

Terrestrial Laser Scanning (TLS) Field Camp Manual

UNAVCO
Boulder, CO
v1.3 - 2013



Compiled by:

Shawn Carr (UNAVCO), Bruce Douglas (Indiana University),
Christopher Crosby (UNAVCO)

With contributions from:

David Phillips (UNAVCO), U. Texas Dallas Cybermapping Lab

Table of Contents

Field Objectives for TLS.....	3
Intro to TLS.....	4
Scan Parameters.....	5
Set up and Work Flow.....	9
TLS Coordinate System.....	11
Products.....	12
Appendix A - Exercises.....	15
Appendix B – Battery Schematic in Series.....	19
Appendix C – Reigl Manufacturer Scanner Specs... 	20

Field Objectives for TLS Scanning

Below is a list of procedures to follow and complete in the field. TLS exercise problems, equipment list, and instructions for a sketch map are listed in Appendix A. Appendix B lists Riegl's manufacturer specifications for the VZ-400 scanner. Use field notebooks to answer questions and draw sketch maps if sheets are not provided and turn in all completed work after you have finished scanning for the day, if required to do so.

1. Project Planning

1.1. Thoroughly read through the hand-out.

1.2. Specify project objectives.

1.3. Use Google Earth, topographic maps, or field photos to determine best locations for scanner, control targets, and GPS. You will need to plan your scan positions and control target positions carefully, so you can always have between 3-5 targets in common (visible) between scan positions.

1.4. Decisions should coincide with scanner capabilities and science research goals. Can you get the scanner and researchers safely into and out of the study site?

1.5. Complete a list of equipment needed for the day with the provided sheet in Appendix A.

2. Pre-scan Metadata

2.1. What type, number, and size of reflector control targets are you using?

2.2. Provide a sketch map describing the topographic layout of the field site. Careful detailed notes of target, GPS, and scanner locations are very important. Instructions are included in Appendix A.

3. Post-scan Metadata

3.1. How many panorama scans did you take and at what resolution?

3.2. How many fine scans were obtained, if any?

3.2.1. List the panorama/fine scan parameters used for each. Include:

3.2.1.1. Duration of scan, scan resolution, mean range to target, mean angle of incidence, and any other comments.

4. Final Point Cloud

4.1. If you completed multiple scans, were they successfully merged and georeferenced?

4.2. Do the images make sense and have achieved preliminary objectives of data collection?

Terrestrial Laser Scanning

1. Intro to TLS

Terrestrial Laser Scanning (TLS) is based on LiDAR (Light Detection And Ranging) technology and may also be called Terrestrial LiDAR or Tripod LiDAR (T-LiDAR). It is a ground-based remote sensing tool that is similar to Radar and Sonar, but uses visible to near infrared light emitted from a laser instrument that then records the reflected light waves from its targets. These recorded light waves can then be converted into points with X, Y, Z coordinates that can be georeferenced with a GPS unit to produce highly precise and accurate 3-dimensional images called *point clouds*, which can then be analyzed for scientific research. TLS is a tool that is quickly becoming very popular in the Earth sciences for topographic mapping, temporal and spatial geomorphic and tectonic change detection such as earthquakes, volcanoes, landslides, stream morphology studies, glacier mass balance and snow depth measurements. TLS is also used widely in biomass investigations in forestry, and for numerous engineering applications.

Because the laser scanner is a static instrument, it provides excellent coverage of objectives that range from several meters to over a kilometer in scale. UNAVCO deploys a pool of Riegl and Leica TLS scanners with maximum ranges of 400-2000 meters with centimeter scale resolution (in ideal situations millimeter scale is possible). This is compared to airborne and satellite LiDAR systems that have resolutions on the 10's of centimeters to meters scales respectively. When fitted with a digital camera, which is common, digital photographic images (RGB) can be merged with point cloud data to produce photo-realistic 3-dimensional images (Figure 1).

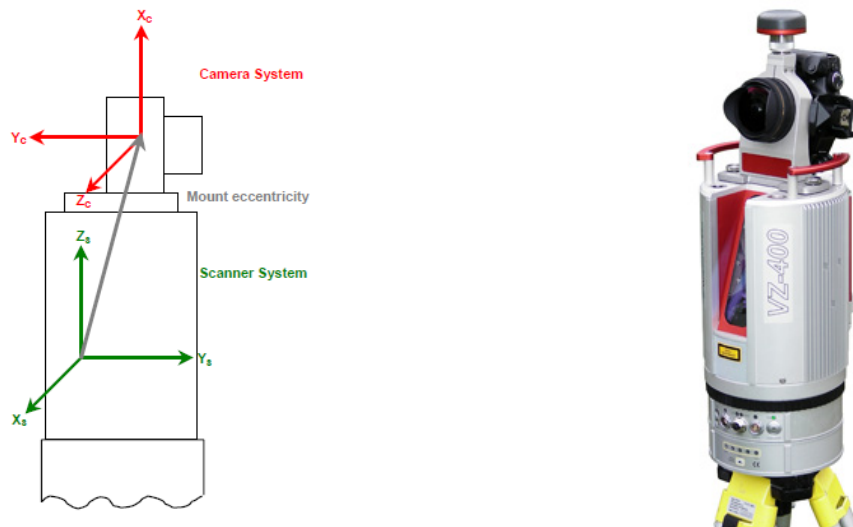


Figure 1. Left image shows the general schematic set up of a TLS scanner with laser housing and camera and the X, Y, Z coordinate system used to register points collected. The right image is of the **Riegl VZ-400** scanner, an instrument commonly deployed by UNAVCO for Earth science research (Images courtesy of Cyber Mapping Lab of UT-Dallas and Riegl USA).

Georeferenced point clouds are produced by measuring (“ranging”) the distance between the scanner and the target. The process happens as the laser emits many short pulses of light that are reflected back and recorded by a receiver. Distance is then calculated by multiplying the round trip time of flight of the initial pulse and return capture by the speed of light, then dividing that in half (Figure 2).

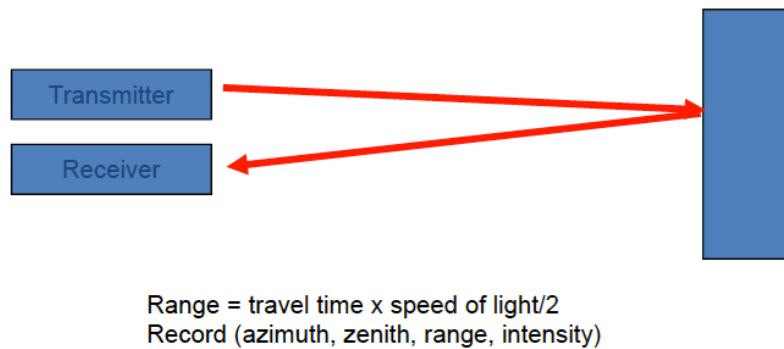


Figure 2. A simple schematic of a laser pulse emitted by the scanner, reflected off of a target, and received by the scanner (UTD CyberMapping Lab).

2. Scan Parameters

Beam Divergence

An important consideration in TLS scanning is beam divergence. The laser beam is a cylindrical beam of photons (light) that slightly deviates when it is first emitted from the laser. As it travels from the TLS laser, the beam begins to widen as a narrow cone that increases in diameter the further it travels called the “beam divergence” (Figure 3).

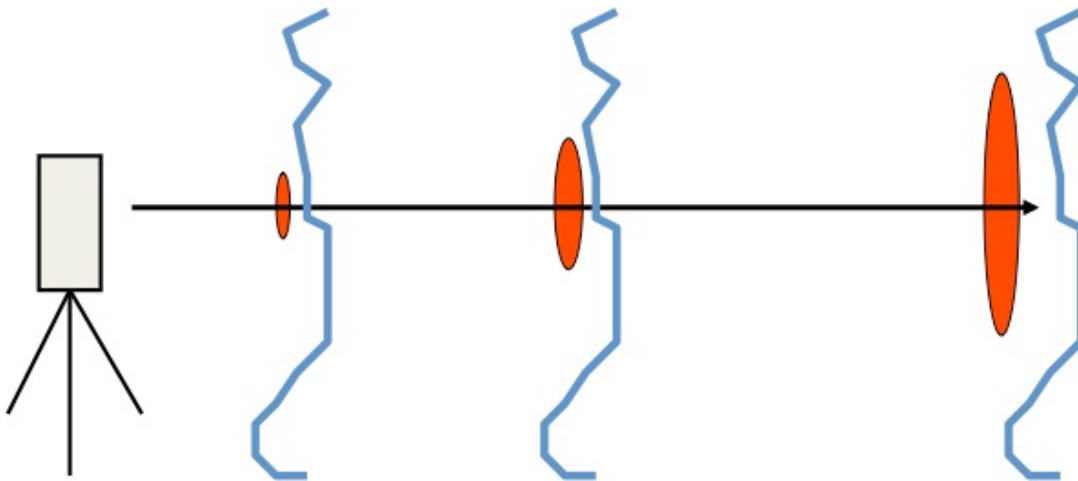


Figure 3. An idealized example of beam divergence as distance increases from laser. Ovals represent beam spot size and the blue lines represent a hypothetical rock out-crop (Image courtesy of Cyber Mapping Lab of UT-Dallas).

Initial beam diameter and divergence varies by LiDAR instrument model and can range from 0.1-1.0 millirads (Gatziolis and Anderson, 2008). The Riegl VZ-400 has a beam divergence of 0.35 millirads and an initial beam diameter of 0.007 meters. Therefore, the spot size on a target will be a function of the diameter of the initial beam as it exits the laser, the beam divergence, and the distance it travels until it hits a target. This corresponds to the beam widening ~ 3 cm per 100 m. The resolution of the scan will be affected by this parameter as the final spot size of the beam that intercepts its target illuminates a certain area. The attributes within the spot are averaged and recorded by the receiver. Thus, the wider the spot size diameter, the less overall detail you will gain on a scale smaller than the spot size (Figure 4).

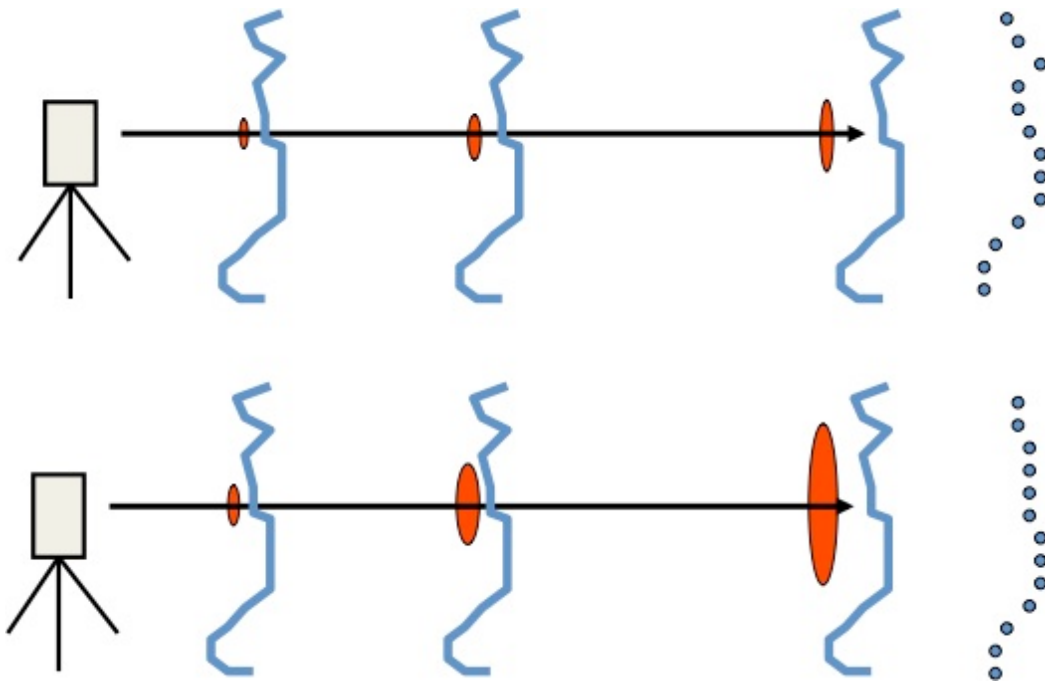


Figure 4. The lasers in this example are both hitting the same target(s) traveling the same distance, but the top laser has a smaller beam divergence resulting in smaller spot sizes that allow for increased resolution and a finer detailed image (blue dots) of the irregularities of the rock outcrop. The bottom example produces a lower resolution, less detailed and averaged (blurry) image (Image courtesy of Cyber Mapping Lab of UT-Dallas).

Spot Spacing

A second important scan parameter that will affect the resolution before you start scanning is **spot spacing** (aka. angular resolution). A function of the stepping angle (increments for each set of pulses) of the laser and range to the target, spot spacing can be reduced or increased by adjusting the stepping angle (aka. angular step) in the scanning software. This will result in increasing or reducing the resolution respectively and the corresponding density of spots or points collected by the scanner (Figure 5). Increasing distance increases spot spacing; so angular step would need to be reduced to obtain a high-resolution scan at long ranges. Angular step can

be adjusted for both the vertical and the horizontal, as the Riegl VZ400 scanner has a scanning range of 360° in the horizontal and 100° in the vertical (60° up/ 40° down). TLS point clouds are very dense, with the scanner collecting 10's of 1000's to 100's of 1000's of points/sec. Depending on your project resolution requirements and the amount of data you want to compile and analyze, angular step can be adjusted accordingly. Extremely dense point clouds require more storage space and processing power on computers, and take a longer time to scan. This will impact the time spent out in the field collecting data and also how long data processing will take, so the should be factored into the project design.

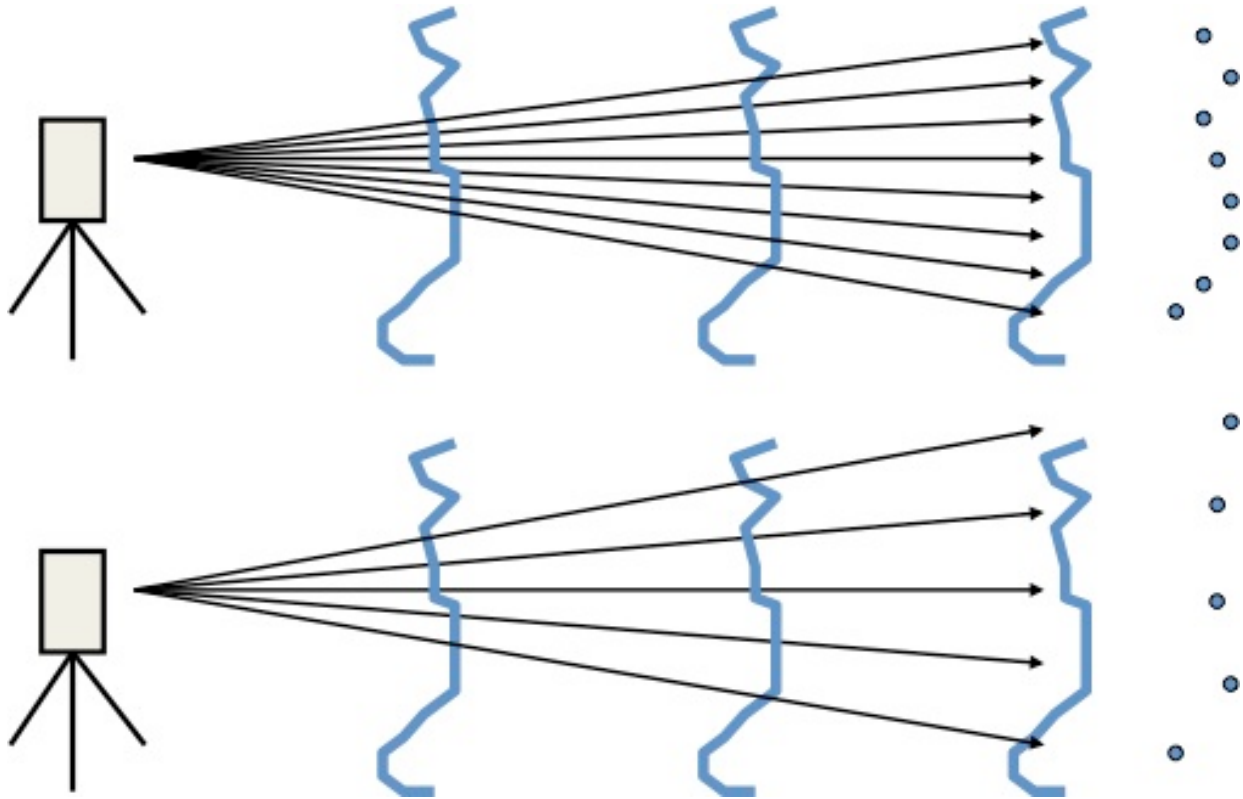


Figure 5. As the angular step and distance of the scanner from its target is increased, the result will be a greater spacing between spots as is shown in these two examples. The lower example has a greater step angle, resulting in increased point spacing and a less detailed, lower resolution image (Image courtesy of Cyber Mapping Lab of UT-Dallas).

Scan Partitioning

In reality most large area topographic scans will contain varying ranges within the target scan that can affect point density and resolution. If the same resolution and point density is desired over a wide range of distances at one scan location (say, a river channel and adjacent terraces and hill slope), the scan will need to be broken up into several scans at determined mean distance intervals. Then, the stepping angle will need to be adjusted as a function of that mean distance to achieve the same resolution and point density. If this is not done, the extremes of the scan distances, “r1” and “r3” in Figure 6, will either be too dense with points or too sparse. Since the

TLS scans in the vertical and horizontal orientations, vertical and horizontal partitioning needs to be taken into consideration during a complex project. Remember, *beam divergence* still plays a roll in desired resolution and will determine the location of scan positions as well.

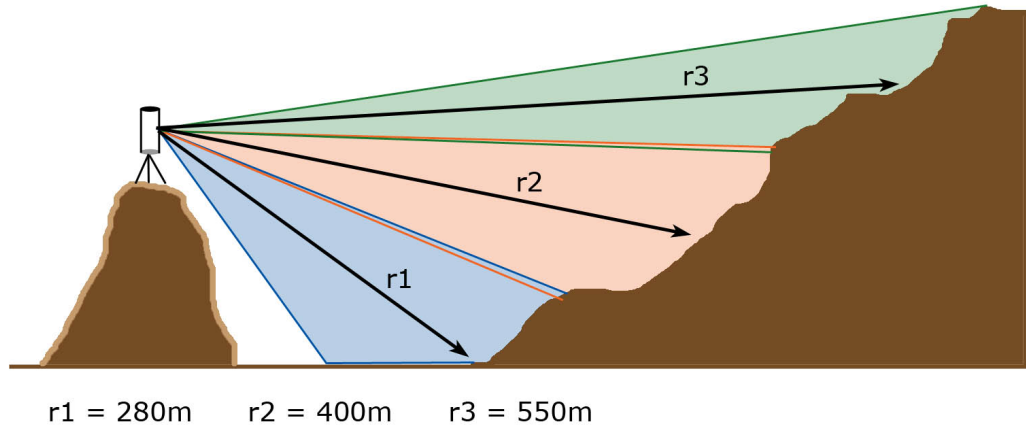
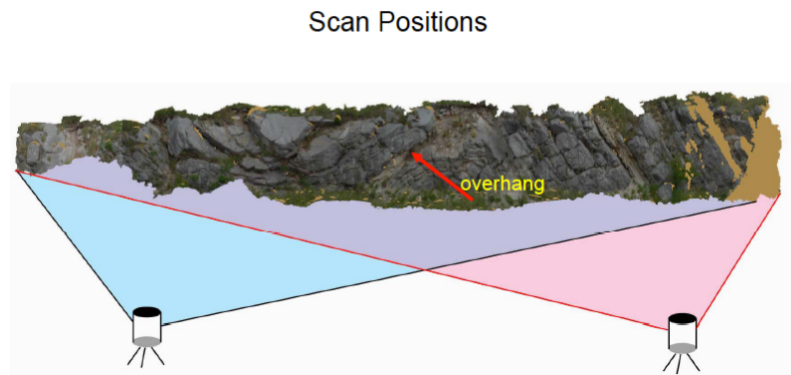


Figure 6. Scan partitioning in the vertical field of view showing sectioned ranges for scans using different stepping angles to achieve the same spot spacing (resolution) and spot density (point density) in each of the three sections. For this example, if the same stepping angle used for “r3” was used for “r1”, then the spot density for “r1” could be 10-15x that of “r3”, requiring an extraordinary amount of time to scan and eating up memory on the computer (Image courtesy of Cyber Mapping Lab of UT-Dallas).

3. Set up and Work Flow

- 1) Scan Position: The first step is selecting effective scan positions that will maximize coverage of the target site to minimize occluded views that will lead to blank spots in the point cloud. A good practice is to pick at least two oblique locations to the target for scanning (Figure 7), but having a third is best, so you’ll have left, middle and right viewpoints providing strong angles of incidence with targets. If you want a true 3D model of a feature (e.g., a building), then you must move the scanner around the structure to capture all sides to capture all sides.

Figure 7. Multiple scan positions are needed to obtain the maximum coverage of a feature, through overlapping illumination of the target. This minimizes the amount of un-illuminated area and thus un-measured features. Having a third scan in the middle would help with this issue, but may not always be necessary (UTD CyberMapping Lab).



- 2) Control Target (tie point) Set up: Control targets are essential to register multiple scans, as they are static markers that allow for easy merging of multiple scans to produce a 3-dimensional image. The control targets should not be placed in a linear fashion or bunched up, but should be as evenly dispersed around the entire scan site as much as possible (both horizontally and vertically) (Figure 8). A bare minimum of three control targets can be deployed, but it is highly recommended to have at least five to account for uncontrollable sight-line blockages from complex topography and other problems such as dense vegetation. The more targets in common between adjacent scans, the better the accuracy of the final point cloud data product (again, a minimum of 3 - 5). Targets should not move during scanning, so secure placement is vital. Movement will introduce error and may possibly be severe enough that you will have to restart the entire project, **do not accidentally bump into or move targets.** Steps 1 and 2 are the most important for a successful scan and should be planned out before scanning (Figure 9).

Figure 8. Examples of good to bad control target geometries represented by the vectors radiating from the center point (scanner) to control targets (out-lying

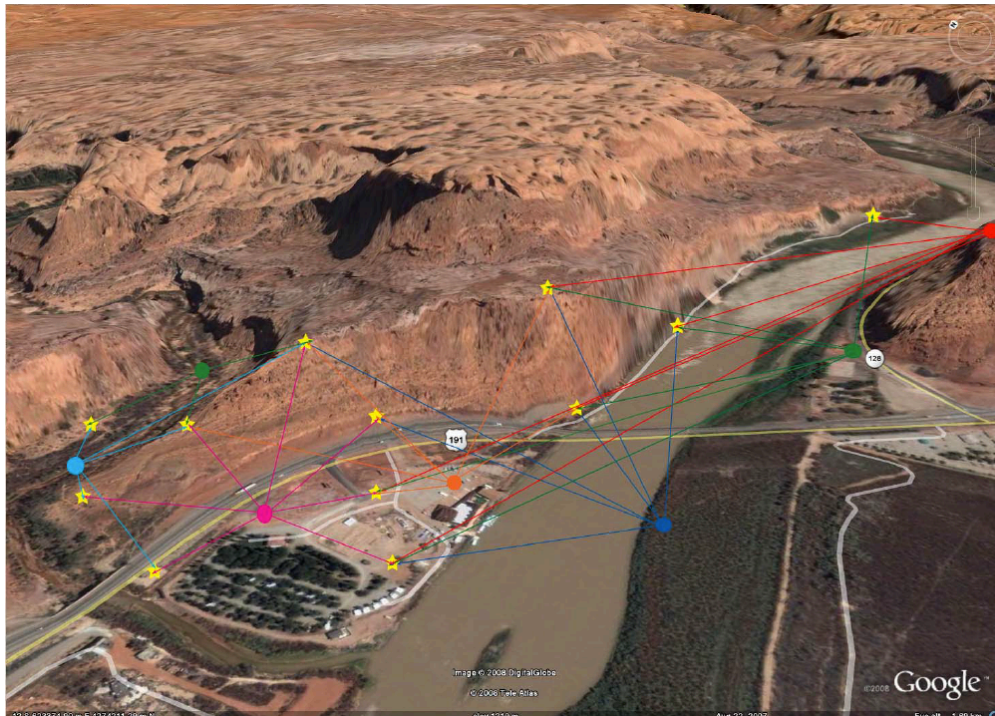
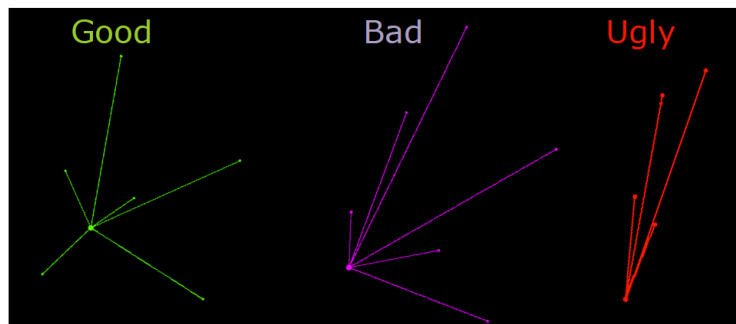


Figure 9. Above is a Google Earth image of a site near Moab, UT and a great example of good scanner placement and control target set up. Six scan positions, represented by the colored circles, were utilized to capture the topography. The stars represent the control targets. Notice how each scan position contains several targets in common with each other to allow for proper registration of the multiple scans.

- 3) GPS Set up: If georeferencing scans is required by the project, the two most common GPS techniques used in TLS are Static (long occupation) and Real Time Kinematic (RTK) GPS (short occupation). Which one is used depends on the specific needs of the project and equipment availability. Both are forms of differential GPS requiring a base station within range and clear sky views for accurate and precise measurements.
- a. Static GPS: Static GPS surveying is the most accurate method. It involves at least 3 antenna receivers configured in a triangular geometry on top of specific control targets within the project location. Long occupations of up to 6-8 hrs are required to obtain an optimal position solution of centimeter to sub-centimeter resolution (the longer the better). A base station, placed on site (collecting data for the day/week/month duration of project) or an established one (ideally < 20km away), with known coordinates is also required to post process and differentially correct the GPS data later in the lab.
 - b. RTK GPS: **Real Time Kinematic** GPS is useful as it is quick, providing real-time position solutions and potentially requires less equipment to carry to the field site. It involves a base station set up on site at the beginning of the project that collects data through out the day, this base then provides “real-time” correction data via a radio link to a receiver called a “rover unit”. Therefore, occupation times can be seconds to minutes with no need for post processing. Position solutions are on the centimeter scale ranging on average between 2-5cm. A disadvantage for RTK vs. Static is the need for a clear line of site for radio communication between the base station and the rover, which can be limited by dense vegetation and complex topography.
- 4) Parameters: As discussed above, it is important to consider several parameters such as beam divergence, spot spacing, and scan partitioning before beginning your scan. Other parameters to be aware of are angle of incidence, which is related to the angle of the beam that intersects the target. You want to make sure you have strong angles, maintaining maximum coverage and overlap between scans. Environmental conditions will play a factor such as the position of the sun relative to the scanner. The albedo (reflectance) of the scanned material, visibility limitations due to clouds, dust, topographic relief, and vegetation also affect the quality of return data.
- 5) Collecting Data: After the control target and GPS framework has been established to coincide with pre-determined scan positions, data collection can begin. Start with a panorama scan of the area accompanied by digital photos. Next fine scan all the control targets as part of the scan registering process. Once that is complete, fine scan an area of interest that is the focus of the project (if necessary). After the first scan is complete, move to the next scan position. For each successive scan position repeat above basic steps then register (tie together) adjacent scans by finding “corresponding points”. Check the accuracies of scan registration in the field so there are no surprises when you are miles away from your site back in the lab. GPS data can be imported into the scan project following scanning. Once all scanning is complete make sure you: **Save all data!**

4. TLS Coordinate Systems

Data collected from a terrestrial laser scanner can be tied to one of three coordinate systems (Figure 10):

- 1) *Scanner Own Coordinate System (SOCS)*: the first set of coordinates established for an individual scan related to the scanner's position.
- 2) *Project Coordinate System (PRCS)*: multiple scans registered (tied) together using stationary control targets (tie points) dispersed around the project area.
- 3) *Global Coordinate System (GLCS)*: independent GPS coordinates are then imported and registered to the point cloud to create a georeferenced final product.

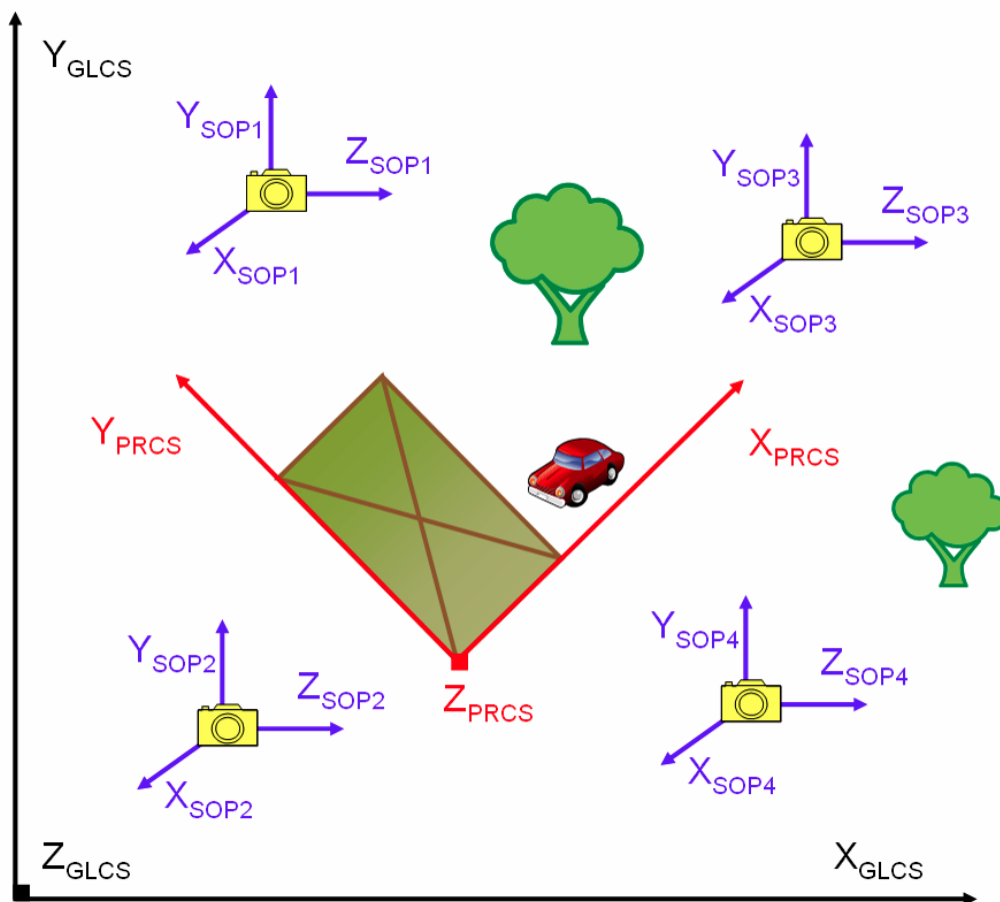


Figure 10. This diagram is a general schematic of the 3 coordinate systems and how they relate to one another. The four scan coordinates (SOP_{1-4}) involving a scan of the car for example, are then registered together to create the overall project coordinates (PRCS). Until GPS data is applied to the point cloud, the project is floating in space. After the GPS data is applied, GLCS is created and your point cloud is now georeferenced. SOP (Scanner Own Position) is another version of SOCS.

5. Products

After a day in the field collecting TLS data, you will be able to produce highly accurate 3-dimensional, georeferenced point clouds of your field site and all specific targets involved that can be analyzed later in a lab. The digital photos that you took can also be merged with the point clouds to produce a 3-dimensional-photo-realistic point cloud. Below are some examples.

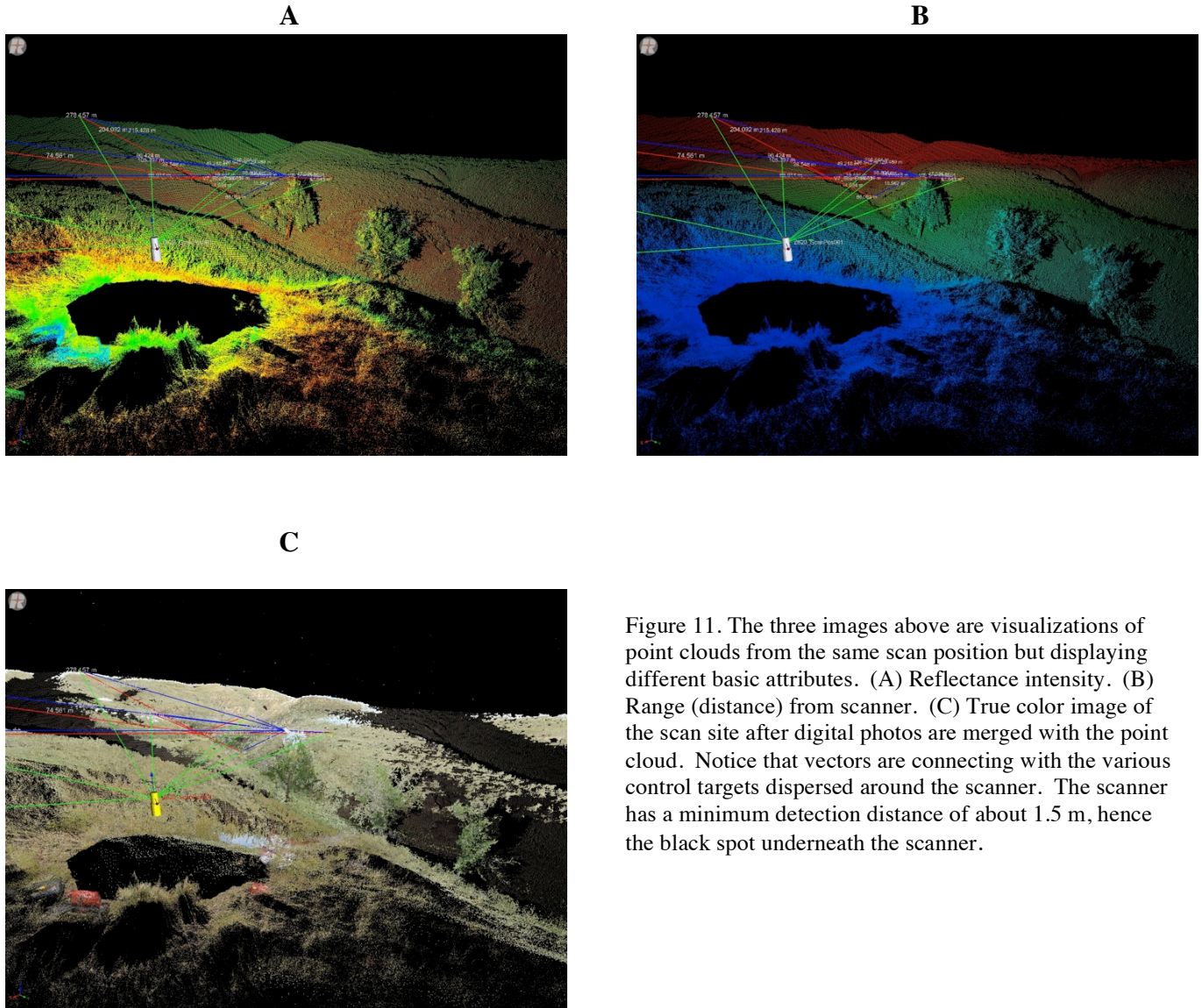


Figure 11. The three images above are visualizations of point clouds from the same scan position but displaying different basic attributes. (A) Reflectance intensity. (B) Range (distance) from scanner. (C) True color image of the scan site after digital photos are merged with the point cloud. Notice that vectors are connecting with the various control targets dispersed around the scanner. The scanner has a minimum detection distance of about 1.5 m, hence the black spot underneath the scanner.

In addition to looking at entire data sets, TLS post-processing specializes in selecting portions of a data set that may be isolated to provide a specific view that allows for specific measurement, or, to create a specific display of a feature for analysis. Figure 12 provides an example of this from the University of Colorado's, Greg Tucker.

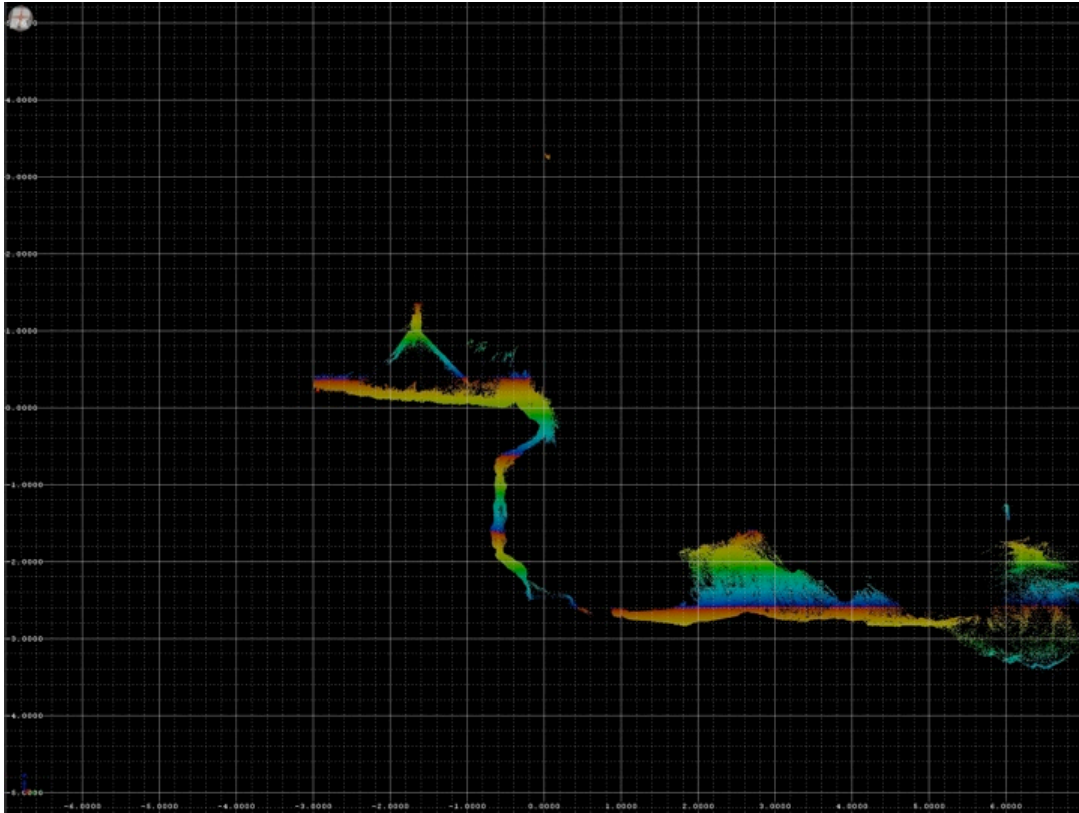


Figure 12. This is an image created in RiScan Pro of a cross section of a hillside from Greg Tucker's research studying erosion and morphologic changes of a hillside through time. Using RiScan Pro, Greg Tucker is able to choose a specific section of an entire point cloud data set and rotate the section into a cross sectional profile. This allows the researcher to analyze and take measurements on morphologic changes to the landscape.

Fault Mapping



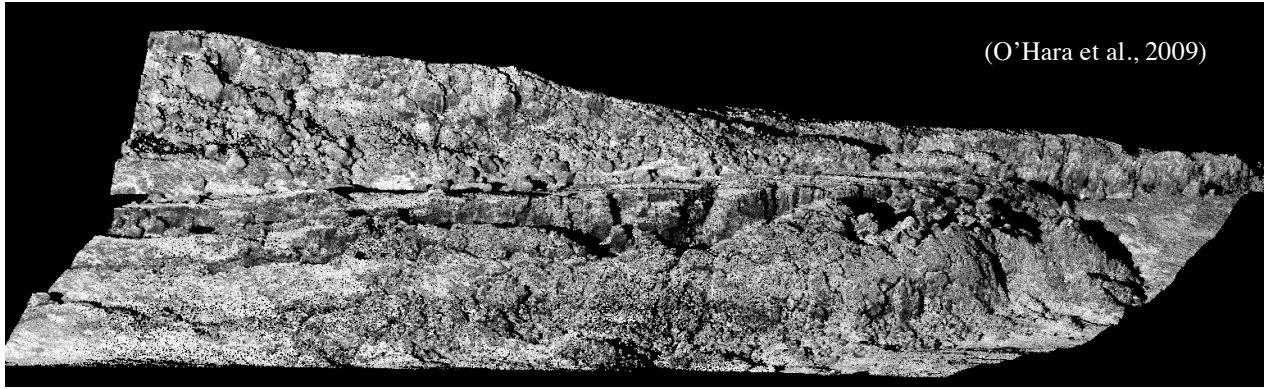
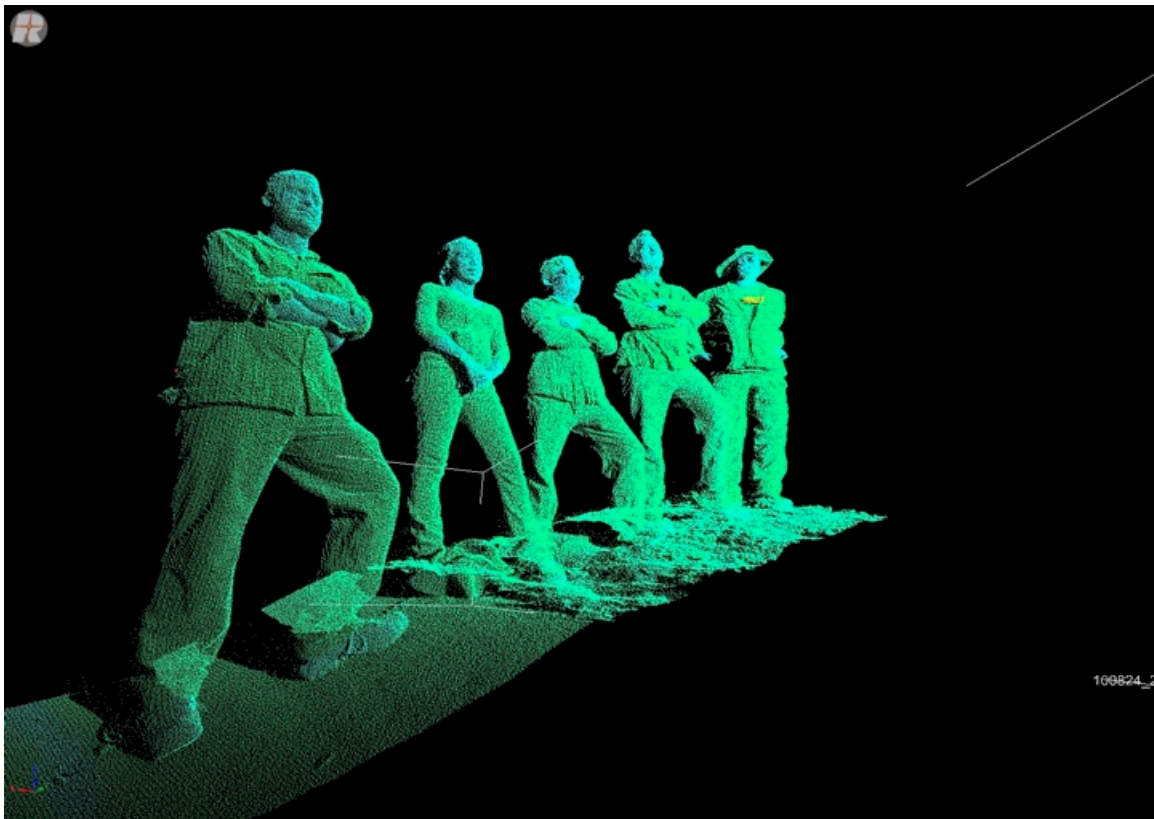


Figure 13. Masters student Caroline O'Hara of Penn State University, along side advisor Peter La Femina, was conducting part of a long-term geologic deformation study utilizing TLS equipment supplied through UNAVCO. The purpose was to investigate the formation and geometry of normal and strike-slip faults across the plate boundary in Iceland. The top photo is the digital photo of her study site with scanner in the bottom right, followed by the final point cloud image below.



After a long serious day in the field TLS can be fun, enjoy!

Appendix A

EXAMPLE PROBLEM #1

Beam Divergence Formula

$$D_f = (BD * d) + D_i$$

D_f = Final beam diameter

BD = Beam divergence

d = distance traveled

D_i = Initial beam diameter

Spot size of the beam can be calculated with a simple formula and can be helpful when determining where to locate your scanner, depending on the resolution of data your project requires. Using a Riegl VZ-400 scanner, with a beam divergence of 0.35 millirads and an initial beam diameter of 0.007 m, calculate the final beam diameter at various distances. Use the above given formula and remember to convert millirads to radians.

Beam Divergence (radians)	Distance traveled (m)	Initial Beam Diameter (m)	Final Beam Diameter (m)
	10		
	50		
	75		
	100		
	200		
	350		
	500		
	800*		

*Beyond the range of a VZ-400

EXAMPLE PROBLEM #2

Now we want to calculate the spot spacing (aka. angular resolution) of a scan with varying stepping angles to get an idea of changes in spot (aka. point) density. We will keep it simple by using a constant range, but remember that range of targets can and will change while scanning. Angular resolution will need to be figured for both the vertical and the horizontal scanning process. The formula for calculating spot spacing is as follows:

Angular Resolution Formula

$$SS = SA * R$$

SS = spot spacing

SA = stepping angle (radians)

R = range

Based on Riegl TLS specifications, we will use a minimum stepping angle of 0.0024° and a maximum of 0.288° for the vertical orientation. Given the various stepping angles, calculate the spot spacing of each scan with a target at 280 meters. You will need to convert degrees to radians for the formula to work. Similarly, the horizontal can be calculated using the Riegl specification range with the same minimum angle of 0.0024°, but with a larger maximum angle of 0.5°. Notice the effect changes in stepping angle has on resolution and think about how to approach a project with targets at varying ranges, to maximize time efficiency and quality of data collection. It is important to note that the smaller the stepping angle, the more data you'll collect, providing a higher resolution scan, but taking more time in the field, and yielding considerably more data that will need to be processed later.

Stepping Angle (Degrees)	Stepping Angle (Radians)	Range (m)	Spot Spacing (m)
0.0024°		280	
0.005°		280	
0.01°		280	
0.05°		280	
0.1°		280	
0.15°		280	
0.2°		280	
0.288° (vert. max)		280	
0.394° (horizontal)		280	
0.5° (horizontal max)		280	

Scan Resolution Parameter Worksheet

Use this worksheet to determine the optimal and realistic scan times based on desired scan resolution.

Beam diameter at instrument: _____m (ReiglZ620=0.014; ReiglVZ400=0.007)

Beam divergence: _____radians (ReiglZ620=0.00015; ReiglVZ400=0.0003)

Constants for a given scanner

Table 1. Scan spacing

Scan site and scan number	Distance to target (m)	Spot size (m) [Dist*Diverg]+ Diameter	Angle of Incidence to target	Ellipse max diameter (m) Spotsize/sine[Angle]	Optimal measurement spacing (m)	Actual spacing used (m)	Comments
	Min						
	Max						
	Mean						
	Min						
	Max						
	Mean						
	Min						
	Max						
	Mean						
	Min						
	Max						
	Mean						

Table 2. Scan time

Scan site and scan number	Horiz scan dist (m)	Optimal # horiz measurements	Vert scan dist (m)	Optimal # vert measurements	Time for optimal scan [#horiz * #vert * time/measurement]	Time for actual scan

Sketch Map of Study Area

In science, it is always important to take down as much information as possible to allow for repeatability of your research as well as a proof to back up what you have done. Sketch maps have been a staple in field geology since the beginning and are a great reference to remind yourself of field conditions. It is no different for TLS scanning and allows you to document the set up of your scan site that photos may not be able to entirely capture. Plus you can make those intangible notes on a sketch map then and there that may not be possible with a photo. When processing TLS data back in the lab, occasionally months after it was collected, a detailed sketch map can be invaluable for fixing problems with data and for reacquainting yourself with the field site.

Use your field notebooks and include:

1. Scanner Locations
 - a) Label 1st, 2nd, 3rd positions, etc., however many scans the project needs.
2. Control Target/Reflector Locations
 - a) Reflector type and shape
3. GPS locations and which control target they coincide with.
4. Distinguishable geologic, hydrologic, biologic, or man-made features (rock outcrop, stream, big tree, building, ect.)
5. Cardinal Directions clearly labeled.
6. The more details, the better. You want it to make sense if you need to revisit the site for a repeat scan another day.

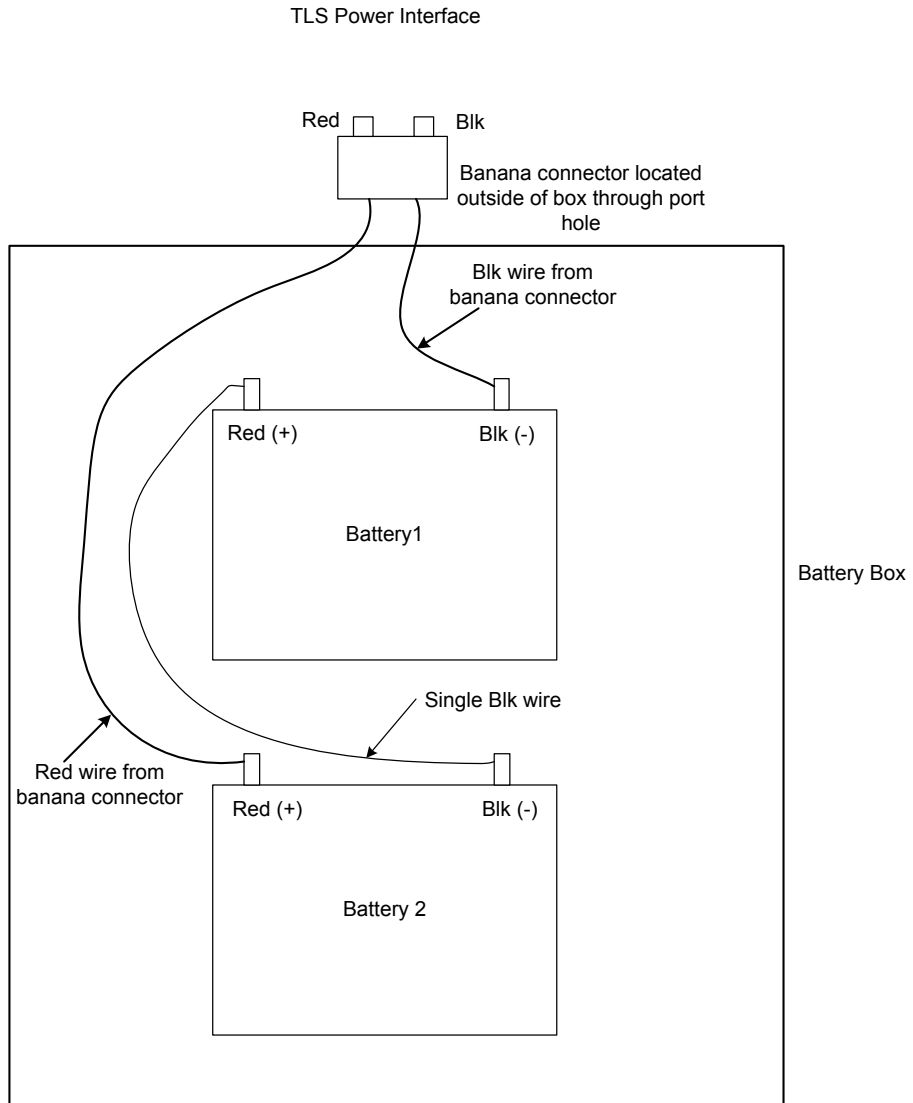
Riegl VZ-400 Equipment List

Principal Investigator: _____

Project Site: _____ Date: _____

Items	Quantity	Notes

Appendix B
Schematic of a Battery
Connected in Series



Appendix C
Riegl Manufacturer Specifications

Listed on the following pages are the manufacturer specifications for the VZ-400 from Riegl.

These were obtained from: www.riegl.com

RIEGL VZ[®]-400

- **very high speed data acquisition**
- **wide field-of-view, controllable while scanning**
- **high-accuracy, high-precision ranging based on echo digitization and online waveform processing**
- **multiple target capability**
- **superior measurement capability in adverse atmospheric conditions**
- **high-precision mounting pads for optional digital camera**
- **integrated inclination sensors and laser plummet**
- **integrated GPS receiver with antenna**
- **various interfaces (LAN, WLAN, USB 2.0)**
- **internal data storage capability**

The V-Line[®] 3D Terrestrial Laser Scanner **RIEGL VZ-400** provides high speed, non-contact data acquisition using a narrow infrared laser beam and a fast scanning mechanism. High-accuracy laser ranging is based upon **RIEGL's** unique echo digitization and online waveform processing, which allows achieving superior measurement capability even under adverse atmospheric conditions and the evaluation of multiple target echoes.

The line scanning mechanism is based upon a fast rotating multi-facet polygonal mirror, which provides fully linear, unidirectional and parallel scan lines. The **RIEGL VZ-400** is a very compact and lightweight surveying instrument, mountable in any orientation and even under limited space conditions.

Modes of Operation:

- stand-alone data acquisition without the need of a notebook, basic configuration and commanding via the built-in user interface
- remote operation via RiSCAN PRO on a notebook, connected either via LAN interface or integrated WLAN
- well-documented command interface for smooth integration into mobile laser scanning systems
- Interfacing to post processing software

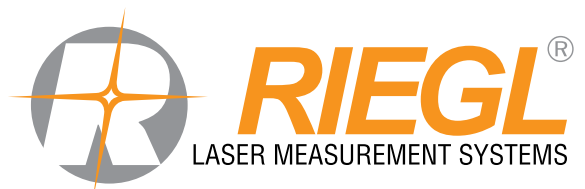
User Interfaces:

- integrated Human-Machine Interface (HMI) for stand-alone operation without computer
- high-resolution 3,5" TFT color display, 320 x 240 pixel, scratch resistant cover glass with anti-reflection coating and multi-lingual menu
- water and dirt resistant key pad with large buttons for instrument control
- loudspeaker for audible signaling of messages by voice

Typical applications include

- **As-Built Surveying**
- **Architecture & Facade Measurement**
- **Archaeology & Cultural Heritage Documentation**
- **City Modelling**
- **Tunnel Surveying**
- **Civil Engineering**

visit our website
www.riegl.com





Scanner Hardware **RIEGL VZ-400**

allows high-speed, high resolution and accurate 3D measurements

- Range up to 600 m @ Laser Class 1
- Repeatability 3 mm
- Measurement rate up to 122 000 measurements/sec
- Field of View up to 100° x 360°
- LAN/WLAN data interface, easily allowing wireless data transmission
- Operated by any standard PC or Notebook or cable less
- Fully portable, rugged & robust

Software **RiSCAN PRO**

RIEGL software package for scanner operation and data processing

- Data archiving using a well-documented tree structure in XML file format
- Object VIEW / INSPECTOR for intelligent data viewing and feature extraction
- Straightforward Global Registration
- Interfacing to Post Processing Software



Digital Camera (optional)

provides high resolution calibrated color images

- NIKON D800, D600, D700
 - D800: 36.3 Megapixel, Nikon FX format
 - D600: 24.3 Megapixel, Nikon FX format
 - D700: 12.1 Megapixel, Nikon FX format
 - USB interface

Mounting device with digital camera can be easily fixed by means of two knurled head screws. Precise position and orientation is provided by three supporting points. Power supply and USB 2.0 interface is provided by the scanner directly.

The combination of the key components **Scanner**, **Software** and **Camera** results in

- Automatic generation of high resolution textured meshes
- Photorealistic 3D reconstruction
- Exact identification of details
- Online position and distance measurements
- Online setting of any virtual point of view

Global Scan Position Registration



Stand-alone Registration

- integrated GPS receiver (L1)
- integrated biaxial inclination sensors (tilt range $\pm 10^\circ$, accuracy typ. $\pm 0.008^\circ$)
- integrated compass, accuracy typ. 1°
(one sigma value, available for vertical scanner setup position)
- RiSCAN PRO Processing and Multistation Adjustment Module (MSA)

Registration via control points

- precise and fast fine scanning of retro-reflectors
- RiSCAN PRO Processing

Totalstation-like-Registration

- setup above well known point (integrated laser plummet)
- integrated inclination sensors
- precise fine scanning of well known remote target (reflector)
- RiSCAN PRO Processing Backsighting function



WLAN antenna

Carrying handles

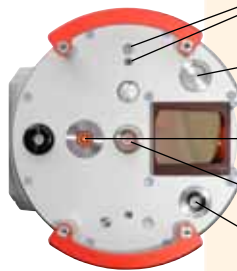
High-resolution color TFT display

Key pad for instrument control

Connectors for power supply and LAN interface 10/100 MBit/sec, power off/on button

Communication and Interfaces

- LAN port 10/100/1000 MBit/sec within rotating head
- LAN port 10/100 MBit/sec within base
- integrated WLAN interface with rod antenna
- USB 2.0 for external storage devices (USB flash drives, external HDD)
- USB 2.0 for connecting the optional digital camera
- connector for GPS antenna
- two ports for external power supply
- connector for external GPS synchronization pulse (1PPS)
- connector for external GNSS receiver



Mounting points (3x) and mounting threads inserts (2x) for digital camera

Connector for external GNSS receiver (optional)

USB and DC power connector for digital camera

Connector for GPS antenna (internal receiver)

Connector for WLAN antenna

Scan Data Storage

- internal 32 GByte flash memory (1 GByte reserved for the operating system)
- external storage devices (USB flash drives or external hard drives) via USB 2.0 interface



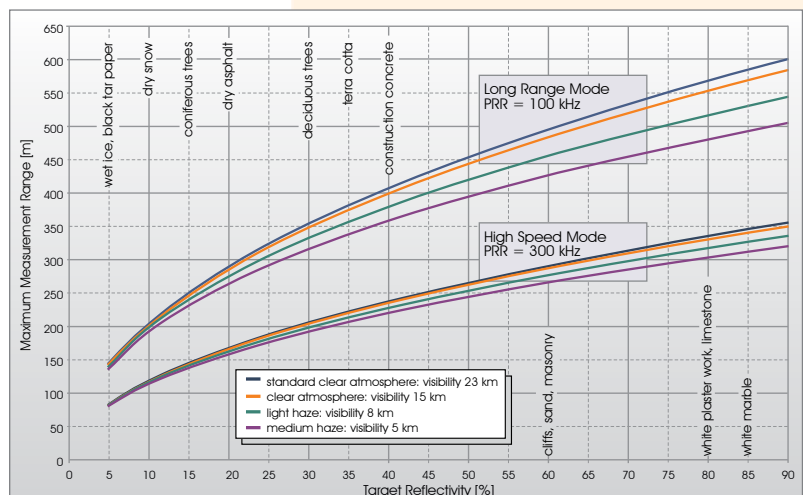
USB 2.0 slot for external memory devices

LAN 10/100/1000 MBit/sec, for rapid download of scan data

Max. Measurement Range

The following conditions are assumed:

Flat target larger than footprint of laser beam, perpendicular angle of incidence, average brightness



Technical Data RIEGL VZ[®]-400

Laser Product Classification

Class 1 Laser Product according to IEC60825-1:2007

The following clause applies for instruments delivered into the United States:
Complies with 21 CFR 1040.10 and 1040.11 except for deviations pursuant
to Laser Notice No. 50, dated June 24, 2007.



Range Performance ¹⁾

	Long Range Mode	High Speed Mode
Pulse repetition rate PRR (peak) ²⁾	100 kHz	300 kHz
Effective Measurement Rate ²⁾	42 000 meas./sec	122 000 meas./sec
Max. Measurement Range ³⁾		
natural targets $\rho \geq 90\%$	600 m	350 m
natural targets $\rho \geq 20\%$	280 m	160 m
Max. Number of Targets per Pulse	practically unlimited ⁴⁾	
Accuracy ^{5) 7)}	5 mm	
Precision ^{6) 7)}	3 mm	

Minimum Range

1.5 m

Laser Wavelength

near infrared

Laser Beam Divergence ⁸⁾

0.35 mrad

1) With online waveform processing.

2) Rounded values.

3) Typical values for average conditions. Maximum range is specified for flat targets with size in excess of the laser beam diameter, perpendicular angle of incidence, and for atmospheric visibility of 23 km. In bright sunlight, the max. range is shorter than under overcast sky.

4) Details on request.

5) Accuracy is the degree of conformity of a measured quantity to its actual (true) value.

6) Precision, also called reproducibility or repeatability, is the degree to which further measurements show the same result.

7) One sigma @ 100 m range under RIEGL test conditions.

8) Measured at the 1/e² points. 0.35 mrad corresponds to an increase of 35 mm of beam diameter per 100 m distance.

Scanner Performance

Scan Angle Range

Vertical (Line) Scan

total 100° (+60° / -40°)

Scanning Mechanism

rotating multi-facet mirror

Scan Speed

3 lines/sec to 120 lines/sec

Angular Step Width $\Delta \vartheta$ (vertical), $\Delta \phi$ (horizontal)

0.0024° ≤ $\Delta \vartheta$ ≤ 0.288° ⁹⁾

between consecutive laser shots

Horizontal (Frame) Scan

max. 360°

rotating head

0°/sec to 60°/sec ¹⁰⁾

0.0024° ≤ $\Delta \phi$ ≤ 0.5° ⁹⁾

between consecutive scan lines

Angle Measurement Resolution

better 0.0005° (1.8 arcsec)

better 0.0005° (1.8 arcsec)

Inclination Sensors

integrated, for vertical scanner setup position, details see page 2

GPS Receiver

integrated, L1, with antenna

Compass

optional, for vertical scanner setup position, details see page 2

Internal Sync Timer

integrated, for real-time synchronized time stamping of scan data

Scan Sync (optional)

scanner rotation synchronization

9) Selectable.

10) Frame scan can be disabled, providing 2D scanner operation.

General Technical Data

Power Supply Input Voltage

11 - 32 V DC

Power Consumption

typ. 65 W (max. 80 W)

External Power Supply

up to three independent external power sources can be connected for uninterrupted operation

Main Dimensions

Ø 180 x 308 mm (diameter x length)

Weight

approx. 9.6 kg

Humidity

max. 80 % non condensing @ +31°C

Protection Class

IP64, dust- and splash-proof

Temperature Range

-10°C up to +50°C

Storage

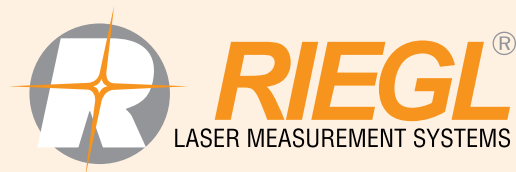
0°C up to +40°C: standard operation

Operation

-20°C: continuous scanning operation if instrument is powered on while internal temperature is at or above 0°C and still air

Low Temperature Operation

-40°C: scanning operation for about 20 minutes if instrument is powered on while internal temperature is at or above 15°C and still air



RIEGL Laser Measurement Systems GmbH, 3580 Horn, Austria
Tel.: +43-2982-4211, Fax: +43-2982-4210, E-mail: office@riegl.co.at

RIEGL USA Inc., Orlando, Florida 32819, USA
Tel.: +1-407-248-9927, Fax: +1-407-248-2636, E-mail: info@rieglusa.com

RIEGL Japan Ltd., Tokyo 1640013, Japan
Tel.: +81-3-3382-7340, Fax: +81-3-3382-5843, E-mail: info@riegl-japan.co.jp

www.riegl.com