TLS Parameters, Workflows and Field Methods

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GSA, September 23rd, 2016

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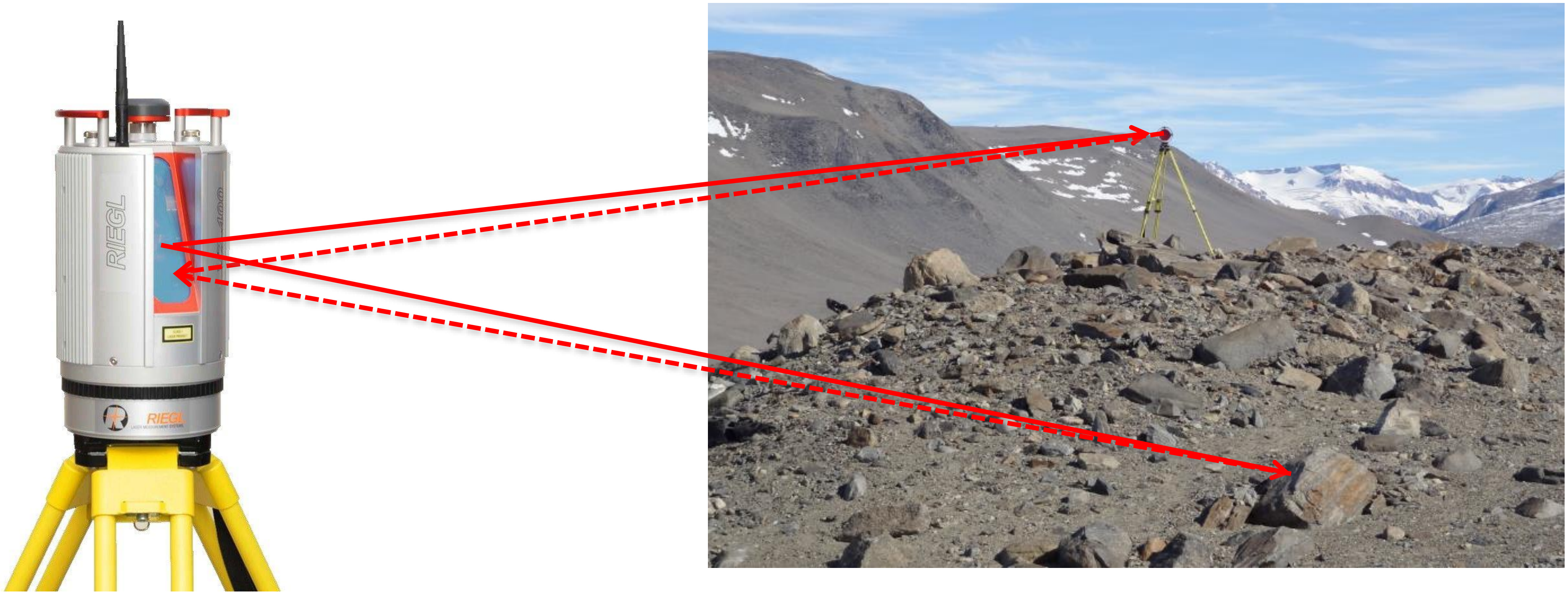
How a Lidar instrument works (Recap)

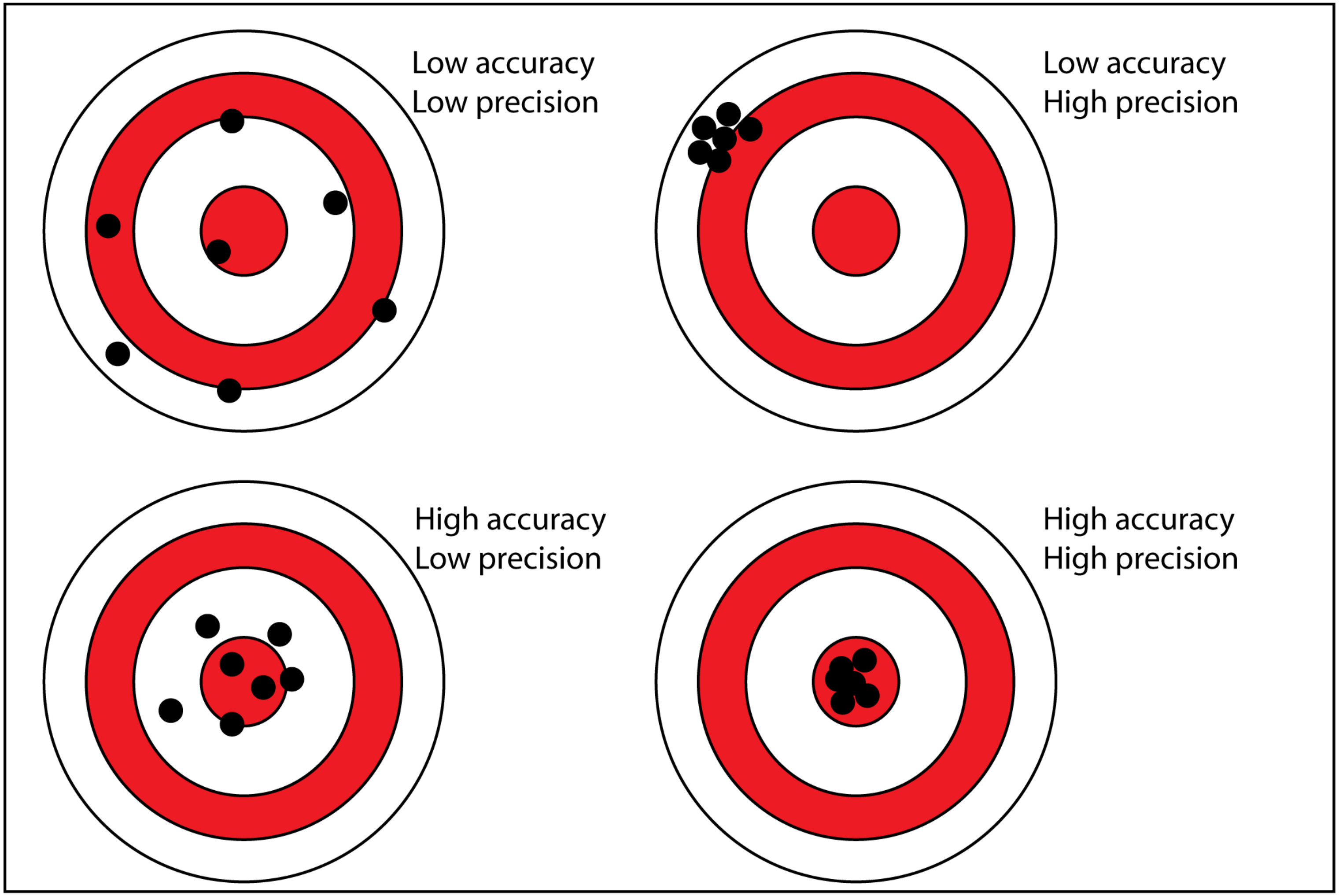
- **Transmits laser signals and measures the reflected light to create 3D point clouds.**
- **Wavelength typically in the near infrared (~1550nm) or green (532nm) spectrum**



TLS Instrument and Survey Parameters

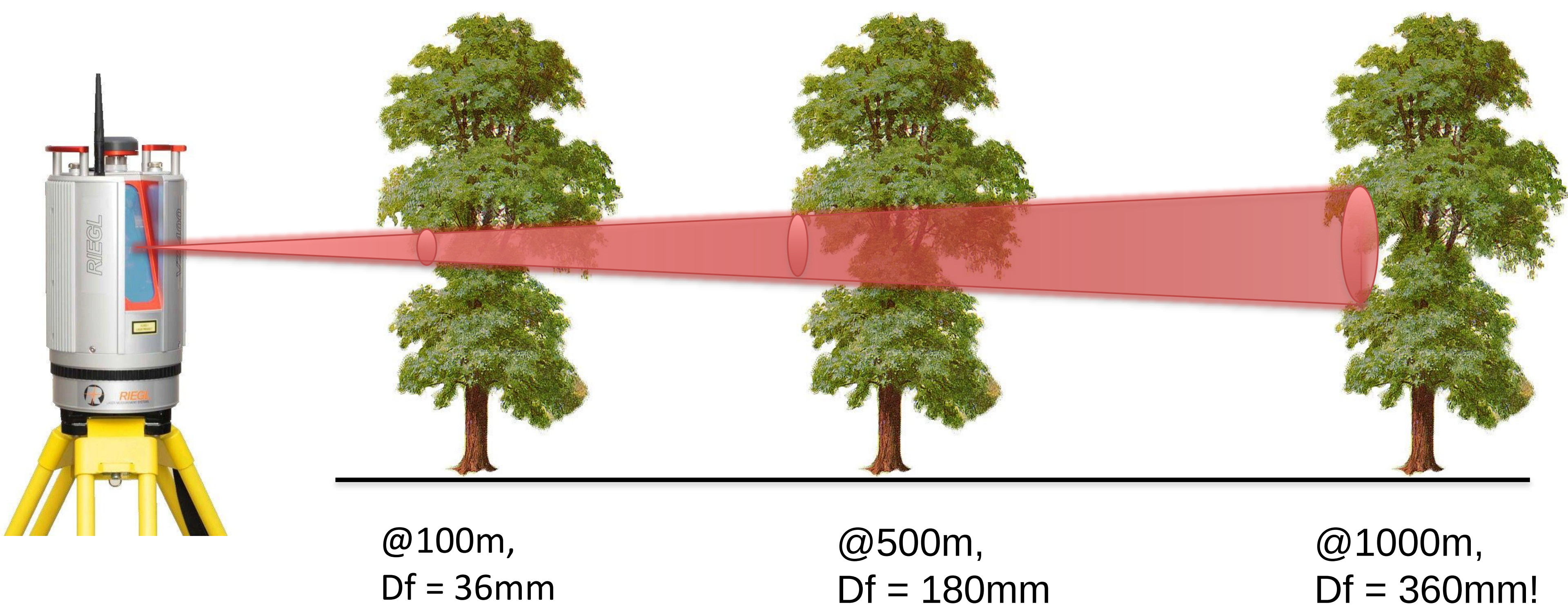
- Precision/Accuracy
- Spot size (range, divergence)
- Spot spacing (range, angular resolution)
- Spot density (range, angle, number of setups)
- Angle of incidence (spot shape, intensity, range)
- Edge effects
- Registration
- Targets
- First return, last return, “other”
- Shadows, Field of View
- Area of Interest

Accuracy vs. Precision



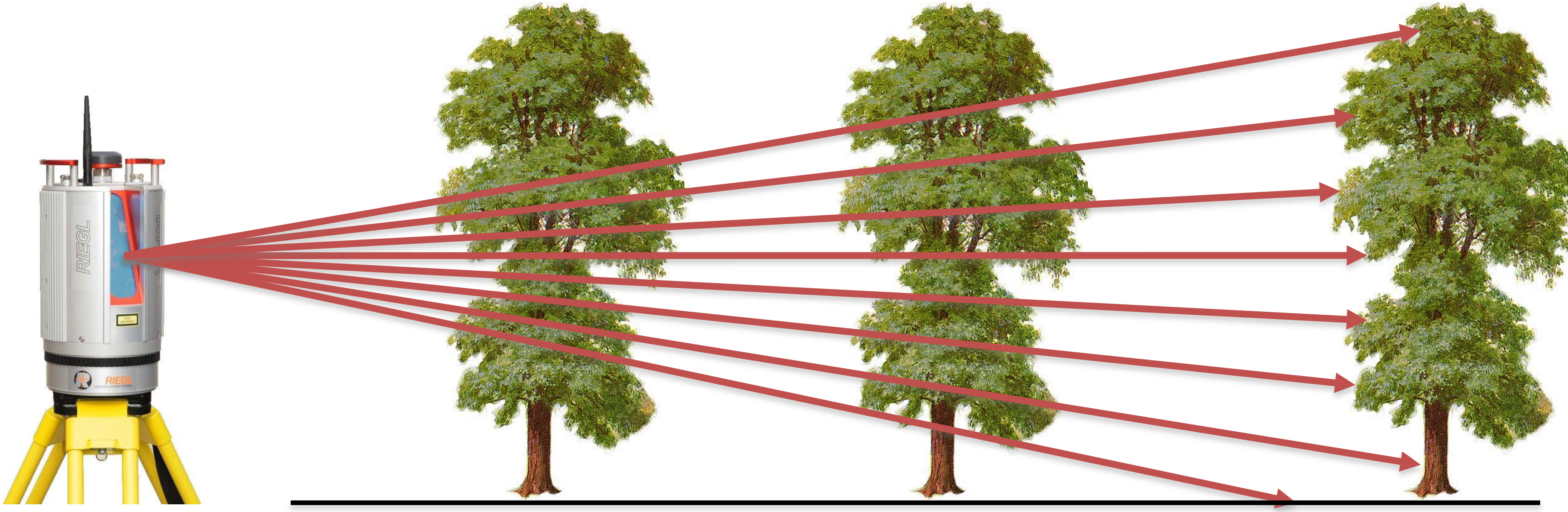
Beam Divergence

Df = (Divergence * d) + Di

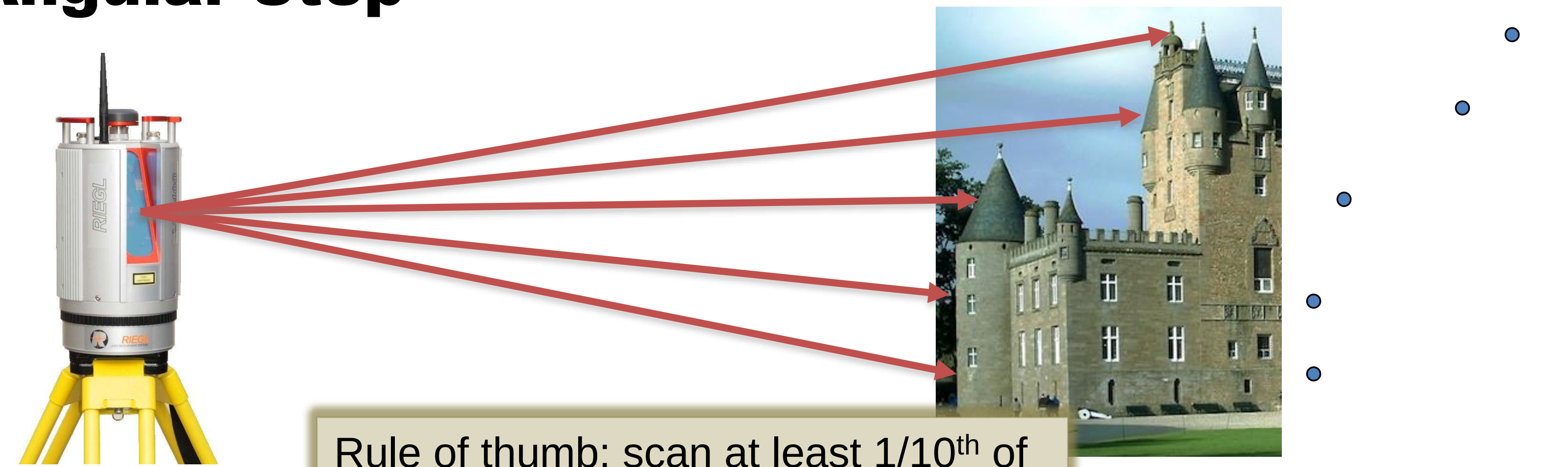


Angular Step

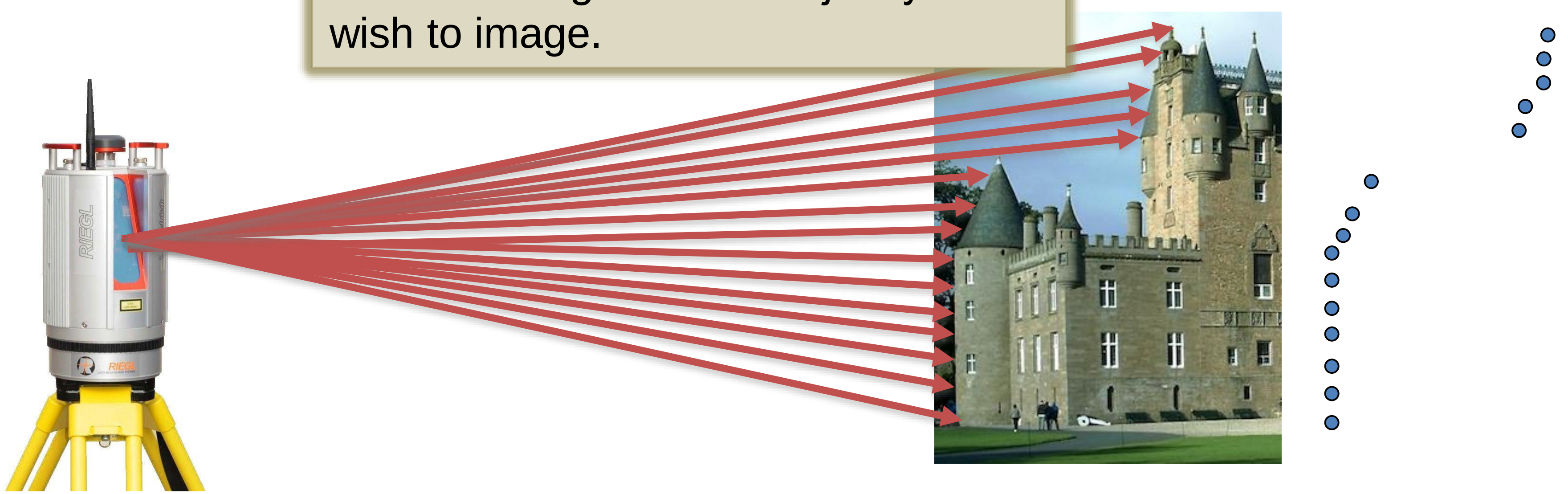
Spacing = d(m)*TAN(step)



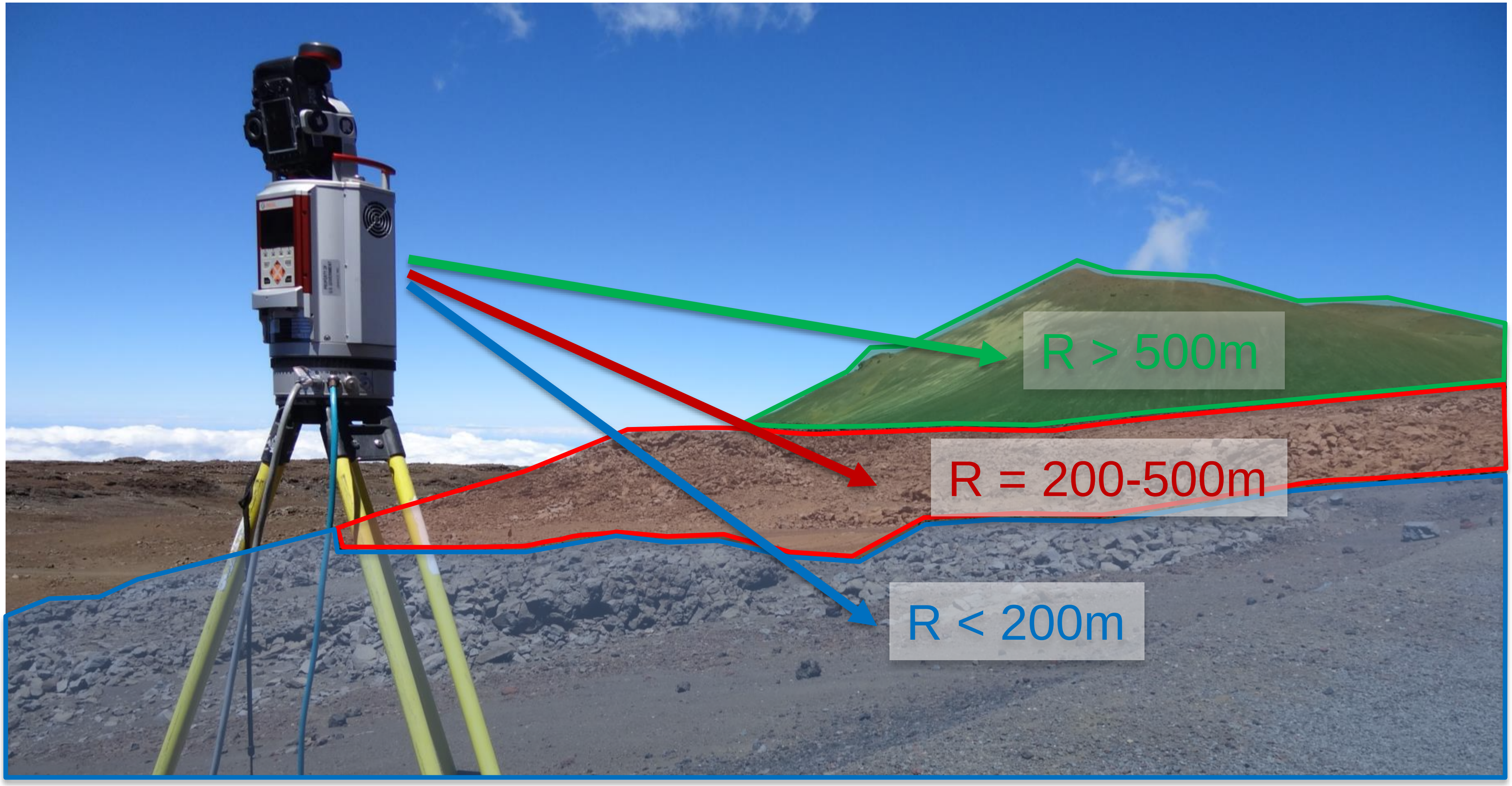
Angular Step



Rule of thumb: scan at least 1/10th of the "wavelength" of the object you wish to image.

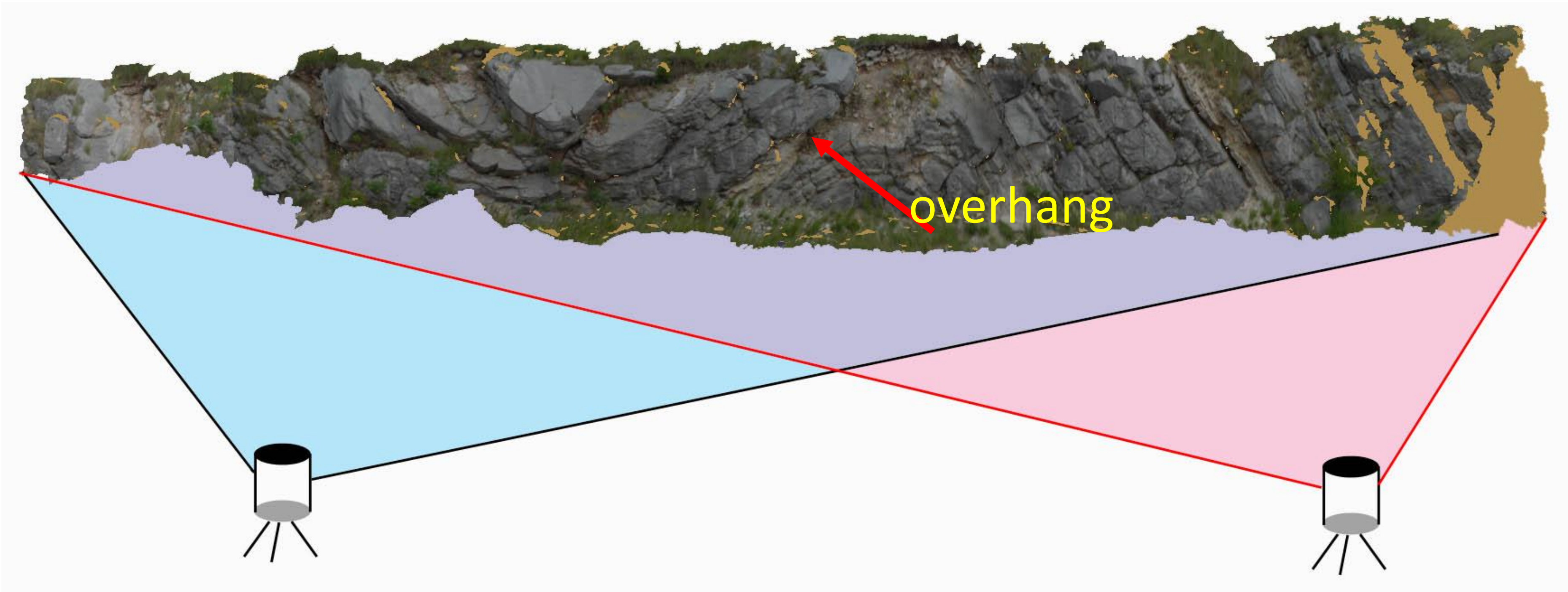


TLS Instrument and Survey Parameters



Shot Spacing / Sample Density

- Shot spacing varies as a function of range to target.
- Choose angular scan resolution to optimize sample density.

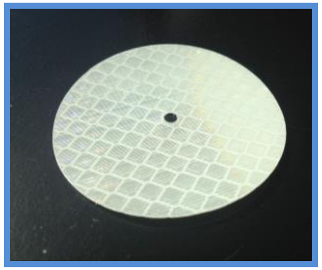
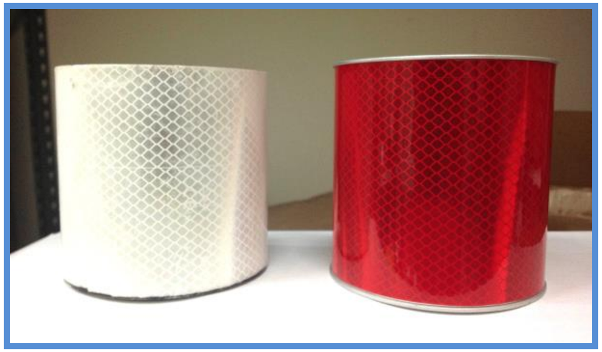


Scan Positions

Choose scan positions to minimize occluded (shadowed or hidden) geometries.

Targets

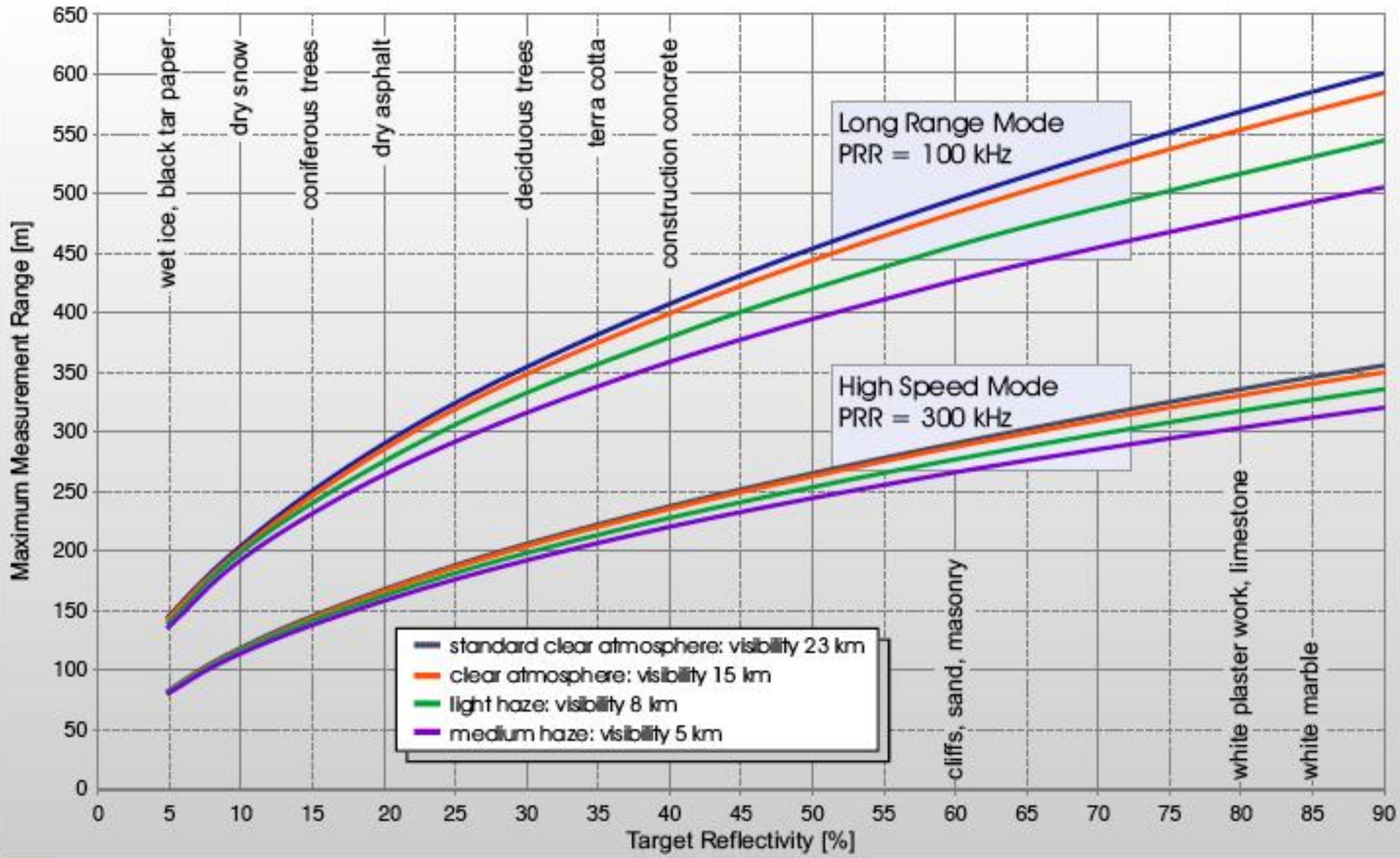
- Reflective objects that serve as reference points for scans.
- Same targets must be common between scan positions.
- Use at least 5 reference targets to register scan positions (the more the better).
- Different shapes and colors serve different functions


(images not to scale)

TLS Instrument and Survey Parameters

Riegl VZ400 – Max. measurement range as function of target material



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TLS Instrument Parameters - Datasheets

Technical Data 3D Scanner Hardware *RIEGL* VZ®-1000

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.

CLASS 1 LASER PRODUCT

Range Performance[1)]

Laser PRR (Peak) [2)]	70 kHz	100 kHz	150 kHz	300 kHz
Effective Measurement Rate [2)]	29 000 meas./sec.	42 000 meas./sec.	62 000 meas./sec.	122 000 meas./sec.
Max. Measurement Range [3)] for natural targets ρ ≥ 90% for natural targets ρ ≥ 20%	 1400 m 700 m	 1200 m 600 m	 950 m[4)] 500 m	 450 m[4)] 350 m
Max. Number of Targets per Pulse	practically unlimited [5)]			
Accuracy [6) 8)]	8 mm			
Precision [7) 8)]	5 mm			

Minimum Range 2.5 m
Laser Wavelength near infrared
Beam Divergence [9)] 0.3 mrad

1) with online waveform processing
2) rounded values, selectable by measurement program
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 an overcast sky.
4) limited by PRR
5) details on request
6) Accuracy is the degree of conformity of a measured quantity to its actual (true) value.
7) Precision, also called reproducibility or repeatability, is the degree to which further measurements show the same result.
8) One sigma @ 100 m range under *RIEGL* test conditions.
9) Measured at the $1/e^2$ points. 0.3 mrad corresponds to an increase of 30 mm of beam diameter per 100 m disdance.

Terrestrial Laser Scanning Project Summary

Project Planning

- Choose instrument based on capabilities and science/data goals.
- Schedule based on instrument availability, science requirements, environmental factors.
- Use Google Earth, field site photos, etc. to establish preliminary locations for scan positions, control targets, registration targets, etc.

Instrument calibration & data collection

Post-processing & Analysis

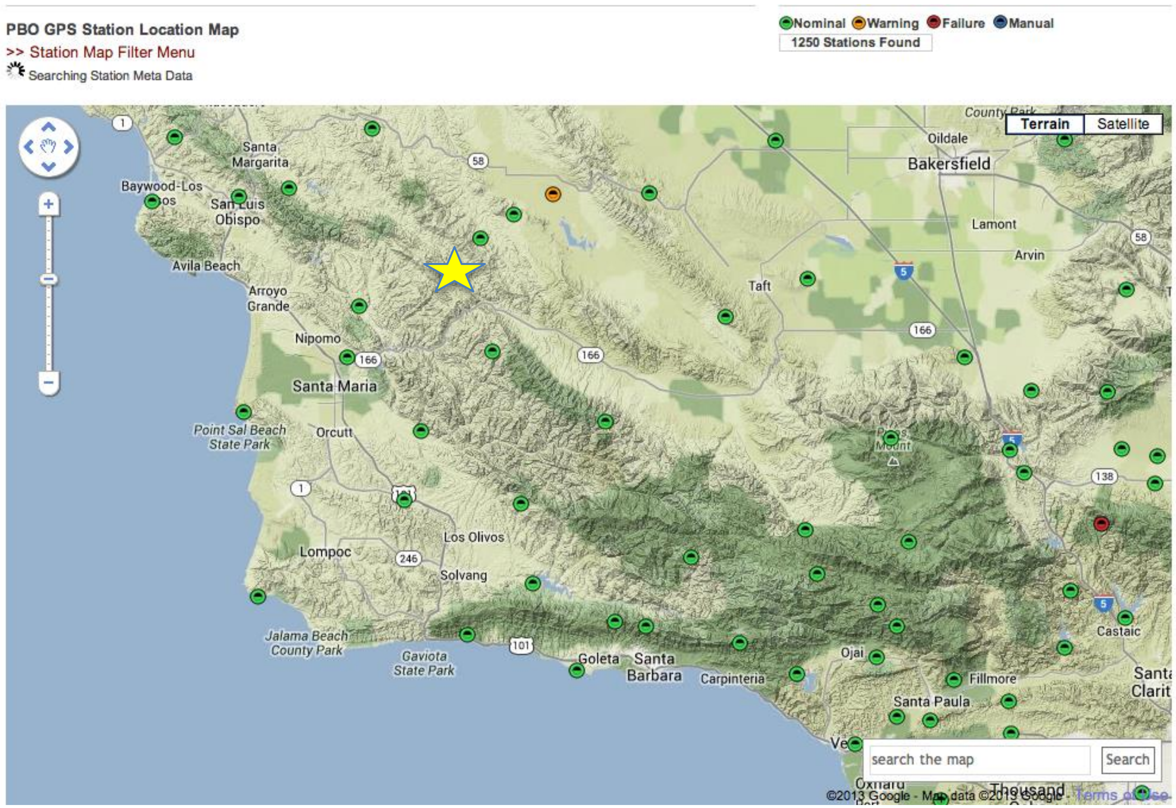
- Make a copy of the data collected in the field. Keep the original project(s) in a safe place. Post process using the copy of the project.

Metadata

- Project summary document.
- GPS data (raw files, rinex files, antenna heights, log sheets, etc.).
- Field photos.
- Google Earth files, etc.

Before heading out into the field

- GPS network – identify base stations, benchmarks and **make sure they are operational!**



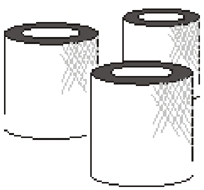
- Understand field site, anticipate challenges you may encounter (complex landscape, is power available in evenings, etc.)

- Give equipment a test run.

Basic Field Kit

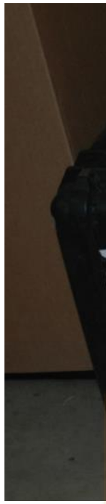
Checklist:

- Scanner
- Power supply
- Laptop
- Scanner tripod
- Reflector tripods
- Flat and Cylindrical Reflectors
- GPS receivers
- Safety gear
- Permit



Up to 300 lbs!!

ield Kit



TLS Survey Workflow

At the field site

- Take a **walk around the field site** before setting anything up. Identify scan positions, target positions and your GPS base station.
- Set up targets and start GPS data collection. 1-2 hours.

Only now are you ready to start scanning!

- Scan Position 1
  - 360-deg Panorama scan + Image acquisition if desired.
  - Target finescan
  - Area of interest finescan
- Scan Position 2 and beyond
  - Same as Scan Position 1+ registration to previous scans + quality check.

Standard tie point workflow

- **Reminders – use at least 5 targets.**
  - **Every scan position sees at least 5 targets**
  - **Every target is seen by at least 2 scan positions**
- **The more targets common to all scan positions, the better**

TLS Survey Workflow

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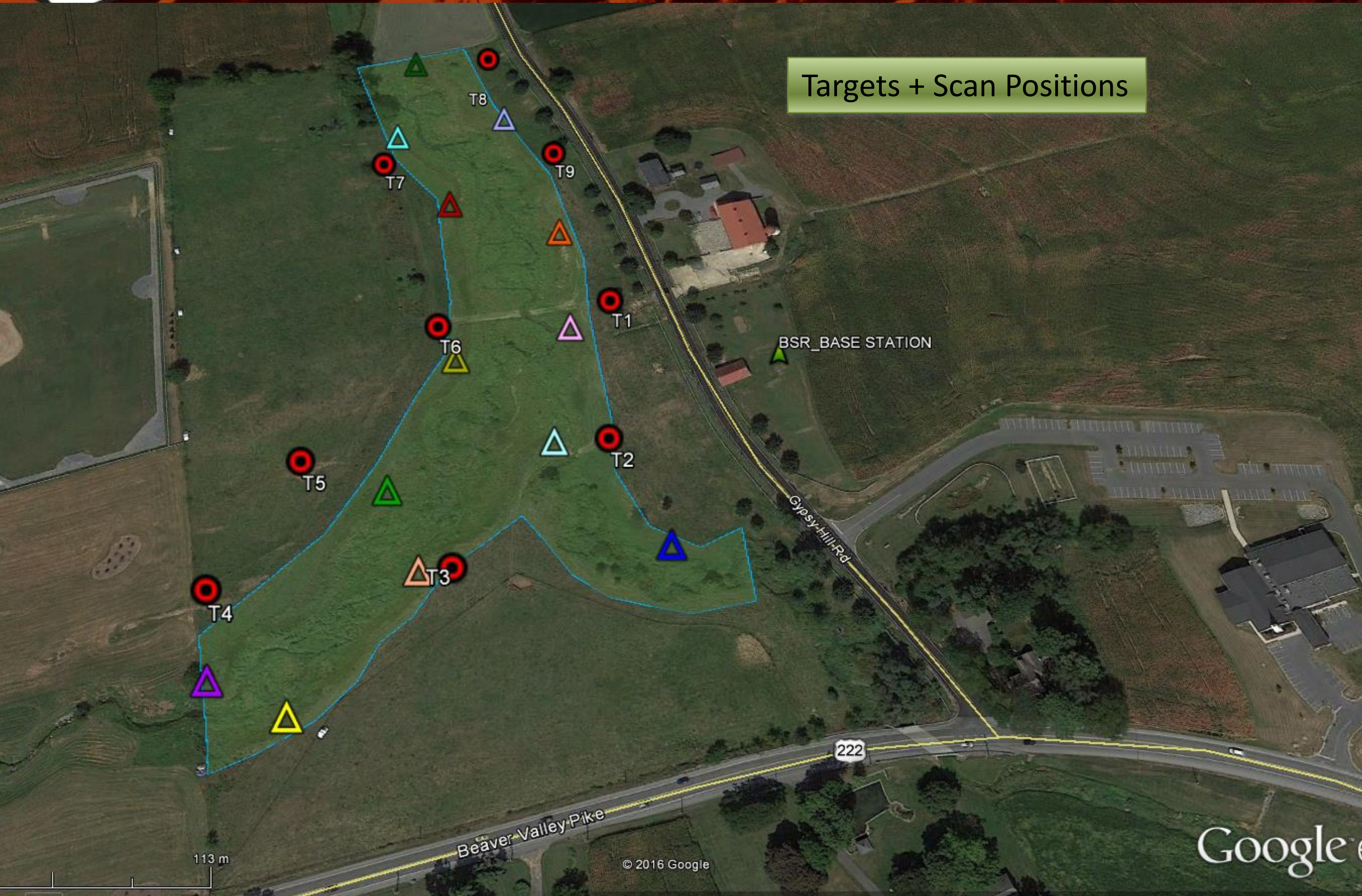
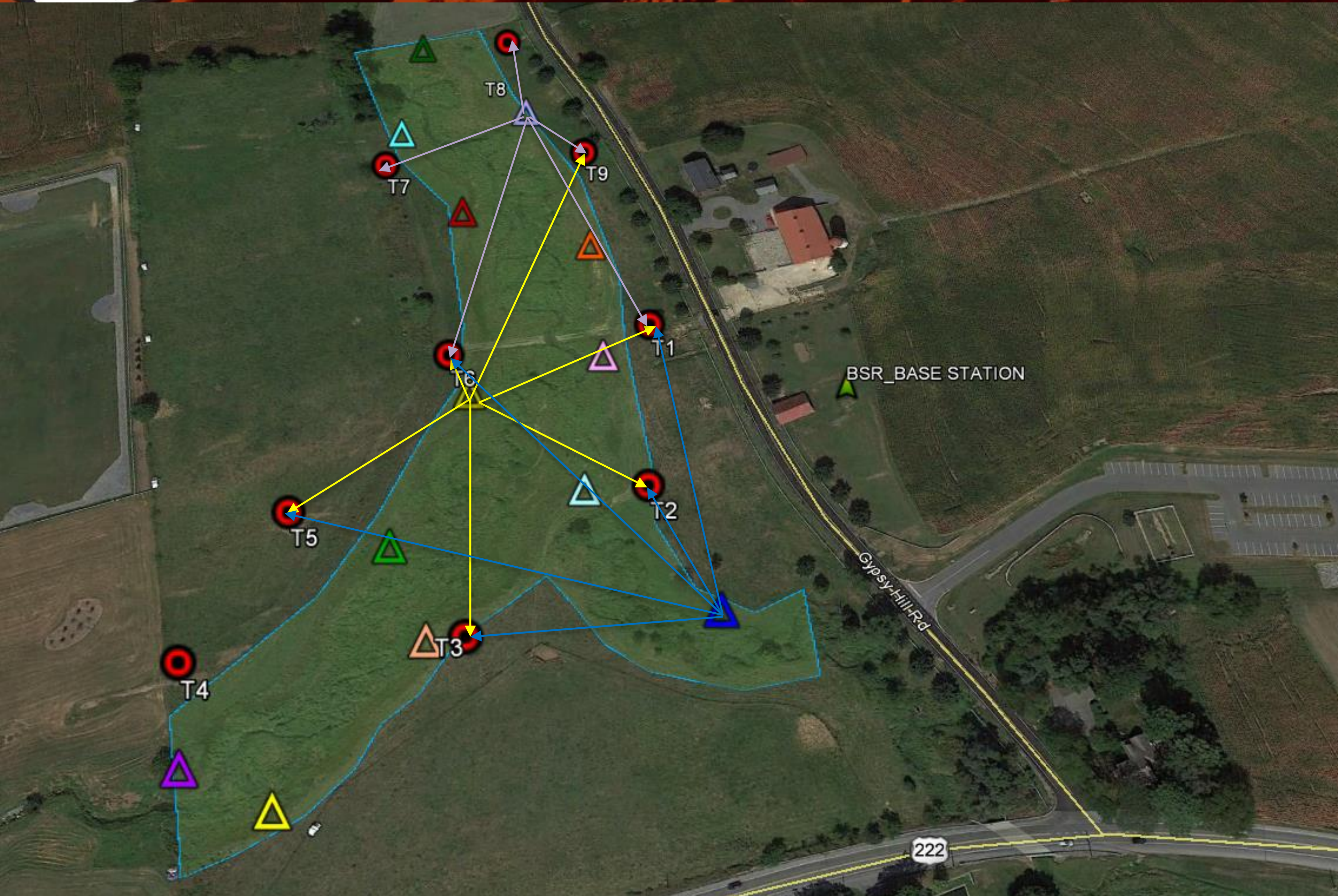
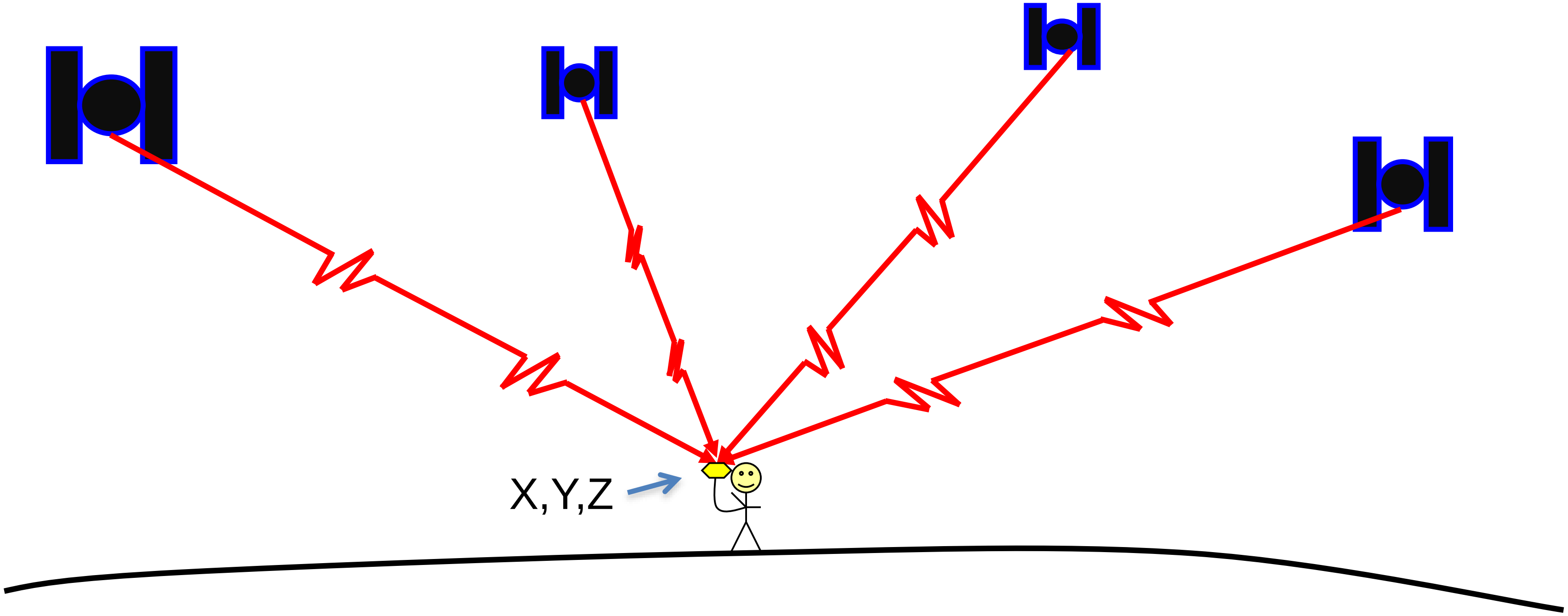


TLS Survey Workflow



Global Positioning System

- Constellation of 31 satellites which each house an atomic clock.
- Precise time information is sent to a receiver on earth.
- A minimum of 4 satellites in sky view is needed to obtain a coordinate.



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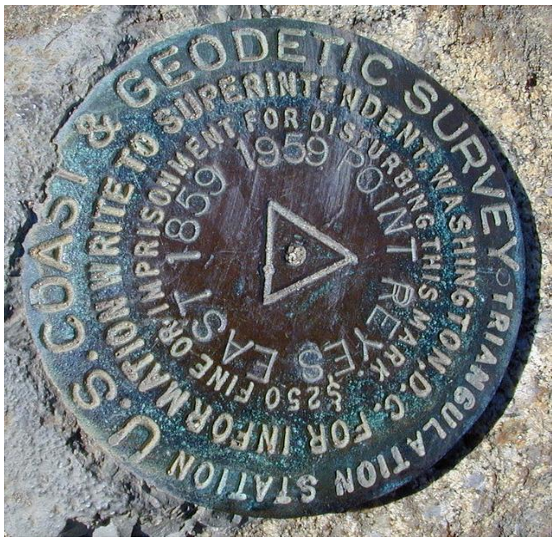
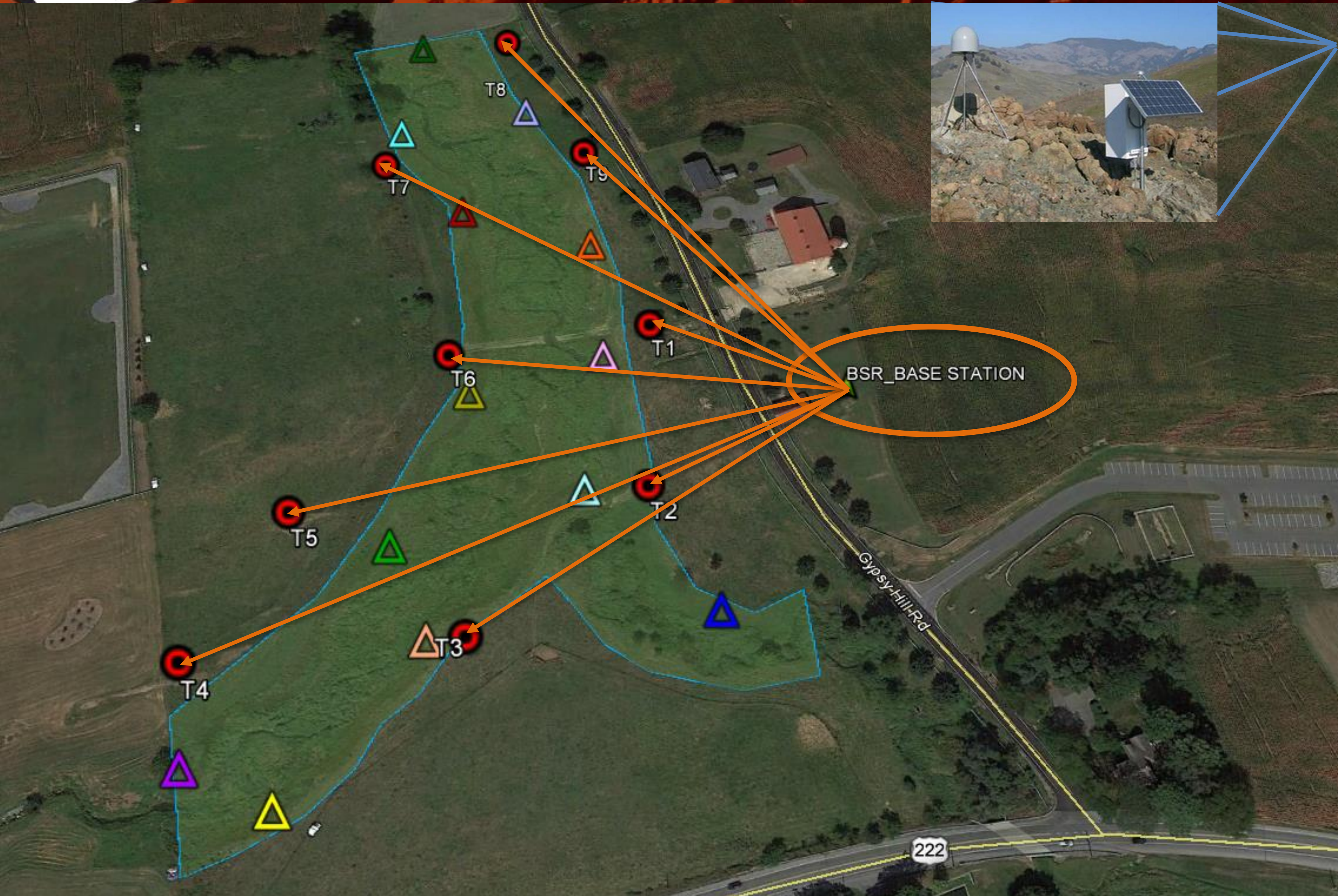
Differential GPS

Uses known reference points (base stations) on the Earth to provide corrections for unknown points.



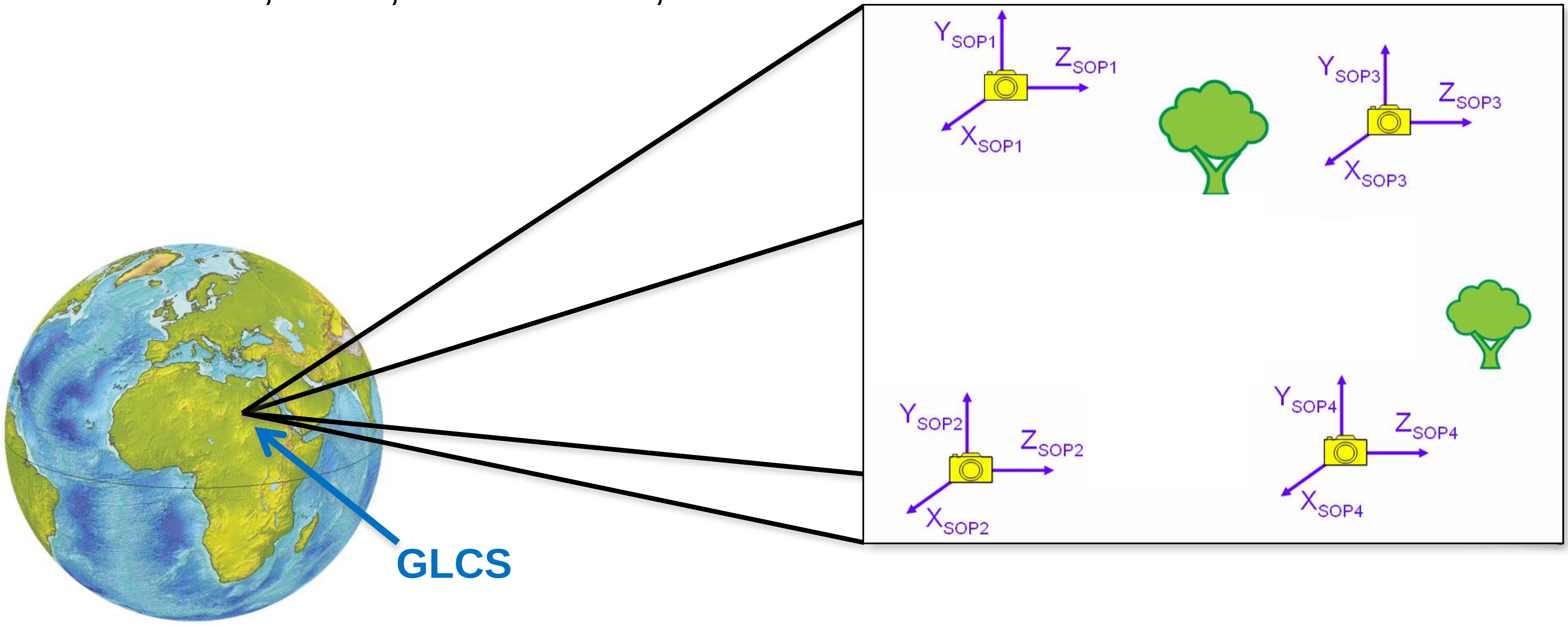
- Advantage is cm to sub-cm precision!
- Base station and unknown points must share same occupation time
- Base stations and unknown points must “see” same errors (same sky view). Practical limit is 100km.
- Vertical precision will always be ~2x less precise than horizontal precision.

Adding GPS to a TLS Survey



Understanding coordinate systems - TLS

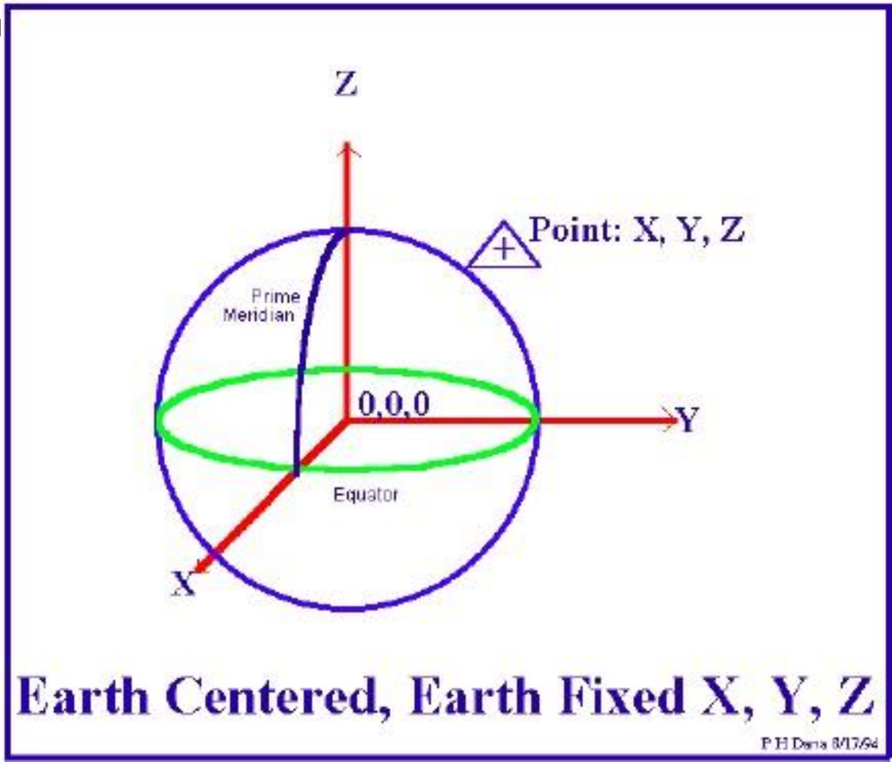
- **SOCS** – **S**canner **O**wn **C**oordinate **S**ystem
  - Each scan position has origin at scanner location
- **PRCS** – **PR**oject **C**oordinate **S**ystem
  - Local coordinate system for entire project
- **GLCS** – **GL**obal **C**oordinate **S**ystem
  - ECEF, UTM, State Plane, etc.



Earth Centered, Earth Fixed (ECEF)

- Origin = center of mass of the Earth.
- Three right-handed orthogonal axis X, Y, Z. Units = meters.
- The Z axis = Earth's rotation axis.
- The (X,Z) plane contains the Earth's rotation axis and the prime meridian.
- The (X,Y) plane in equatorial plan

- Preferred by geodesy community
- Not GIS friendly! Requires transformations into 2D cartesian (e.g., UTM).
- Application of data matters
- Con: **Z ≠ height**



TLS Workflow

After data collection is complete…

- The bulk of the work begins…not a joke! Data processing will be the most time consuming (and hardest) portion of the project.
  - Colorize data from photos
  - Filter/clean points
  - Re-register all scans to get best fit (especially important for larger field areas)
  - Georeference point cloud(s)
- Archive your raw data set/project ASAP – multiple copies.
- Archive final project and create metadata.
- Create higher order datasets (Chris will cover these).
- Export data to appropriate format.

Metadata Reporting

All of the information you can think of!

- Project objectives
- Atmospheric conditions
- GPS observations
- Who, what, when, where
- Someone tripped over the tripod, cow knocked over target…
- Target types and geometry
- Coordinate system
- Etc, etc, etc!

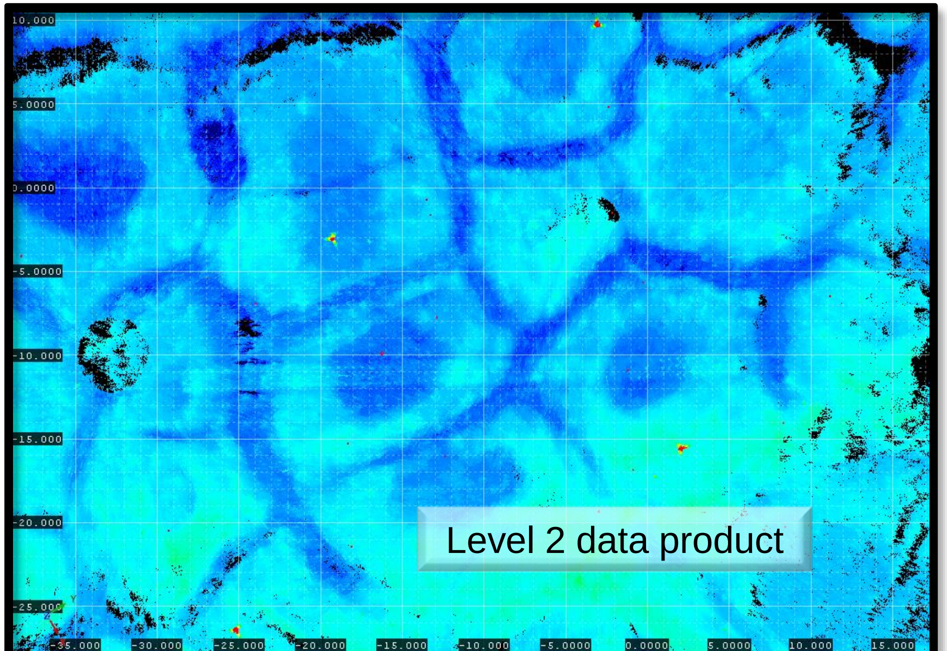
BIG SPRING RUN STREAM RESTORATION, LANCASTER COUNTY, PENNSYLVANIA – METADATA REPORT

SITE SURVEY APRIL 11-13, 2014

By Marianne Okal, UNAVCO Inc.

Prepared June 29th, 2014

Exporting and Archiving Data

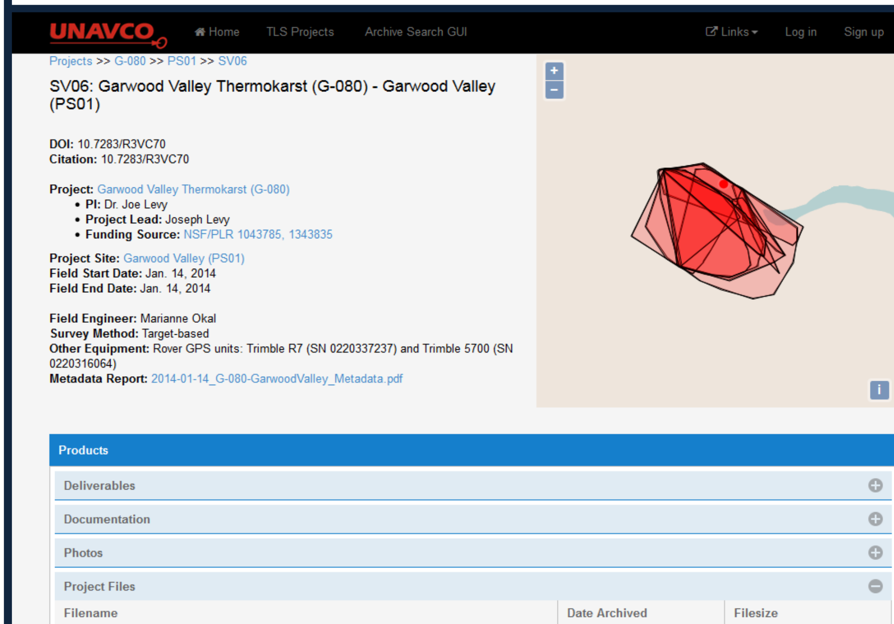


Exports

UNAVCO **standard deliverable:** merged, aligned, georeferenced point cloud in ECEF in LAS format

UNAVCO TLS Data Archive

- https://tls.unavco.org
- All project materials archived
- All materials available to public free of charge
- User account required to download – please sign up!

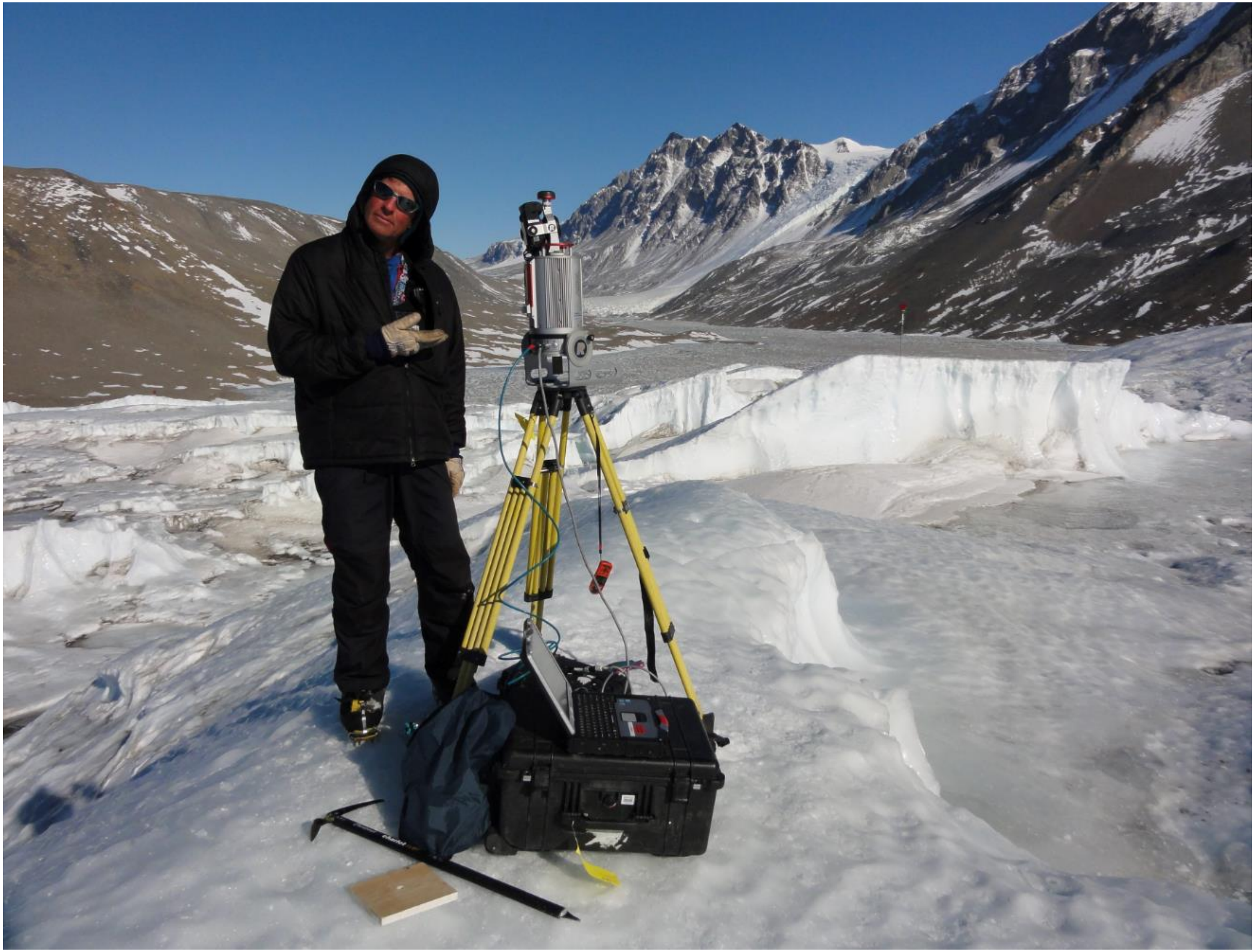


Data considerations

Data volume can be a problem:

- **Technology outpaces most software for data processing & management.**
- ***Just because you can, doesn't mean you should***
- **Science application should define data collection.**

Questions?



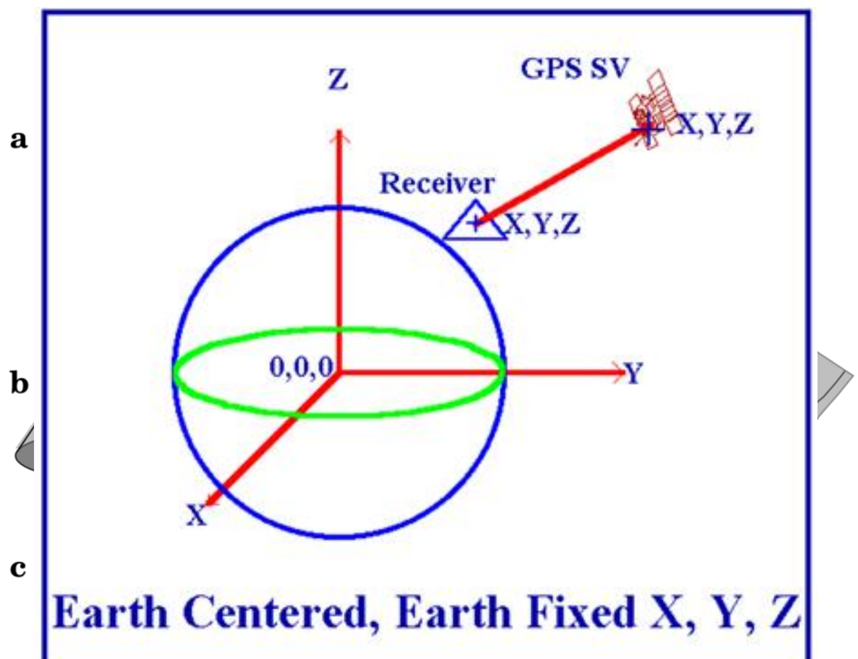
Understanding coordinate systems - GPS

Point ID	Northing	Easting	Elevation	Latitude	Longitude	Ellip. Height	X (ECEF)	Y (ECEF)	Z (ECEF)
BF - UTD1	1370462.012	577608.894	94.429	-77.72225	162.27091	40.108	-1296058.157	414350.03	-6210455.012
BF - UTD2	1370484.93	577645.326	78.213	-77.72203	162.27239	23.892	-1296088.759	414322.955	-6210433.867
BF - UTD3	1370451.914	577632.2	92.861	-77.72233	162.27192	38.539	-1296056.922	414324.606	-6210455.347
BF - UTD4	1370446.605	577618.498	95.796	-77.72238	162.27135	41.474	-1296047.793	414335.745	-6210459.505
BF - UTD5	1370480.558	577607.267	97.233	-77.72208	162.2708	42.912	-1296075.07	414358.23	-6210453.832

Projected values (ex. UTM)

Spherical coordinates

Earth Centered Earth Fixed (ECEF)



Earth Centered, Earth Fixed X, Y, Z