collected from ScanPos002 and the data has been registered to Scan Position 1, you are done with the scanning portion of the validation. Save a copy of the RiSCAN Pro project folder to a flash drive.

Pack up the scanner and cables, laptop, battery box, Kestrel weather station and mounting hardware (be sure to remove the brass coupler from the bottom of the scanner before you replace it in its Pelican case). After all of the equipment has been put away you can begin processing the data.

Appendix C: Exporting Data (Expanded)

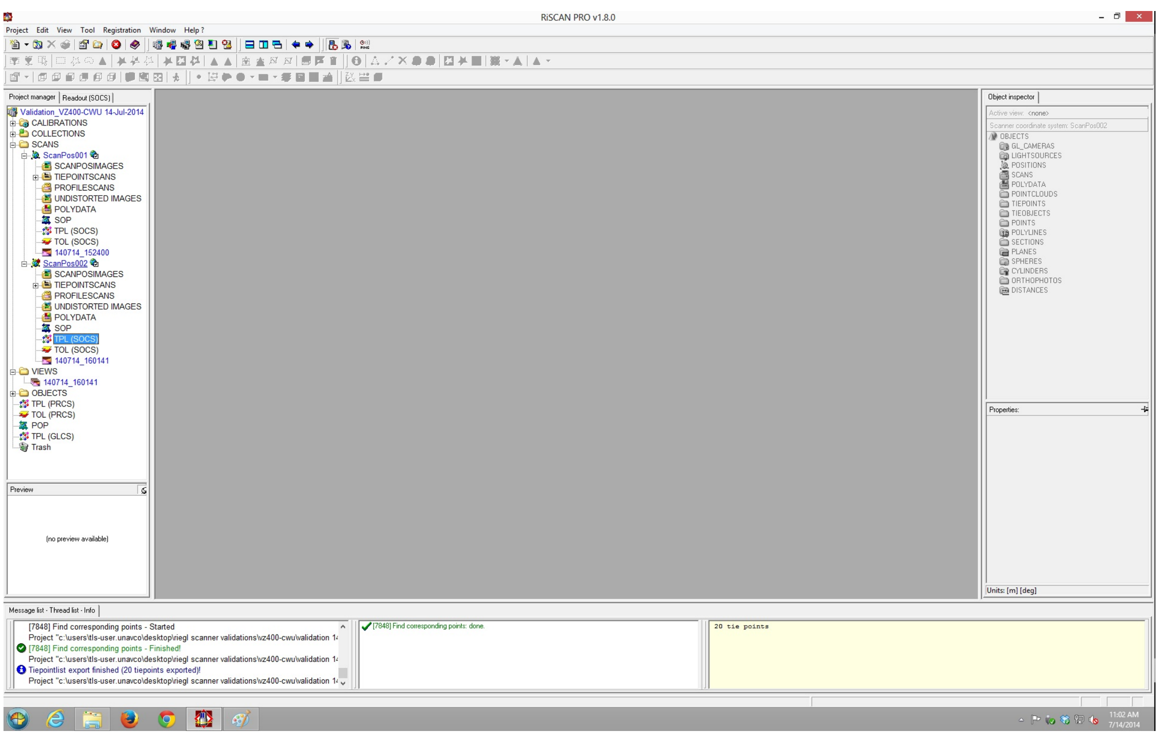
You will use the LiDAR lab computer to process the validation data. It is located across from the TLS room. Plug in your flash drive. Then on the TLS computer open the “Riegl Validations” folder and open the folder for the scanner you have just validated. Next you will created a new folder and call it “yyyy-mm-dd_Validation_VZxxxx”. Now copy the RiSCAN project folder here.

Do not erase the RiSCAN project from your flash drive; this will serve as backup until the project has been uploaded onto the UNAVCO data archive.

Open the project in RiSCAN. Follow the steps below to export the data.

Step 1

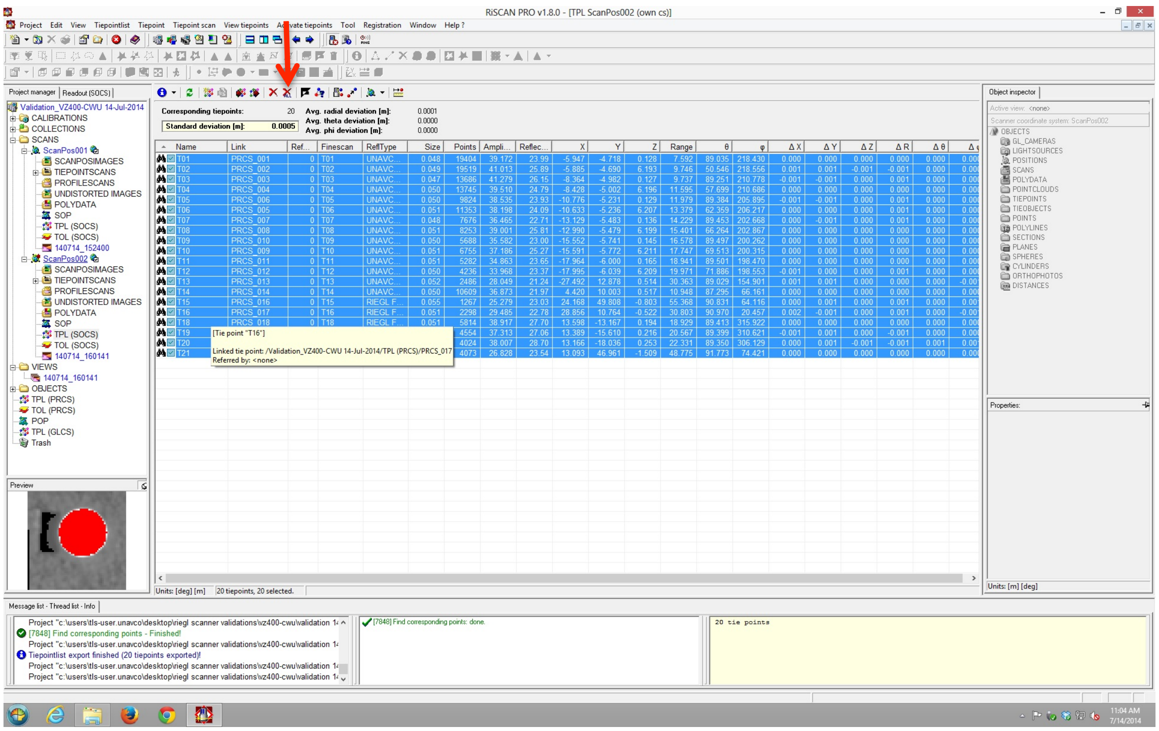
First, export the tiepoint data for each of the scanpositions to a .csv file. To do this, double-click on the “SCANS” folder in the “Project manager” window. Then double-click on ScanPos001. Next double-click the TPL (SOCS) icon.



You will see the tiepoint list with all parameters for each tiepoint.

Step 2

Next press Ctl+A on the keyboard to select all tiepoints. Click the “Export tiepoints” icon indicated by the red arrow as shown in the following image.

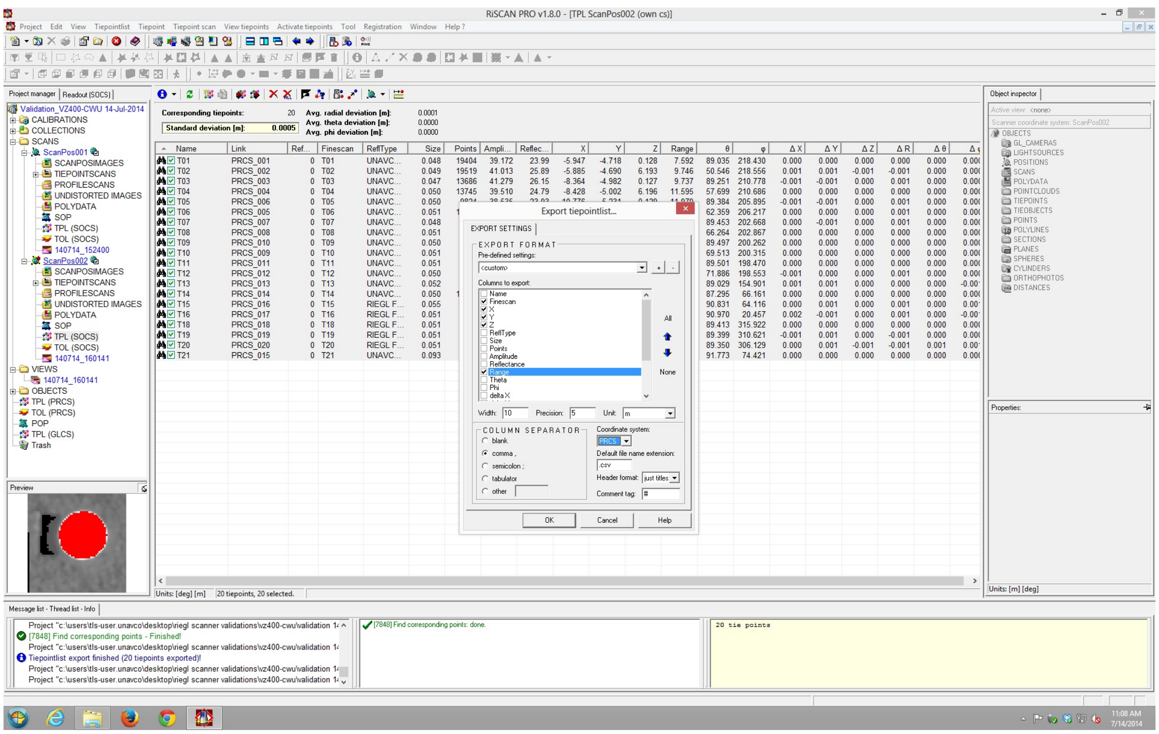


A small options window called “Export tiepoints” will appear.

Step 3

In the “Export tiepointlist” window you can choose which attributes you would like to export. For the sake of validation you will only be transporting the “Finescan”, “x”, “y”, “z”, and “Range” attributes. Make sure that only these characteristics have checkmarks by them.

The “Finescan” attribute is under the x, y, and z attributes so after you select it, use the blue “Up” arrow to the right to move it above the x-coordinate in the list. The order in which these attributes appear here is the order their columns will appear in the spreadsheet.



Next, click on the X coordinate so that it is highlighted. Change the “Precision” setting from “2” to “5”. Do this for Y, Z, and Range as well. Finally, you will change the “Coordinate system” from SOCS to PRCS by clicking the dropdown menu and selecting PRCS from the menu. Once all of these settings have been have been changed, click “OK”.

You will be asked to save the document. Save it in the “Validation dd-Month-yyyy” folder (it should be the folder one level up from the .RiSCAN folder). Save the file as TPL ScanPos001. Once the TPL for ScanPos001 has been exported, repeat this process for the ScanPos002 TPL.

Once both TPLs have been exported you can process the data.