Experiences & Insights from Introducing Terrestrial Laser Scanning (TLS) to Geology Field Courses

Christopher Crosby (UNAVCO), Bruce J. Douglas (Indiana University), Shawn Carr (UNAVCO), David Phillips (UNAVCO)

2013 Geological Society of America meeting
UNAVCO is a non-profit, membership governed consortium of universities that facilitates geoscience research and education using geodesy.

UNAVCO supports GPS, InSAR and LiDAR data acquisition, data archiving, equipment, development & testing, training.

UNAVCO operates and maintains the Plate Boundary Observatory network of instruments.

UNAVCO Education & Community Engagement works to promote a broader understanding of Earth science.
**Support Resources**
- Instrumentation (6 scanners)
- Field engineering
- Data processing
- Training
- Data archiving & dissemination

**Community Building**
- Workshops
- Inter-Agency collaborations & partnerships

**Education and Outreach**
- Training courses
- Field camps (~90 students in 2013)

---

### Scanners funded by the National Science Foundation

<table>
<thead>
<tr>
<th>Model</th>
<th>Laser Wavelength</th>
<th>Effective Range (max)</th>
<th>High-speed meas. rate</th>
<th>Precision</th>
<th>Accuracy</th>
<th>Field of View</th>
<th>Dimensions</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riegl VZ-1000</td>
<td>1550 nm (near IR)</td>
<td>1400 m</td>
<td>122,000 points/sec</td>
<td>5 mm</td>
<td>8 mm</td>
<td>100° x 360°</td>
<td>308mm x 180mm</td>
<td>9.8kg</td>
</tr>
<tr>
<td>Riegl VZ-400</td>
<td>1550 nm (near IR)</td>
<td>500 m</td>
<td>125,000 points/sec</td>
<td>5 mm</td>
<td>5 mm</td>
<td>100° x 360°</td>
<td>308mm x 180mm</td>
<td>9.8kg</td>
</tr>
<tr>
<td>Riegl Z620</td>
<td>1550 nm (near IR)</td>
<td>2000 m</td>
<td>11,000 points/sec</td>
<td>10 mm</td>
<td>10 mm</td>
<td>80° x 360°</td>
<td>463mm x 210mm</td>
<td>16kg</td>
</tr>
<tr>
<td>Leica C10</td>
<td>532 nm (green)</td>
<td>150 m</td>
<td>50,000 points/sec</td>
<td>4 mm</td>
<td>6 mm</td>
<td>270° x 360°</td>
<td>238mm x 395mm</td>
<td>13 kg</td>
</tr>
</tbody>
</table>
TLS field camp overview

- Initiated in 2009 at Indiana University Geologic Field Station as part of G429 course (geophysics elective).
- 2013 = Indiana, U. Houston, U. Michigan, UC Santa Cruz

Program:
- 5 day elective within or at end of camp program
- UNAVCO provides staff, TLS and GPS instruments. Faculty define exercises, study sites, curriculum.
- Emphasis = TLS technology, survey design, hands-on operation of equipment, and analysis of data.
• New scan site each day – increasing complexity and independence
• Emphasis placed on project metadata and documentation
  ➢ Instrument set up and data processing flow charts
  ➢ Equipment lists, site maps, and tables of scan parameters.

*Day 1: Harrison borrow pit site w/ fault. Scanner operation and offset measurements from TLS data*
TLS at IUGFS

Sand/mud ratios for an interval of the Kootenai Fm at Sandy Hollow. [Matt Booth, Whitman College]

Comparison of 1959 fault scarp observations with TLS scan data to evaluate scarp degradation. [Elizabeth Horne, Utah State]
Final Project: Independently design & propose a survey, deploy the instruments, collect and analyze data.

Scan network for IUGFS campus dataset
Morphologic dating of Star Valley faults

10 cm bare earth DEM
TLS field camp manual

- Developed for use at IUGFS
- TLS introduction
- TLS theory

Illustration of the impact of angular step size on scan resolution

Rule of thumb: scan at least 1/10th of the “wavelength” of the object you wish to image.
TLS field camp manual

- Exercises & worksheets

Using basic trigonometry, calculate various parameters to determine scan resolution, time, etc.

<table>
<thead>
<tr>
<th>Scan Resolution Parameter Worksheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use this worksheet to determine the optimal and realistic scan times based on desired scan resolution.</td>
</tr>
</tbody>
</table>

**Constants for a given scanner**

- Beam diameter at instrument: \[ \text{Beam diameter at instrument} = \frac{\text{Beam divergence}}{\text{Autofocus range}} \] (\text{ReiglZ620}=0.014; ReiglVZ400=0.007)
- Beam divergence: \( \text{Beam divergence} = \frac{\text{Beam divergence}}{\text{Autofocus range}} \) (ReiglZ620=0.00015; ReiglVZ400=0.0003)

### Table 1. Scan spacing

<table>
<thead>
<tr>
<th>Scan site and scan number</th>
<th>Distance to target (m)</th>
<th>Spot size (m) [Dist*Divergence]</th>
<th>Angle of Incidence to target</th>
<th>Ellipse max diameter (m)</th>
<th>Spotsize/sine[Angle]</th>
<th>Optimal measurement spacing (m)</th>
<th>Actual spacing used (m)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. Scan time

<table>
<thead>
<tr>
<th>Scan site and scan number</th>
<th>Horizon scan dist (m)</th>
<th>Optimal # horizon measurements</th>
<th>Vert scan dist (m)</th>
<th>Optimal # vert measurements</th>
<th>Time for optimal scan [#horizon * #vert * time/scan]</th>
<th>Time for actual scan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Group size & time management:**

- Small groups, downtime
- Keep students working on activities, outcrop orientations, site maps
- Interleave TLS w/ mapping?

**Practical Considerations I**

- Data processing takes time. Leave processing to UNAVCO staff(?). Advanced products not feasible overnight.
- TLS data analysis = less field time
Site selection:
• Compact sites with limited vegetation preferable.
• Ease of access important
• Outcrops, fault scarps, fluvial terrace risers & cut banks, recently burned slopes.

Computing Resources:
• Analysis of data requires computer access.
• Pre-install TLS and GIS software.
• Budget time to distribute data
• 90+ geoscience students introduced to TLS technology and data analysis in 2013.

• Cutting-edge technology is complimentary to traditional field geology program, esp. when project areas/topics are tied into course curriculum.

• Students engaged. Demand increasing. Sponsor enthusiastic.

• Planning is essential – site selection, time management, computing resources necessary to streamline operations and keep students engaged.
Thanks!

crosby@unavco.org  http://unavco.org/tls