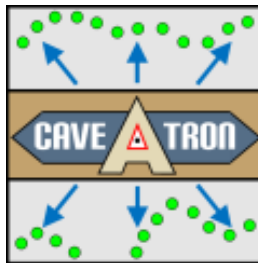


CAVEATRON PROCESS SOFTWARE 2

USER MANUAL

Version 2.5.0
Revision: 2024-03-31



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QUICK START FOR POST-PROCESSING CAVEATRON DATA

1. Download the *.cvl*, *.srv*, and *.imu* files from the Caveatron.
2. (Optional) Pre-process the *.srv* file in [Walls](#) or [Compass](#) cave mapping software to handle loop closures or combine with other survey data. After processing in Walls, export as an *.lst* file. For Compass, first convert the *.srv* file to a Compass *.dat* file in Caveatron Process using the [Convert Survey to Compass](#) command in the File menu. Process the data in Compass to generate a *.plt* file.
3. In Caveatron Process, press the [Select LIDAR File](#) button and chose the *.cvl* file for loading.
4. Press the [Select Survey File](#) button and chose the *.srv*, *.lst*, *.plt*, or *.txt* file for loading.
5. (Optional) In the Survey Review window, choose a different reference station and/or enter coordinates for that station, if desired.
6. After reviewing the survey, press [Accept](#).
7. Select a scan in the scan list for processing and press the [Review](#) button
8. In the Scan Review window, examine the Rangefinder Distance Readings plot in the lower left for any points that are above or below the line of LRF points that decreases from upper left to lower right. If these points are automatically detected, a red warning message will be shown and the erroneous points will be flagged with an orange marker. Click on any erroneous points to select them for removal (CTRL or Command – click for multiple selection). Press the [Remove Points](#) button to remove them.
9. (Optional) In the Scan Review window at upper right, adjust the Outlier filter parameters to remove spurious points. Points for removal are marked in red. In the IMU view window at upper left, adjust the Azi/Inc filtering and Velocity filtering parameters as desired to produce a smooth scan path.
10. Press the [Process and Save](#) button and save the processed point cloud file.
11. Repeat steps 5-8 until all the scans are processed.
12. Convert the survey station points to a point cloud file under File->Convert Survey to Points
13. Continue processing in a point cloud processing program such as [CloudCompare](#) to load the individual scan point clouds into a complete point cloud for the survey. Some scans may require fine adjustments to fully align them. Merge the individual scans into a combined point cloud and export.
14. (Optional) In CloudCompare or in 3D rendering program such as [Meshlab](#), import the merged point cloud and use the Poisson Reconstruction function to create a rendered solid model for the survey.

QUICK START FOR POST-PROCESSING CAVEATRON SV DATA

1. Download the *.cvp* and *.srv* files from the Caveatron SV.
2. (Optional) Pre-process the *.srv* file in Walls or Compass cave mapping software to handle loop closures or combine with other survey data. After processing in Walls, export as an *.lst* file. For Compass, first convert the *.srv* file to a Compass *.dat* file in Caveatron Process using the Convert Survey to Compass command in the File menu. Process the data in Compass to generate a *.plt* file.
3. In Caveatron Process, press the Select LIDAR File button and chose the *.cvp* file for loading. Be sure to select "Points file (*.cvp)" from the file-type pull-down menu in the open file dialog box or the points file will not be visible.
4. Press the Select Survey File button and chose the *.srv*, *.lst*, *.plt*, or *.txt* file for loading.
5. (Optional) In the Survey Review window, choose a different reference station and/or enter coordinates for that station, if desired.
6. After reviewing the survey, press Accept.
7. Press the Process and Save button
8. If more than one point type exists in the *.cvp* file, a dialog box will allow you to choose whether to save the points in a single point cloud file or separate files by type (i.e. wall, profile, cross section).
9. Convert the survey station points to one or more point cloud files under File->Convert Survey to Points
10. Open the generated files in a point cloud processing program such as CloudCompare to view the points and stations in 3D.

DESCRIPTION AND PROCESSING OVERVIEW

The Caveatron Process program is used to post-process the data collected by the Caveatron and convert it to a standard point cloud format for viewing or further processing with separate software. It provides information on the acquired scans, visualization of the LIDAR and survey data, the ability to reference the survey to other coordinate systems, and settings to filter the data and adjust the processing parameters.

Caveatron Process requires two or three files. The standard Caveatron provides a LIDAR file (*.cvl*) that contains all of the LIDAR scan data, a survey file (*.srv*) that contains the coordinates of the stations to which the scans are referenced (several types available), and a Caveatron Calibration file (*.imu*) that provides the calibration information on the IMU and LIDAR. The *.imu* file is only required for the advanced processing algorithms used in “IMU processing” mode. If no *.imu* file is available or the data was collected by a pre-version 2 Caveatron unit, then the “v1 processing” mode can be employed. The difference is that IMU processing mode utilizes raw gyroscope, accelerometer, and magnetometer data stored in the *.cvl* file to estimate the position and orientation of each rotation using a Kalman filter between the LRF-established position measurements. In the original v1, non-IMU based processing mode, a simple linear motion is assumed between each LRF-established position and it is entirely based on the measurements as taken. The advantage of IMU processing mode is increased accuracy and better ability to tolerate sparse LRF data. As of CVL format 3.1 (supported in Caveatron Process 3.5) processing is now fully dependent on the IMU file. What that means is that if you had a bad calibration when you took the scans, you can later obtain a corrected IMU calibration and use that to process the CVL file as if you had a good calibration when you took the data.

The Caveatron SV does not include a LIDAR but has the capability to record single point measurements around a station. These can also be converted to 3D points viewable in point cloud software with Caveatron Process. The points are saved as a Points file (*.cvp*) which are used along with the survey file (*.srv*). No IMU file is needed to process the Caveatron SV points.

The survey files can be of several types. If the cave is simple, with no loop closures or only one loop closure, and only a single survey is needed, then the survey file output from the Caveatron (*.srv*) can be used directly. If there are additional loop closures or the data needs to be combined with other surveys, then it is highly recommended that the survey be pre-processing. Caveatron Process supports both the freely available [Walls Cave Mapping software](#) and the commercial Fountainware [Compass Cave Survey software](#). For Walls, the *.srv* file is directly compatible for easy import. Once the survey is processed or combined with other surveys, use Walls to output a *.lst* file. This file provides a list of stations and their x, y, z coordinates which can be imported in Caveatron Process. For Compass, Caveatron Process provides a conversion utility under “File”->“Convert Survey to Compass” that produces a Compass *.dat* survey file from the Caveatron *.srv* file. In Compass, once the survey is satisfactory, press “Process and View Cave” in the Project Manager, which generates a *.plt* file. (This file can also be created in a user selected location from the File menu in Compass’s Cave Viewer.) The *.plt* file can then be loaded into Caveatron Process as the survey file. A third input option is to use your own method and create a comma delimited text file with four fields per line including the station name and x,y,z coordinates in meters (*.xyz* file).

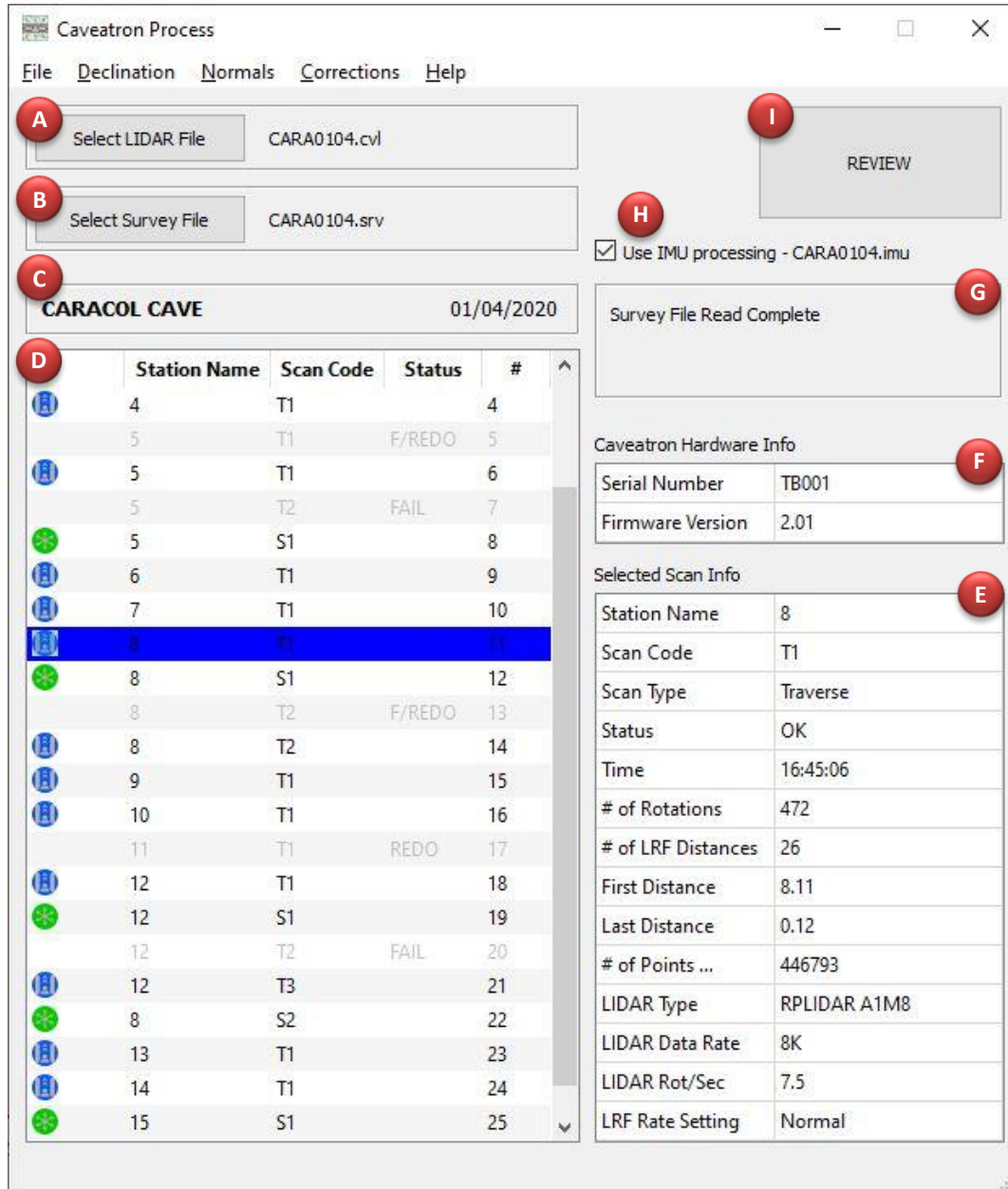
Caveatron Process processes one LIDAR scan at a time, saving each one as a separate text file in an x, y, z, nx, ny, nz (where x, y, z are the coordinates in meters and nx, ny, and nz represent the vector normal for the point.) This is intended for import into the freely available [CloudCompare software](#), or other point cloud viewer. The stations can also be saved into a compatible format for importing to CloudCompare as well. For the Caveatron SV, the points from the survey can be saved in a single text file or in separate files for Walls, Profile, and Cross Section per station, in an x, y, z format.

Within this software, scans can be further post-processed, if necessary, to fine-tune the scan alignment, the cave can be visualized in 3D, fly-through animations can be created, and the individual clouds merged and saved into a single point cloud file. A quick way to make the data look nice visually in CloudCompare is to turn on the “EDL Shader” under “Display” -> “Shaders & Filters” and bump up the point size 1 or 2 times with the “+” that appears next to “Default point size” when the mouse is hovered near the upper left of the point cloud display pane.

Finally, the point cloud data can be rendered into a solid model using a Poisson Reconstruction Filter. Though CloudCompare has this function, the freely available [Meshlab software](#) is recommended. This can be found in Meshlab under “Filters” -> “Remeshing, Simplification, and Reconstruction” -> “Screened Poisson Surface Reconstruction”. A reconstruction depth of 10-11 is recommended and the settings should be adjusted to give the best results.

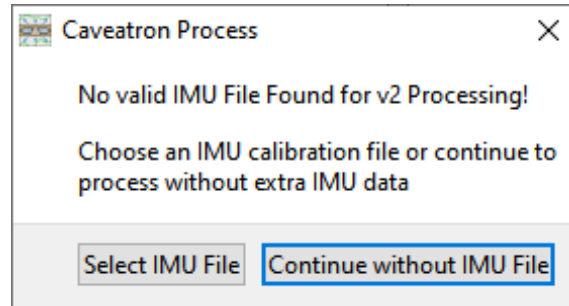
MAIN WINDOW

The main window provides the ability to access settings in several menus, load files, access a list of scans in LIDAR file, viewing basic info about each scan, and initiate processing of a scan.



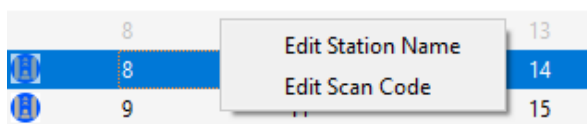
(A) Load LIDAR File: Opens a file dialog to select a Caveatron LIDAR file (.cvl) or Caveatron Points file (.cvp) for loading. (To select a .cvp file type, you must select it from the file-type pull-down menu). All LIDAR file format versions v3, v2, and v1 are supported. Depending on how large the file is, it may take a minute or more to load a LIDAR file. If a v3 or v2 .cvl file is loaded, the program looks for a matching .imu calibration file. (This file must have the same base file name as the .cvl file and be located in the

same directory – all files from a given survey are given the same base file name by the Caveatron). If the file is found, it is automatically loaded, otherwise a dialog box appears ([shown below](#)) allowing you to select the .imu file or just use the older v1 style processing. Caveatron .cvp files do not load an IMU file as they are not required.



- (B) **Load Survey File:** Opens a file dialog to select a survey file. Four formats are currently supported: A [Walls Cave Mapping software](#) survey file (.srv) generated natively by the Caveatron, a Walls list file (.lst), a [Compass Cave Survey software](#) plot file (.plt), or a comma delimited text file (.xyz) in the format of <Station_Name,x,y,z>, with x, y, z coordinates in meters. After loading the file, the [Survey Review Window](#) automatically opens.
- (C) **Survey Info Box:** Provides the name of the cave and the date of the survey.
- (D) **Scan List:** This is a list of the scans in the LIDAR file. The icons represent either a Passage Mode scan (blue) or a Room Mode scan (green). The columns provide the station name, the scan code, whether the scan failed or was redone, and the sequential scan number in the file. Contextual menu (right click) options are also available as described below. (The box is not used for point files from the Caveatron SV.)

CONTEXTUAL MENU OPTIONS IN THE SCAN LIST



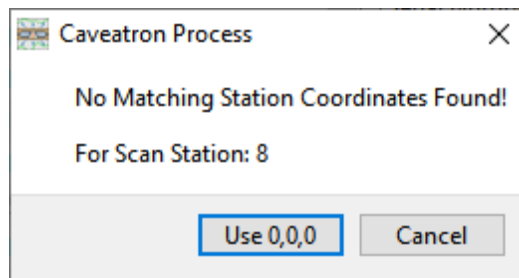
- **Edit Station Name:** Allows the station name to be changed
 - **Edit Scan Code:** Allows the survey code number to be changed (the prefix letter is fixed by scan type).
- (E) **Scan Info:** This table provide a variety of information about the currently selected scan in the Scan List including station name, scan code, whether it is a traverse or splay scan, whether the scan completed ok, failed or was redone, the time when the scan was performed, the number of rotations of the LIDAR during the scan, the number of successful laser rangefinder measurements, the distance of the initial LRF reading in meters, the distance of the final LRF reading in meters, the total number of LIDAR points scanned, the LIDAR type used in the scan, the data rate setting for the LIDAR, the LIDAR rotation speed in rotations per second, and rate setting for the LRF.

(F) **Caveatron Hardware Info:** Shows the serial number and firmware version of the Caveatron unit.

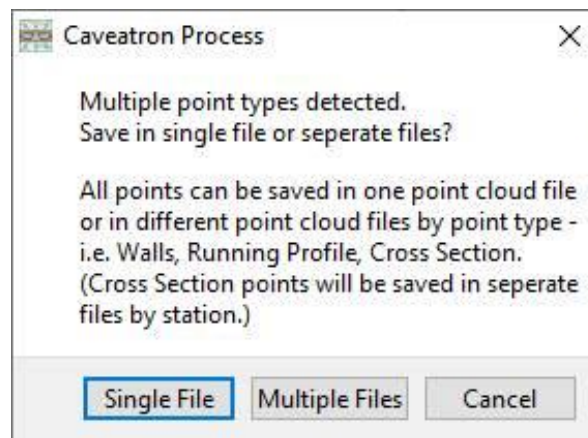
(G) **Status Box:** Shows a progress bar when files are loading or when loading is complete.

(H) **IMU Processing:** Checkbox to select whether to use the IMU processing mode for data taken with a Caveatron containing a full inertial measurement unit (IMU) with gyroscope, or whether to use the processing method from prior versions of Caveatron Process (v1). The checkbox is automatically checked when a v2 or later format .cvl file is loaded and is not shown when pre-v2 format .cvl files are loaded or any .cvl file without gyroscope data. If no .imu file is found with the calibration data, then v1 processing mode is required.

(I) **Review Button / Process and Save Button:** Initiates processing of the scan currently selected in the Scan List and opens the [Scan Review Window](#). If a survey file has not been loaded or there is no station in the survey file that matches the station name of the scan selected for review, then a dialog box appears ([shown below](#)). You can either cancel or continue to process the scan by selecting “Use 0,0,0” in which case the station location for that scan will be set to those coordinates.

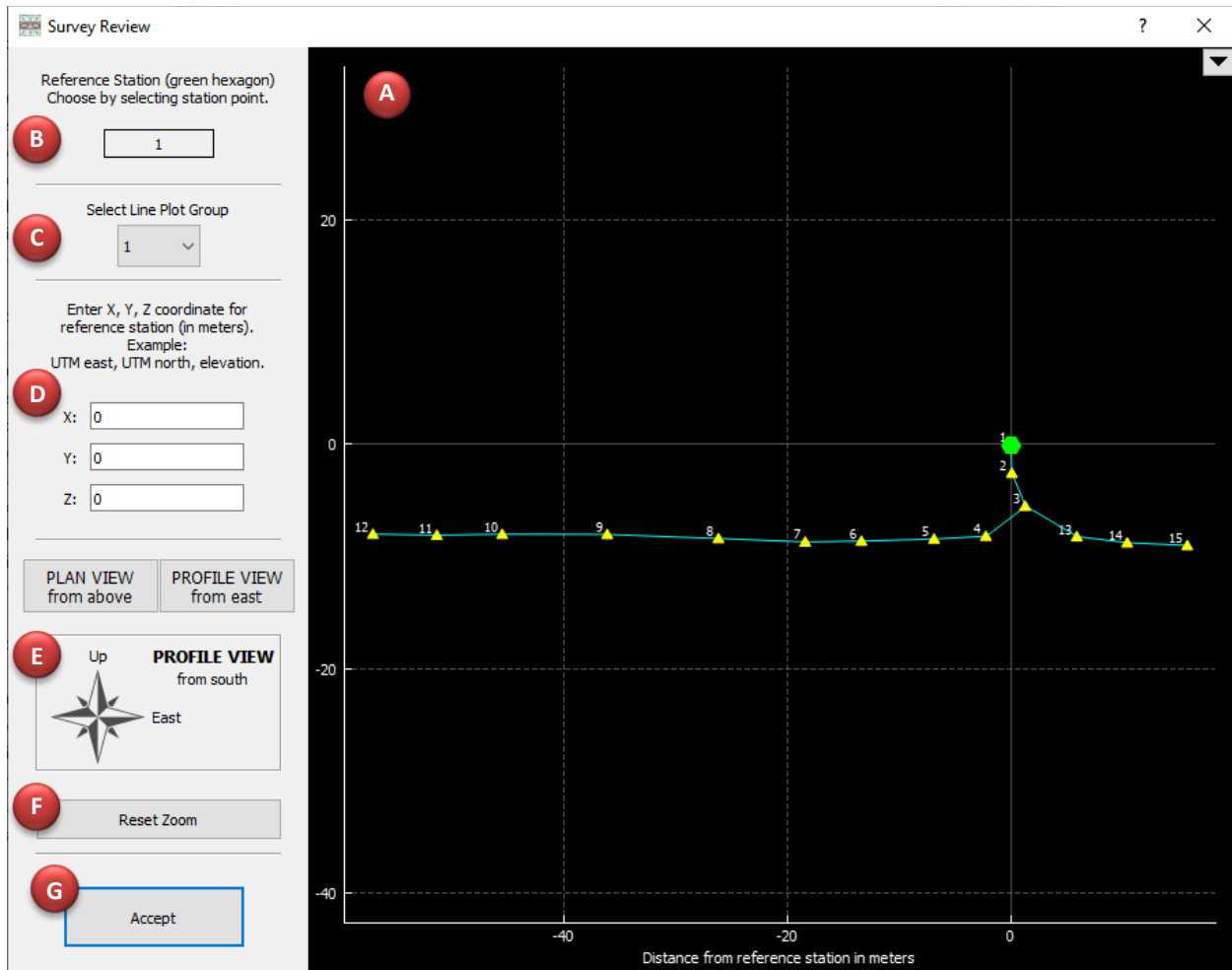


If a Caveatron SV Points file has been loaded, this button changes to “Process and Save”. This performs immediate processing of all points in the survey and opens a save dialog box to save the output to a file or files. If multiple types of points were collected (wall, profiles, or cross sections), then a dialog box appears ([shown below](#)) which allows the user to save all the points to a single file or to different files by point type. In the latter case, cross sections are saved to separate files for each station. A base file name is entered in the dialog box and “_Walls”, “Profile”, or “_Section_Station Code”. A warning message will appear in the event that some points cannot be matched to any station. All points that have a matching station are still saved.



SURVEY REVIEW WINDOW

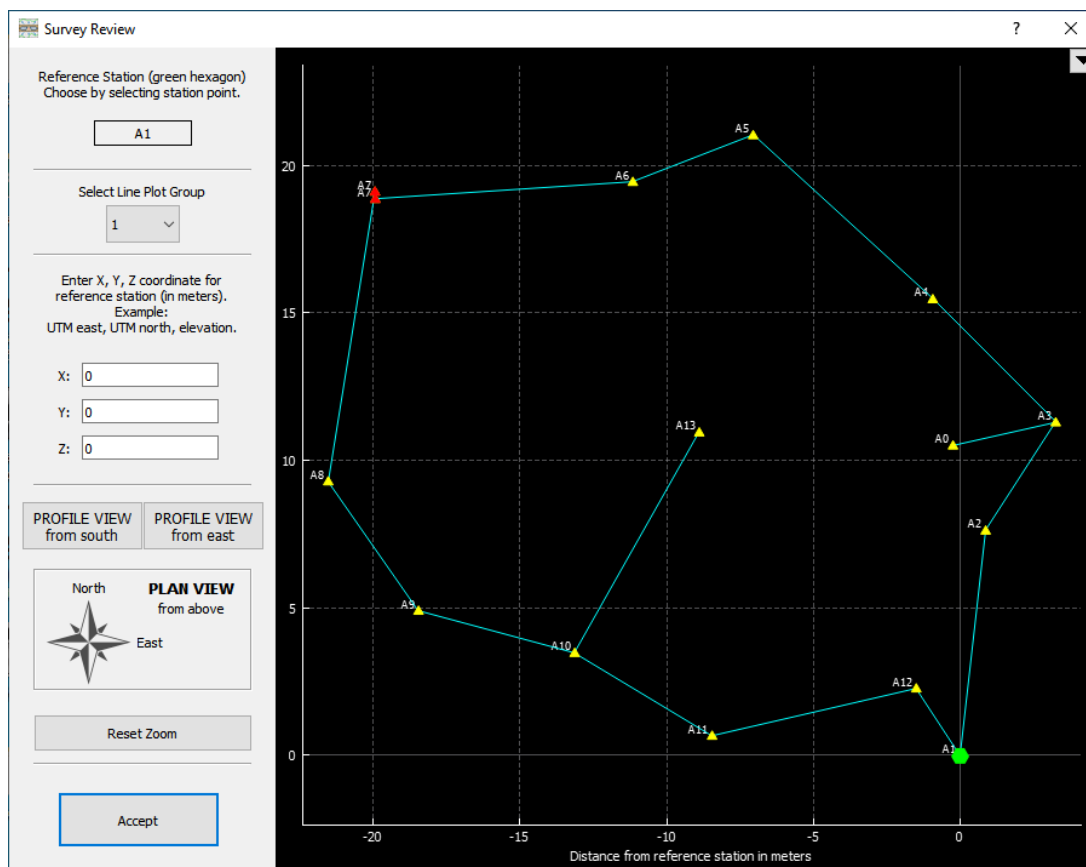
This window opens when a survey file is loaded and allows the survey data to be reviewed, the reference station to be set, and absolute coordinates for the survey to be entered which will be used to reference the scan data to another coordinate system.



(A) Survey Plot: The survey data is shown in this plot including station names. If data is loaded from a *.srv* or *.plt* file, then the vector lines (cyan lines) between stations (yellow triangles) are shown, otherwise only the stations are shown. The grid line scale shown at the edges is in meters. Using the scroll wheel on a mouse, the plot can be zoomed in or out and left clicking and dragging will pan the plot. The current reference station is shown as a green hexagon. The default reference station is either the first station in the file, the station designated with a #FIX (*.srv* survey file), or a station whose coordinates are 0,0,0 (*.lst* or *.xyz* station coordinate file). Clicking on a station selects it as the new reference station. Clicking on the down triangle button in the upper right corner opens or closes the plot legend.

(B) Reference Station: Shows the station name of the currently selected reference station.

- (C) **Plot Group:** If the survey contains more than one unconnected group of stations, they are defined as separate plot groups. This pull-down menu allows selection of a different plot groups in the survey. Each plot group can be assigned its own reference station and reference coordinates.
- (D) **Reference Station Coordinates:** Allows entry of a set of coordinates for the selected reference station which will be applied throughout the survey. These could be the UTM coordinates of the cave entrance, if you want to geo-reference the survey, or they could be coordinates of a station that connects to another part of the survey that was done at a different time. Note that values entered here are applied as an offset to the survey so if the survey file is already referenced, leave these boxes as zeros. If a .srv survey file is loaded that has a #FIX directive to establish a reference station, the coordinates of that station are populated in these boxes.
- (E) **View:** Press the buttons to change the view direction of the Survey Plot to Plan view or two different Profile views (from south or east). A compass symbol shows the current orientation.
- (F) **Reset Zoom:** Centers and zooms the Survey Plot to its default setting.
- (G) **Accept Button:** Pressing this button accepts the survey, establishes the reference station, calculates the offset from the entered coordinates, and returns to the [Main Window](#).

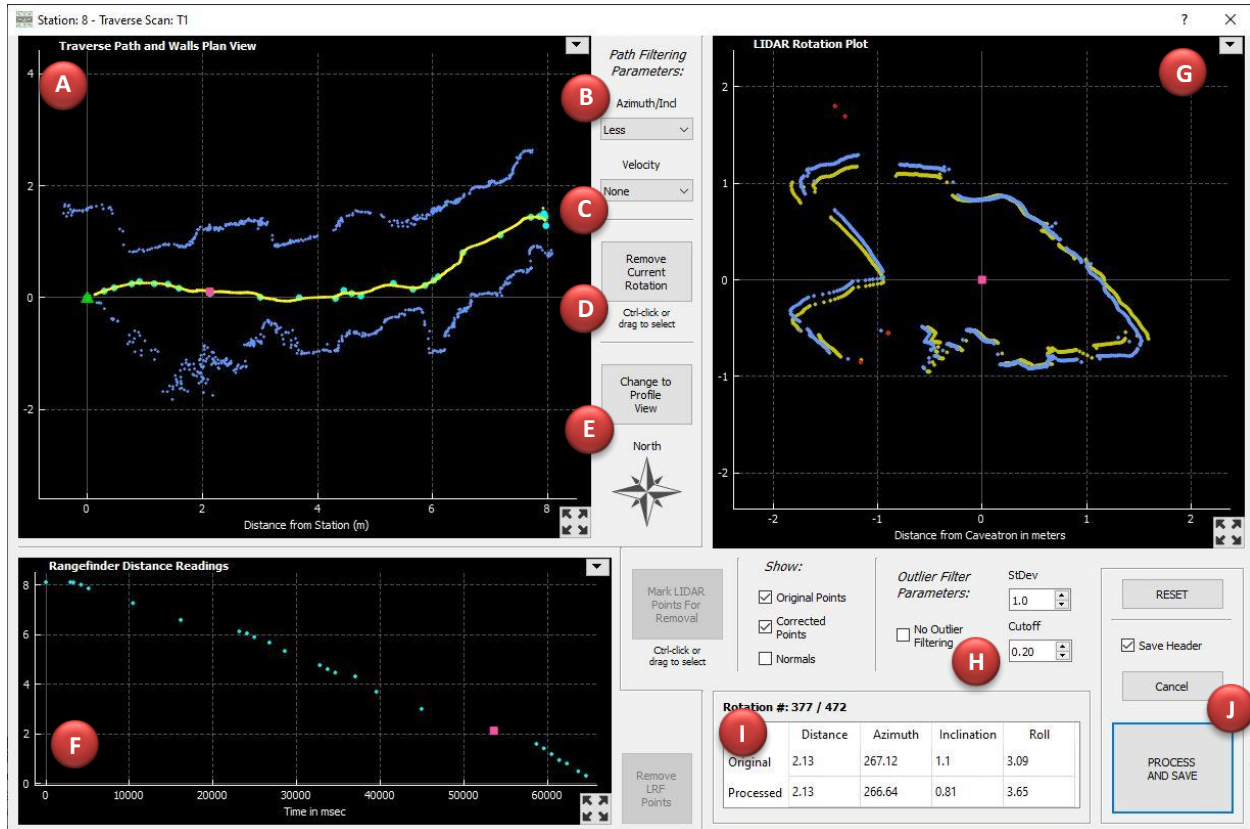


When a .srv survey file is first loaded, it is scanned for loop closures. If any are found, a dialog box appears informing you of the presence of the loops and suggesting that alternate pre-processing of the survey file

should be performed. The Survey Plot display shows the loop closure points as two red triangles instead of a single yellow triangle to illustrate the quality of the loop closure (as [shown above](#) for station A7). If there is only a single closure and the points are reasonably close to each other, then the Caveatron Process software will give satisfactory results and no other pre-processing is needed. Caveatron Process simply averages the position of the two closure points to obtain the final position of the station.

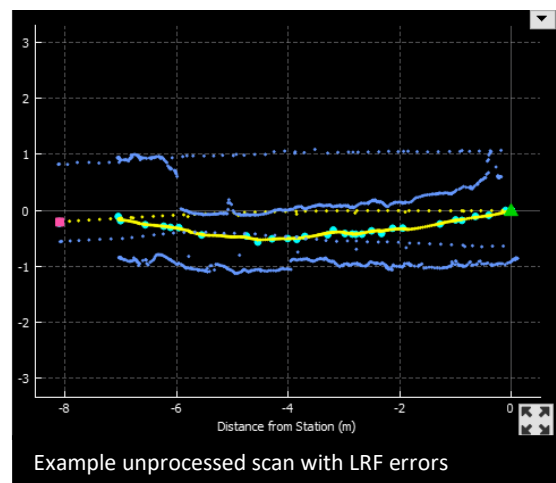
SCAN REVIEW WINDOW

This window is displayed when the Review button in the [Main Window](#) is selected for a particular scan. It allows for all the data for that scan to be reviewed in several ways, provides some limited editing capabilities, and processing parameters can be adjusted before final processing and saving of the point cloud file.



(A) Traverse Path and Walls View Plot

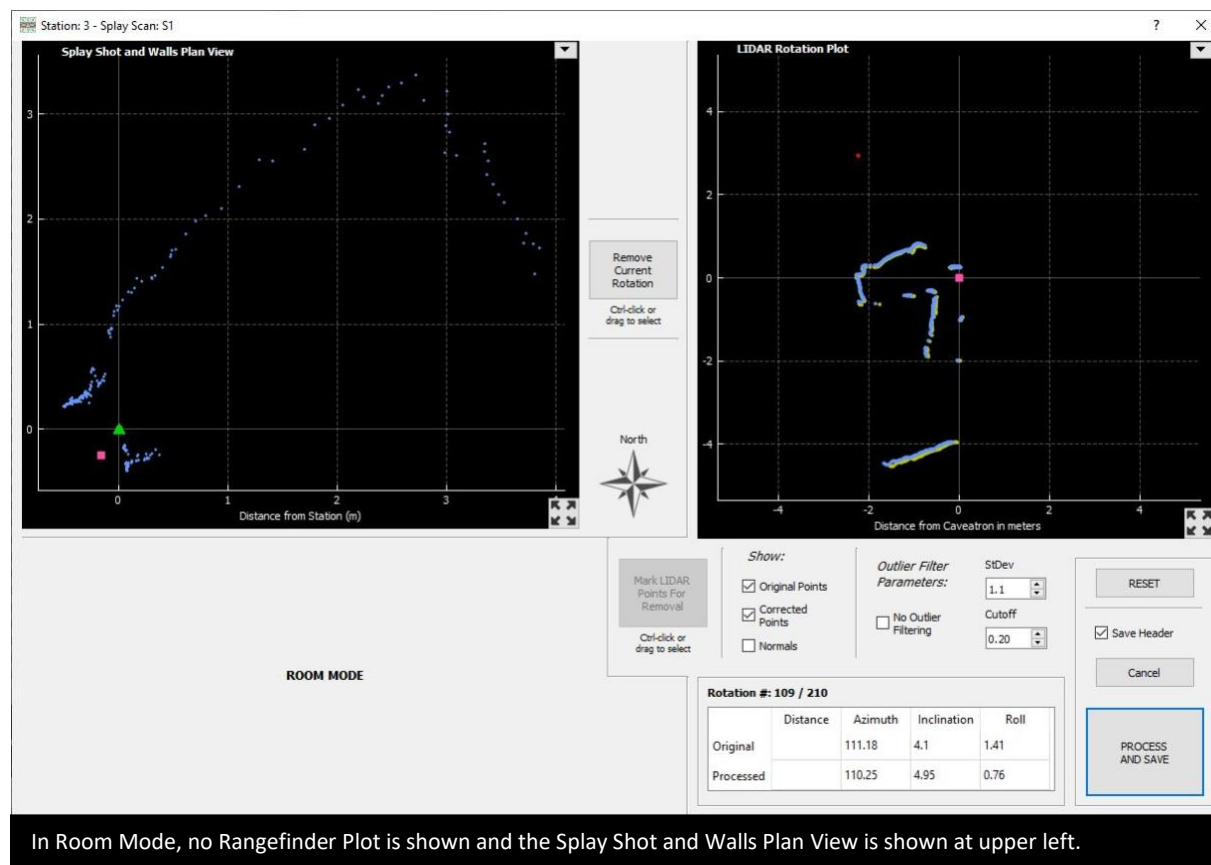
This plot is useful for getting a quick overview of the plan or profile view for each scan and for setting the level of filtering employed in the processing algorithm. The dark blue points indicate the cave walls directly to the right or left of the Caveatron (in Plan view) or above and below (in Profile view). The cyan points are the positions when a LRF reading was obtained. Although these points provide reasonably good true positions, the error increases when far from the station or when movement is challenging, such as in a crawlway. These LRF points are used as the framework to estimate the positions for all the other LIDAR rotations when a distance reading was not



obtained. Those estimated positions for each rotation are shown as the yellow points. The estimated positions (along with separate orientation estimates) are then used to compute the absolute location of all the LIDAR points.

One additional thing to note in the Traverse Path and Walls Plot is that if there is a set of widely spaced wall points that form straight lines overlapping with the actual walls, this is an indication of an erroneous LRF reading (see example at right), which can be identified and removed in the [Rangefinder Distance Readings Plot](#). Once the erroneous LRF reading(s) are removed, the wall points in the Traverse Path and Walls Plot will be recomputed to their correct locations.

The location of the station used for this scan is shown as the green triangle and the pink square shows the Caveatron position for the rotation currently shown in the LIDAR Rotation Plot. Note that this plot is shown slightly differently for a Room Mode scan ([see below](#)). In this case only a plan view is available and no path is shown. However, the Caveatron and station positions are identified as indicated above.

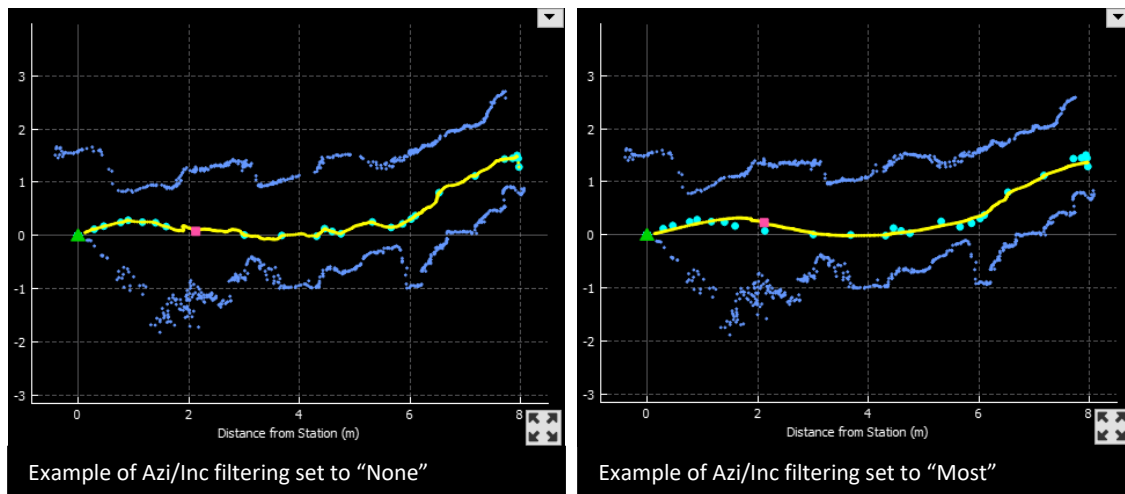


(B) Azimuth/Inclination Filtering

This pull-down menu allows selection of a filtering level to reduce the side-to-side wiggles in the plot and make it straighter. A level of "None" would mean that the estimated position line (yellow) would always hit the LRF points ([see below, left](#)). This is not usually realistic since body movements and the size of the card cause some amount of error. Increasing the filtering moves closer toward a straight line interpolated between the LRF points. Too straight of a line is also not usually realistic since it smooths out the true path

through the cave ([see below, right](#)). Adjust the filter level by looking at the path and the walls in both plan and profile views to select a level that gives realistic walls while also removing as much of the effect of your motion through the cave as possible. If the scan was in an easy walking passage and the scan was smooth, then a level of “Less” or “Least” would give the most accurate path. If the scan was in a tough crawlway with lots of body movement and up and down or side to side motions, then a level of “More” or “Most” would be appropriate. “More” would also be appropriate for very long scans where it is difficult to stay on target for the first part of the scan and LRF points are sparse. “Medium” is the default setting and is good for most scans. The Azimuth/Inclination filter level chosen is retained between scans but not after quitting the program.

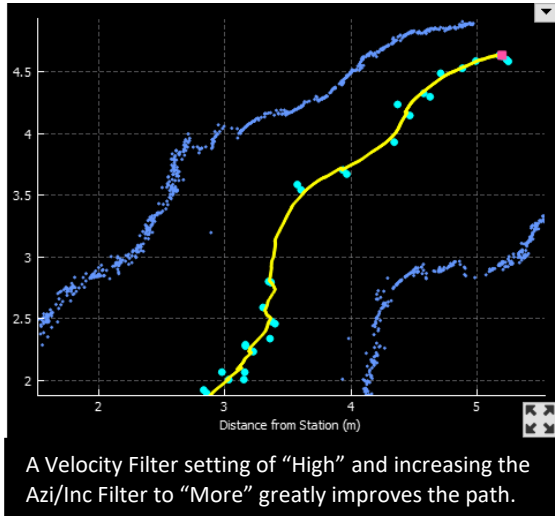
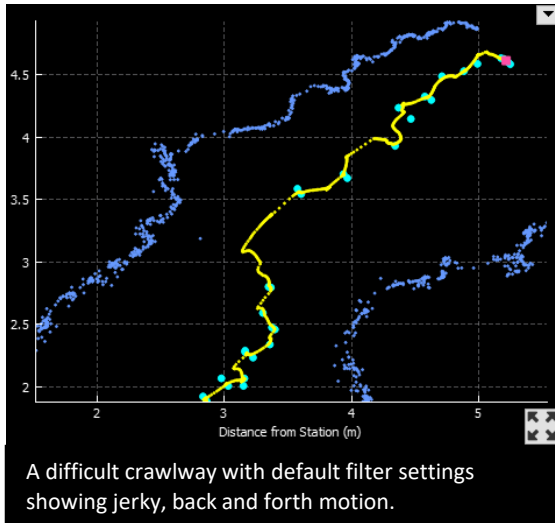
Note that this option is not available when processing Room Mode scans.



(C) Velocity Filtering

Using IMUProcessing, the software generates a velocity profile between each LRF position allowing for the positions of the Caveatron for each LIDAR rotation to be estimated. Sometimes the velocity profile is incorrect due to sudden motions resulting in position estimates that may move forward and backward along the motion path in an inaccurate way. These can be reduced or removed by applying Velocity Filtering. A level of “None” applies no filtering, meaning that the gyroscope and accelerometer are fully used for the position estimate, and is the default. This level is fine for many scans. However, for scans where jerky motions occurred, some level of filtering may be required to smooth out the path ([see example below](#)). Zoom in on location where the Caveatron path (yellow line) moves backwards and increase the level until this is reduced. Also look at the cave walls (blue points) for places where it looks like there is wall overlap and increase the level so that the overlap is minimized or removed. A level of “Total” essentially reverts to v1 processing by creating a pure linear path between each LRF position estimate. The Velocity filter level is not retained between scans but reverts to “None” since it should only be used for unusual scan situations.

This option is not available when processing Room Mode scans or when processing v1 format scans.



(D) Remove Selected/Current Rotation(s)

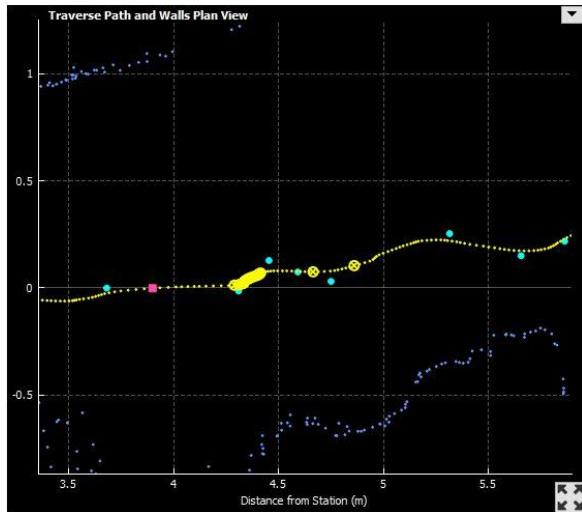
Allows rotations to be removed from the scan data. This can be useful if there are sections of data that are problematic in terms of the azimuth or inclination and cannot be fixed with the filters. Without any selection, the current rotation is removed. If you want to remove multiple rotations or a rotation other than the current rotation, they are selected by clicking on any of the yellow path points in the Traverse Path and Walls View plot ([see below, left](#)). By holding the control button while dragging the mouse, multiple path points can be selected. Selected points appear as a yellow circle with an X inside. To deselect all points, just click elsewhere on the plot. After pressing the Remove Rotations button, the LIDAR data will no longer be included in the final output ([see below, bottom](#)). If you made a mistake by removing rotations, you can undo the most recent removal by right clicking anywhere in the non-plot areas of the Scan Window and selecting "Undo Rotation Delete" to restore the points.

(E) Toggle Plan / Profile View Button

Switches between plan view and profile view in the Traverse Path and Walls View plot.

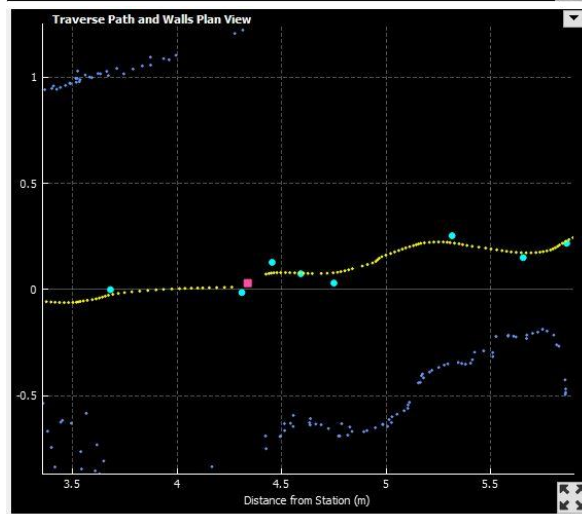
(F) Rangefinder Distance Readings Plot

This plot is used to view all the LRF readings collected during the scan and remove readings with erroneous values. Each LRF reading is shown as a cyan colored point. The plot shows time from the start of the scan in milliseconds on the horizontal axis and the distance from the station in meters on the vertical axis. For every scan, these points should form a gradually decreasing line from the upper left to the lower right. In general, any point that is above or below this line is an erroneous reading and should be removed. The program attempts to detect these points and marks them with an orange arrow above the point ([see below, left](#)). If any erroneous point is detected, a red warning box appears in this plot when the Scan Review Window is first opened. As soon as you click on the Rangefinder plot, the warning box disappears.



(LEFT) Rotations are selected for removal in the Traverse Path and Walls View plot by clicking on any of the yellow path points which are then marked with a circle and X. Multiple points are selected by using the CTRL button and clicking multiple point or dragging the mouse.

(BELOW) After pressing the “Remove Selected Rotations” button, the rotation points are no longer included in the Traverse Path and Walls View plot or the LIDAR Rotation plot as shown. To undo the most recent rotation removal, right click anywhere outside of a plot and select “Undo Rotation Delete” as shown.



Path Filtering Parameters:

Azimuth/Ind

Less

Velocity

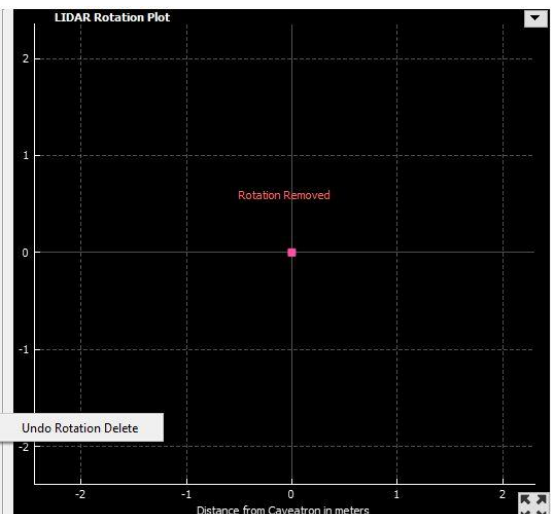
None

Remove Selected Rotations

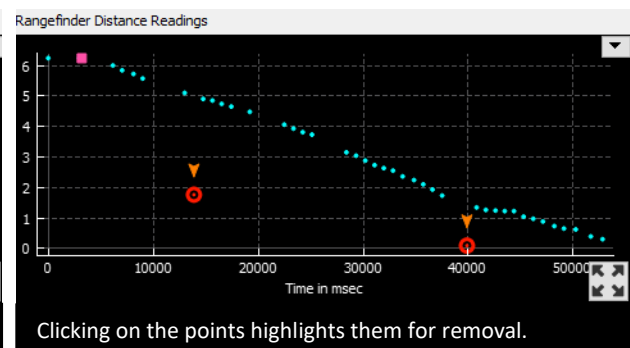
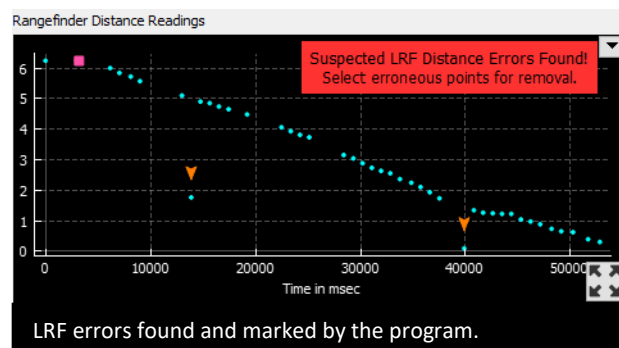
Ctrl-click or drag to select

Change to Profile View

North



To remove an erroneous LRF point, click on it and a red bulls-eye appears marking it for removal ([see below, right](#)). You can pick multiple points by holding the Control key (Windows) or the Command key (Mac) while selecting points. Clicking on an already selected point un-selects it. To remove the points, click on the “Remove LRF Points” button to the lower right of the plot. If you decide you made a mistake by removing a point, click the Cancel button at the bottom right of the window. This will close the window and you can start the review again.



The pink square on the plot shows the position of the Caveatron for the rotation currently shown in the LIDAR Rotation Plot. This can be useful for determining where a given rotation is during the course of the scan.

The grid line scale shown at the edges is in meters. Using the scroll wheel on a mouse, the plot can be zoomed in or out and left clicking and dragging will pan the plot. Pressing the button in the lower right resets the zoom and center to default. Clicking on the down triangle button in the upper right corner opens or closes the plot legend.

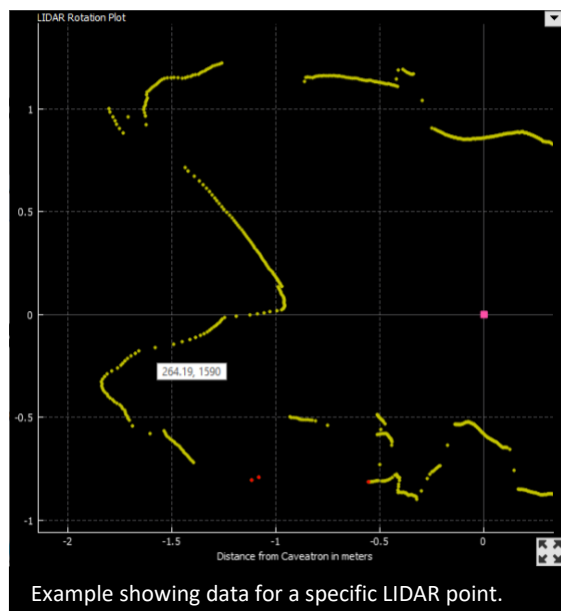
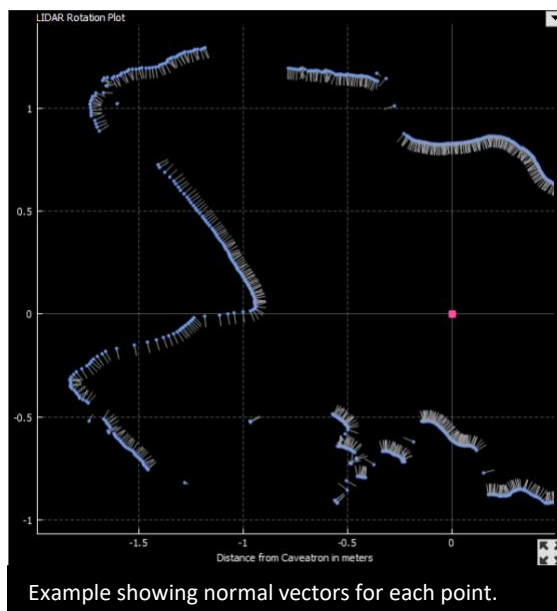
This plot is not shown when processing a Room Mode scan.

(G) LIDAR Rotation Plot

Shows the data from one rotation of the LIDAR. The original points are shown in yellow and corrected points after processing are shown in blue. Outlier points being filtered for removal are shown in red and the surface normal vector for each point can be shown as a thin gray line. The position of the Caveatron is shown as the pink square. The original, corrected points, and normals can separately be turned on or off with the checkboxes below the plot ([see below, left](#)).

To step through each rotation in the scan, use the arrows on the keyboard. The current rotation number and the total rotations in the scan are shown to the lower left of the plot. The right arrow advances to the next scan while the left arrow goes to the previous scan. Hitting the left or right arrow from the first or last scan, respectively wraps around to the end or start. Sometimes the LIDAR Rotation Plot loses focus when interacting with the other plots so that the arrows no longer work. Simply click anywhere on the LIDAR Rotation Plot to restore its focus and use the arrow keys. You can also directly go to any rotation in the scan by double clicking on one of the yellow rotation points in the Traverse Path and Walls View plot.

Clicking on any of the original (yellow) points in the LIDAR Rotation plot allows you to view the distance from the Caveatron (in mm) and angle (in degrees) of that point ([see below, right](#)).

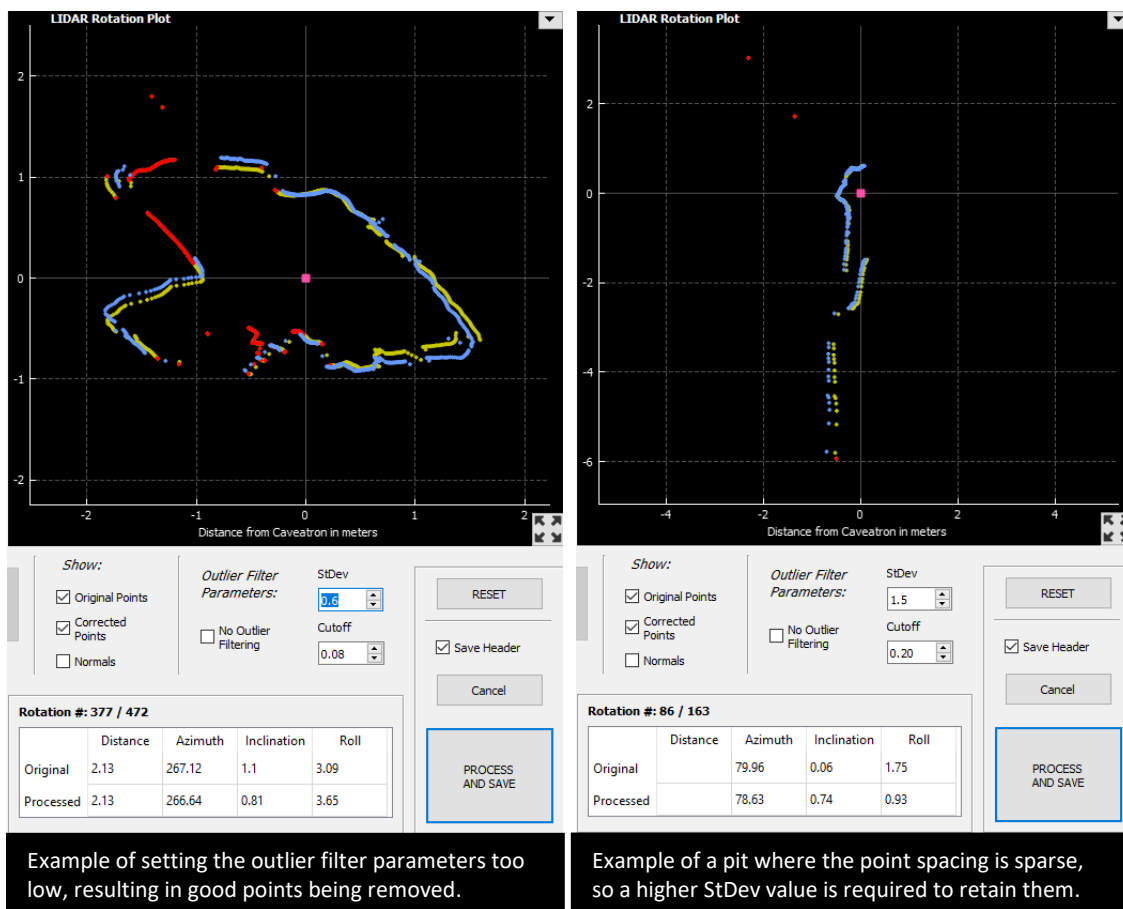


The grid line scale shown at the edges is in meters. Using the scroll wheel on a mouse, the plot can be zoomed in or out and left clicking and dragging will pan the plot. Pressing the button in the lower right resets the zoom and center to default. Clicking on the down triangle button in the upper right corner opens or closes the plot legend.

(H) Outlier Filter Parameters

These two boxes allow for the outlier filter parameters to be adjusted. The outlier filter removes noisy points from the LIDAR data. The effect of these parameters is shown by examining the red dots in the LIDAR Rotation Plot. Small values of StDev and Cutoff increases the amount of filtering (removes more points) whereas increasing the values allows more points, but may also allow undesired noise into the processed point cloud. The default value for StDev is 1.0 and can be adjusted from 0.5 to 2.0. the default value for the Cutoff is 0.20 and can be adjusted from 0.05 to 0.30.

If the value is adjusted too low, valid points will may be removed ([see example below, left](#)). If you have a narrow feature such as a tube or a pit heading away from the scan where the walls were only measured obliquely, then real wall points may be flagged as noise ([see example below, right](#)). In this case, increasing the StDev to about 1.5 will usually allow these points to be included. Since each cave is different, it is best to step through a couple of scans before starting to process to look for unwanted noise points being passed (not highlighted red) or for real points being filtered (highlighted red) and adjust the filter parameters until you are satisfied.



The outlier filtering parameters are automatically retained as a settings. The default values can be restored in the Main Window under the menu option “File”-> “Reset Default Settings”. Outlier filtering can be disabled for the current scan by selecting the “No Outlier Filtering’ checkbox.

(I) Rotation Table

This table shows the position and orientation data of the Caveatron for the currently displayed LIDAR rotation as distance (in meters), azimuth, inclination, and roll (all in degrees). The top row shows the original data and the bottom row shows the computed position and orientation after processing. Distances are only shown for rotations where a distance reading was obtained from the LRF, otherwise those cells are blank. If the azimuth, inclination or roll data for a rotation contains an error (value of 999), that rotation is not considered in processing and the processed cells are highlighted in red with the rotation shown as removed in the plot.

(J) Process and Save/Reset/Cancel Buttons

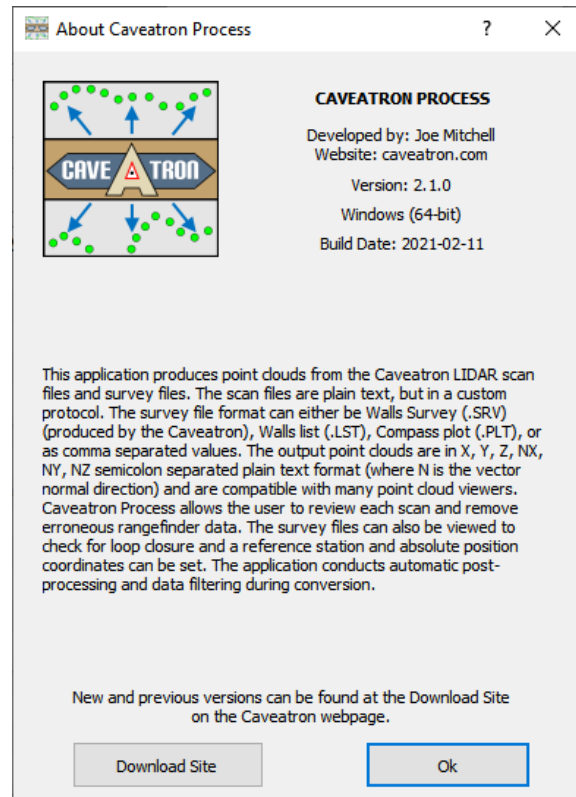
Pressing the Process and Save Button will complete the processing of the scan and save it as a point cloud file. The file format is semicolon separated x, y, and z coordinate in meters, and optionally includes the normal vector, which is necessary to render the point cloud into a solid model. (Details of the file format can be found in Appendix A.) The format is setup for direct import into [CloudCompare software](#). The file dialog box has the file name pre-populated with the station name and scan code but can be changed. When the file is saved, the Scan Review Window is closed, and you are taken back to the [Main Window](#) to process the next scan.

The “Save Header” checkbox allows you to include a two-line header in the point cloud file with information about the processing settings used for that scan. This can be useful if you need to go back and determine how it was processed at a later date. (Details of the header format can be found in Appendix A.) The header is configured so that CloudCompare should ignore it during import. If it does not, then the Cloudcompare import menu has an option to skip a user entered number of lines. The state of this checkbox is automatically retained as setting.

The Reset button removes all changes to the scan and restores the Scan Window to its original condition as if the Review button from the Main Window had just been pressed. The Cancel button closes the Scan Review window without performing any processing on the scan.

ABOUT WINDOW

This window is selected from the menu and provides information about the Caveatron Process software and the version in use. It also has a button that opens a web browser window to the site where the current version of Caveatron Process software can be downloaded. Previous versions are also available from that website.



MENUS

FILE

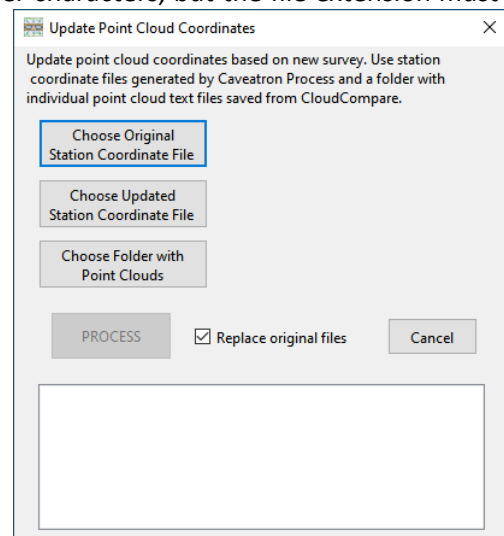
SAVE STATION COORDINATES

Allows you to save a list of survey station names and coordinates in a text file (.txt) formatted for importing into a point cloud viewer such as CloudCompare.

UPDATE POINT CLOUD COORDINATES

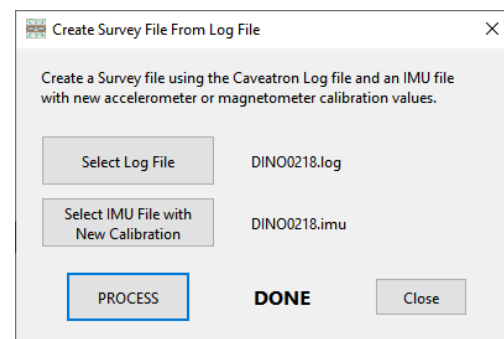
When new surveys are conducted, corrected data or additional loop closures may result in shifts in the location of stations in previous surveys. This menu function allows the coordinates of previously processed point clouds that have been aligned in CloudCompare to be updated without having to re-process them or realign them. First, station coordinate files generated by the “Save Station Coordinates” menu item above must be created for both the original survey and the updated survey. Next, the point clouds for which you wish to update coordinates must be exported from CloudCompare. Unfortunately, there is no way at present to batch export clouds from CloudCompare and have them retain their name, so they must be exported one at a time. To do this, in CloudCompare, select the cloud you want to export in the DB Tree and select File->Save in the menu. In the save dialog box, be sure that “ASCII cloud” is selected from the “Save as type” pull down menu. The file must be named with the station name as the first part of the filename followed by an underscore (_) character, which is the default unless you have changed the cloud names. The underscore can be followed by any number of other characters, but the file extension must be “.txt”. All the cloud files must be placed in the same folder. Files not matching any station name in the survey coordinate files will be skipped during processing.

In the dialog box for this menu item, select the original and updated station coordinate files, then the folder that contains the point clouds to update. Note that the point clouds in this folder will be overwritten with the updated coordinates, unless the “Replace original files” checkbox is deselected. Select PROCESS to begin the update. The box at the bottom of the dialog shows the progress and the results of the processing for each file “FINISHED!” is displayed when processing is complete. The updated clouds can now be re-imported into CloudCompare with their new coordinates but with their orientations retained.



CREATE SRV FROM LOG FILE

In the even that you discover that you had a bad calibration when you performed the survey, all is not lost. The Caveatron Log files stores data from about each shot and scan. It is mostly intended for troubleshooting but also contains some raw accelerometer and magnetometer data from each shot. Using this function that data can be extracted with a new corrected calibration to give you a better survey. As soon as you discover the bad calibration, obtain a new one that is good. Download the new IMU file and then use this menu function. Select the



log file from the original survey, then select the new IMU file. Click “Process” and a dialog box opens to choose the name of the newly created survey (SRV) file. The new IMU file should then also be used when processing the LIDAR data from the CVL file. To do that either be sure that the new IMU file has the same base name as the CVL file or that there is no IMU file with the same base name in the folder with the CVL file so you will be prompted to choose the new one.

There are several things to note about the new survey file created from the log file. It does not contain all of the information that an original survey file does and only has the basic shot info including the “from” station, “to” station, distance, azimuth, and inclination. Also, it contains every successful shot including shots that were redos, reshoots, or were later deleted, so you will have to sort through these manually and remove the shots you do not want to use before using this file for processing scans. “Redo” or “Reshoot” is noted next to each shot line that was redone or reshot. Back-sights are still noted as usual. Also note that only a single raw set of measurement is retained for each shot in the log file so will not give quite the same azimuth and inclination value as the original since it does not benefit from the multiple measurement averaging that occurs during the original shot.

CONVERT SURVEY TO COMPASS

Converts a Walls format .srv file generated by the Caveatron to a Compass format .dat file.

CONVERT CVL v3 to v2

Converts a version 3 CVL file (LIDAR data stored at binary) to a version 2 CVL file (LIDAR data stored as text). This can be useful for troubleshoot or manual data verification but the file size is much larger.

RESET DEFAULT SETTINGS

Several settings in the program are automatically stored in a settings.ini file for retention after the program quits. This includes the true/magnetic north, declination, the outlier filtering parameters, the header save option, and the most recent directory used to open or save a file. This command resets these saved settings to their initial defaults.

DECLINATION

SAVE AS MAGNETIC NORTH

Sets the saved point cloud output files to use magnetic north.

SAVE AS TRUE NORTH

Sets the saved point cloud files to use true north. Opens a dialog box to enter in your magnetic declination. If chosen, this selection and the declination are automatically retained as settings.

NORMALS

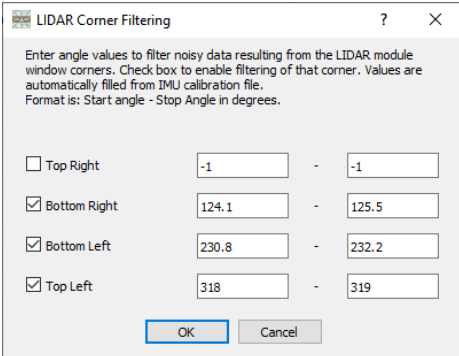
SAVE NORMALS

If this menu item is selected, the surface normals are saved with the point cloud (default). Surface normals are required if you intend to visualize the data with shaders or render the point cloud into a solid model.

CORRECTIONS

FILTER LIDAR CORNERS

Allows four ranges of angles to be entered that remove noise resulting from the corners of the LIDAR enclosure windows. These are automatically populated from the values in the Caveatron IMU file but can be edited here. Check or uncheck the box to use the values for a particular corner or enter “-1” in both boxes for a particular corner to remove any filtering from that corner. Edited values are not saved when quitting the program but are reloaded from the *.imu* file. They can be saved in the header for the point cloud (if selected.)



The screenshot shows a dialog box titled "LIDAR Corner Filtering". It contains instructions: "Enter angle values to filter noisy data resulting from the LIDAR module window corners. Check box to enable filtering of that corner. Values are automatically filled from IMU calibration file. Format is: Start angle - Stop Angle in degrees." Below the instructions are four rows, each with a checkbox, a text input field, a minus sign, and another text input field. The rows are: "Top Right" (checkbox unchecked, inputs "-1" and "-1"), "Bottom Right" (checkbox checked, inputs "124.1" and "125.5"), "Bottom Left" (checkbox checked, inputs "230.8" and "232.2"), and "Top Left" (checkbox checked, inputs "318" and "319"). At the bottom are "OK" and "Cancel" buttons.

Corner	Start angle	Stop Angle
<input type="checkbox"/> Top Right	-1	-1
<input checked="" type="checkbox"/> Bottom Right	124.1	125.5
<input checked="" type="checkbox"/> Bottom Left	230.8	232.2
<input checked="" type="checkbox"/> Top Left	318	319

FILTER MIN/MAX RANGE

Enter values in this dialog to override the default values for the LIDAR. Enter “0” to restore the default values for the LIDAR. The entered values are not saved when quitting the program but can be saved in the header for the point cloud (if selected.)

APPLY LIDAR WINDOW CORRECTION

Selects whether the LIDAR window correction calibration is applied to the processing of a scan. Activated by default on each program start.

HELP

USER MANUAL

Opens the user manual in the default PDF viewer.

APPENDIX A: POINT CLOUD FILE FORMAT

Caveatron Process saves point clouds in a plain text format for maximum compatibility. They can be saved with or without normal vectors. There is also an option to save a two-line header at the start of the file with information about the settings used to process the scan data.

Data Format

Semi-colon delimited with each point on a separate line.

X;Y;Z;NX;NY;NZ

X, Y, and Z are the point coordinates in meters from the overall reference station selected when importing the survey. If UTM coordinates were entered when importing the survey, the points are referenced to those values. If no survey was loaded, then the points are referenced to the station for that scan.

NX, NY, and NZ are the normal vector for that point in a direction inward into the cave passage from that point. These are unitless values. If normal vectors were not selected for output or the data originates from a Points file from the Caveatron SV, these values are not included and the line only contains X;Y;Z

Header Format

The header is optional (and not used with points output from the Caveatron SV) and each item in the header is separated by a “/” character. The first line provides general information about the scan from which the point cloud was generated and the second line provides specific settings used to process the scan.

Line 1

- Caveatron Process 2.xx vy
xx = Caveatron Process version number
y = CVL file version (v1, v2, or v3)
- Cave name
- Survey date (YYYY-MM-DD)
- Station name
- Scan code Xy
X = T for traverse scan or S for splay scan
y = scan number

Line 2

- Outlier Standard Deviation filter setting
- Outlier Cutoff filter setting
- Azimuth/Inclination filter setting (value = NA for v2 processing)
- Velocity filter setting (value = NA for v1 processing or for splay scans)

- Window corners *a,b c,d e,f g,h* (Four groups separated by spaces with each start and end value comma separated - points with angles between the comma separated values are removed.)
 - a* = upper right corner filtering start filtering
 - b* = upper right corner filtering end filtering
 - c* = lower right corner filtering start filtering
 - d* = lower right corner filtering end filtering
 - e* = lower left corner filtering start filtering
 - f* = lower left corner filtering end filtering
 - g* = upper left corner filtering start filtering
 - h* = upper left corner filtering end filtering
- LIDAR range limits *a,b* (Points outside of these range limits are removed.)
 - a* = lower LIDAR range limit
 - b* = upper LIDAR range limit
- North setting
 - "Mag" = Points are oriented for magnetic north (no declination adjustment)
 - x* = Points are oriented true north with the value *x* for magnetic declination