TLS Parameters, Workflows, and Field Methods

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Yesterday it worked
Today it is not working
Windows is like that

Out of memory.
We wish to hold the whole sky,
But we never will.

Windows has crashed.
I am the Blue Screen of Death.
No one hears your screams.

A crash reduces
your expensive computer
to a simple stone.

Serious error.
All data have disappeared
Screen. Mind. Both are blank.

A file that big?
It might be very useful.
But now it is gone.

ABORTED effort:
Close all that you have.
You ask way too much.

To have no errors
Would be life without meaning
No struggle, no joy

Chaos reigns within.
REFLECT, REPENT, REBOOT.
Order shall return.

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How a Lidar Instrument Works

- LiDAR Light Detection And Ranging

- Active (i.e. energy is emitted)

- Point Cloud – a collection of 3D points that are recorded using precise measurement of the angle and range information from the emitter.

How a Lidar Instrument Works

- Transmits laser signals and measures the reflected light to create 3D point clouds.

- Wavelength is usually in the infrared (~1550nm) or green (532nm) spectrum

TLS Instrument and Survey Parameters

- Spot size (range, divergence)
- Spot spacing (range, angular resolution)
- Spot density (range, angle, number of setups)
- Angle of incidence (spot shape, intensity, range)
- Targets
- Edge effects/mixed pixels
- Registration
- First return, last return, “other”
- Shadows, field of view
- Scan object characteristics (albedo, color, texture)
- Area of interest

Beam Divergence

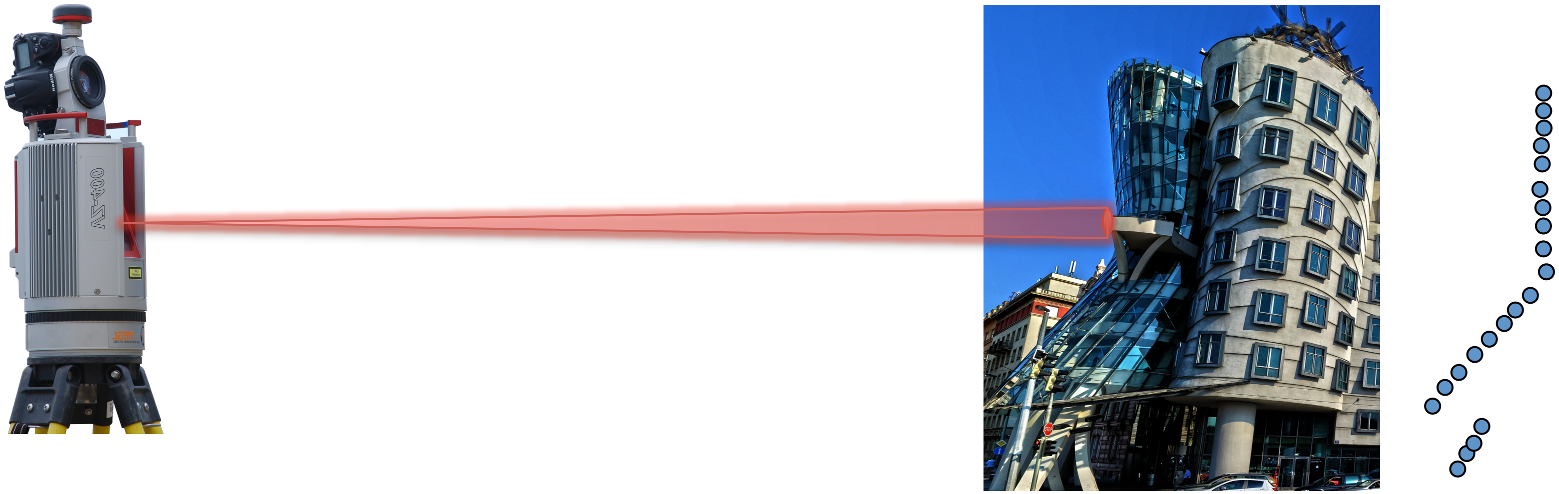
Df = (Divergence * d) + Di

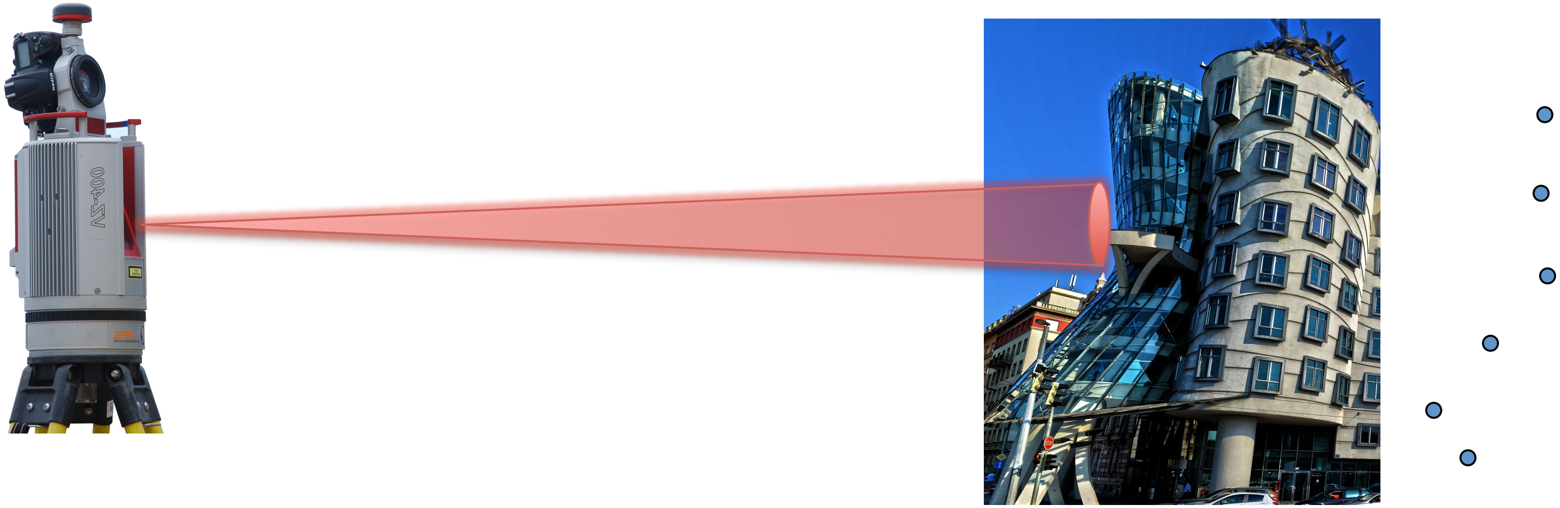
@100m,
Df = 36mm

@500m,
Df = 180mm

@1000m,
Df = 360mm!

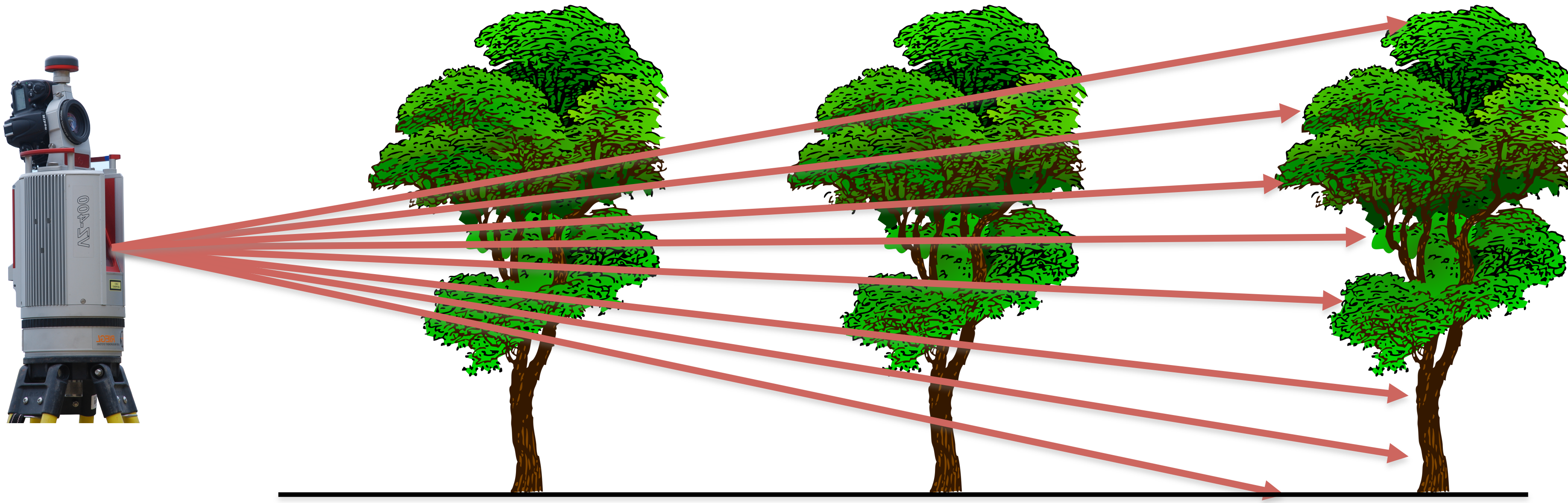
Beam Divergence



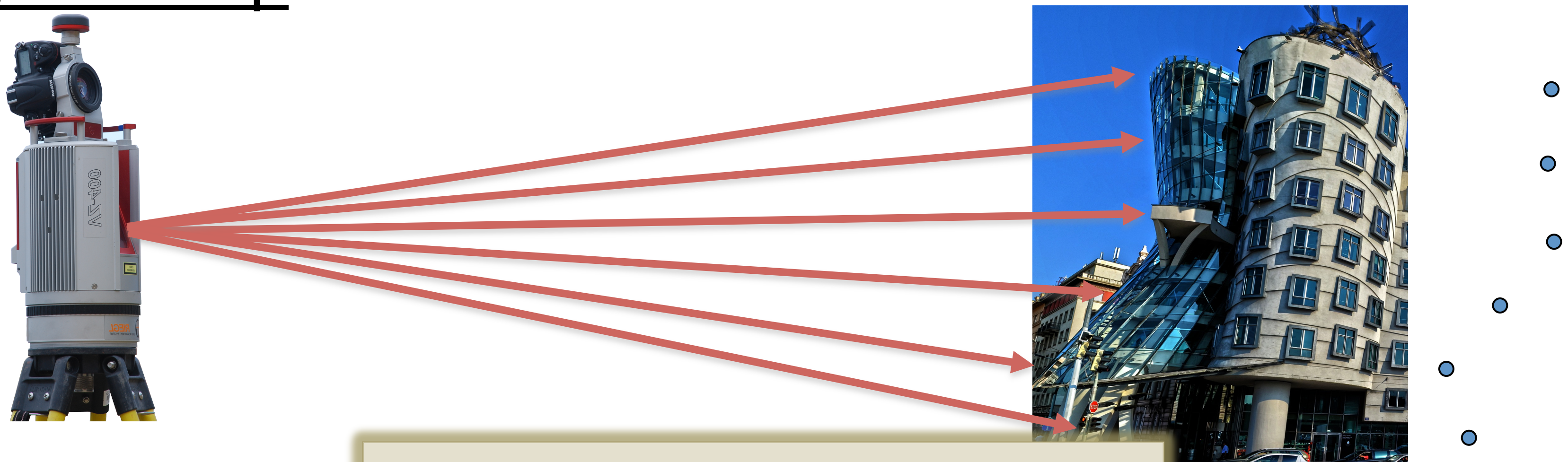


Angular Step

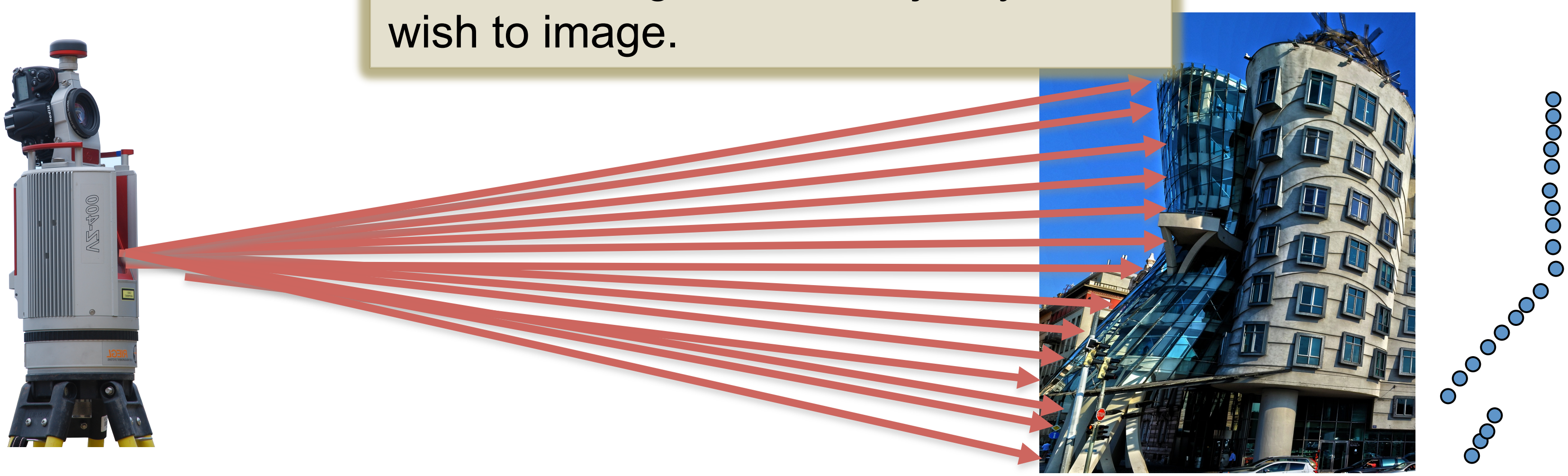
Spacing = d(m)*TAN(step)



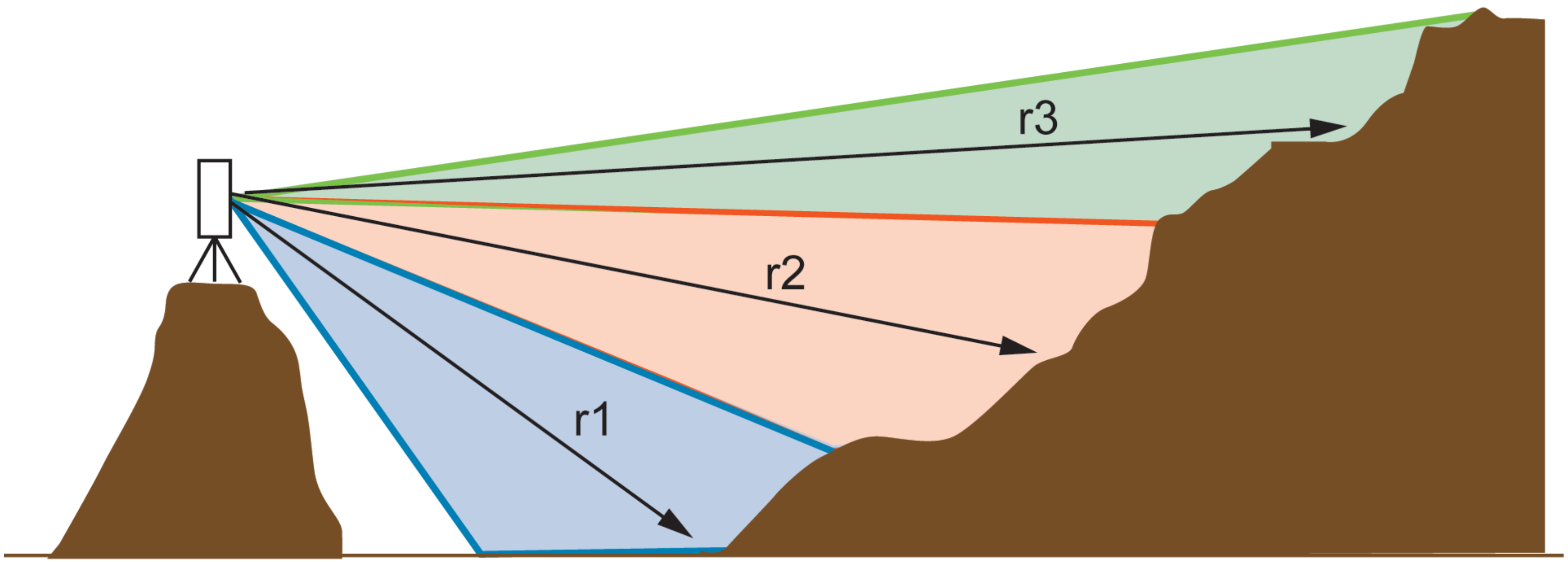
Angular Step



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



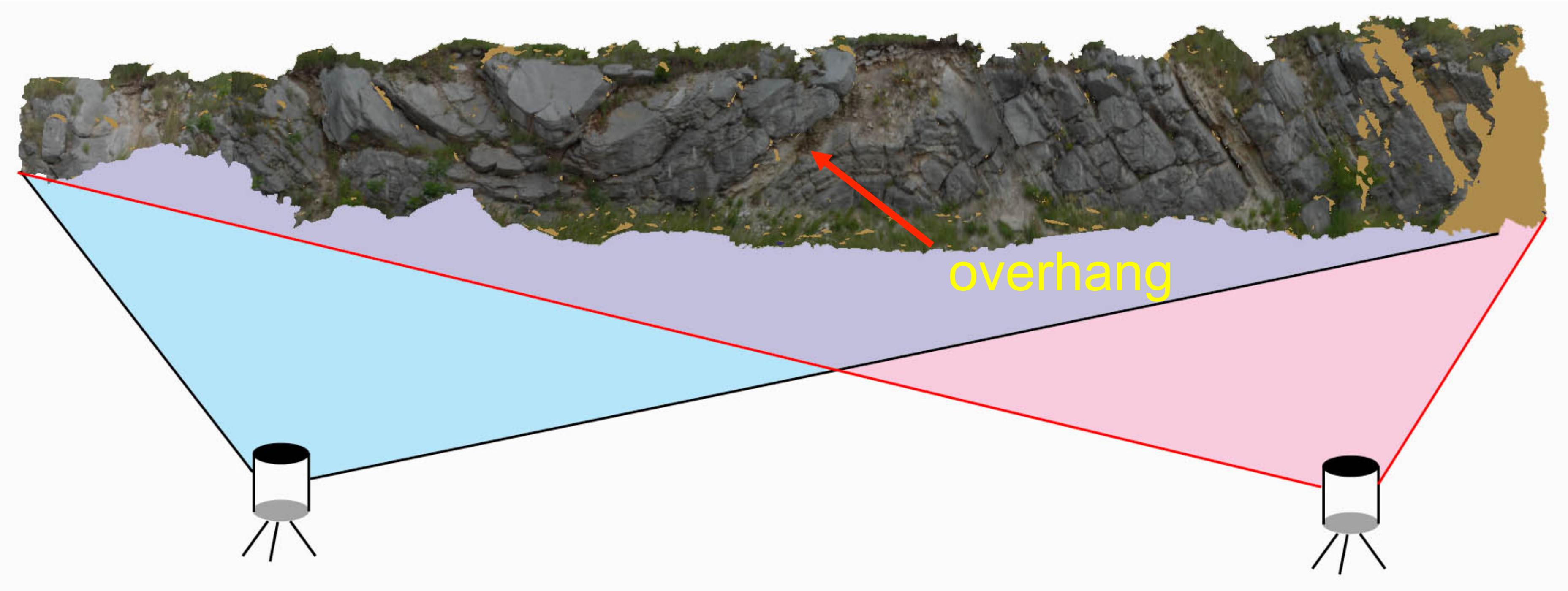
Shot Spacing/Sample Density



r1 = 280m r2 = 400m r3 = 550m

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

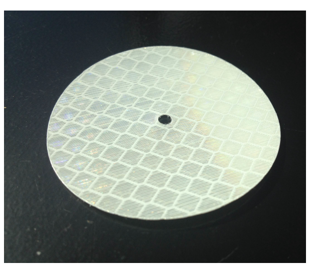
Scan Position



- 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

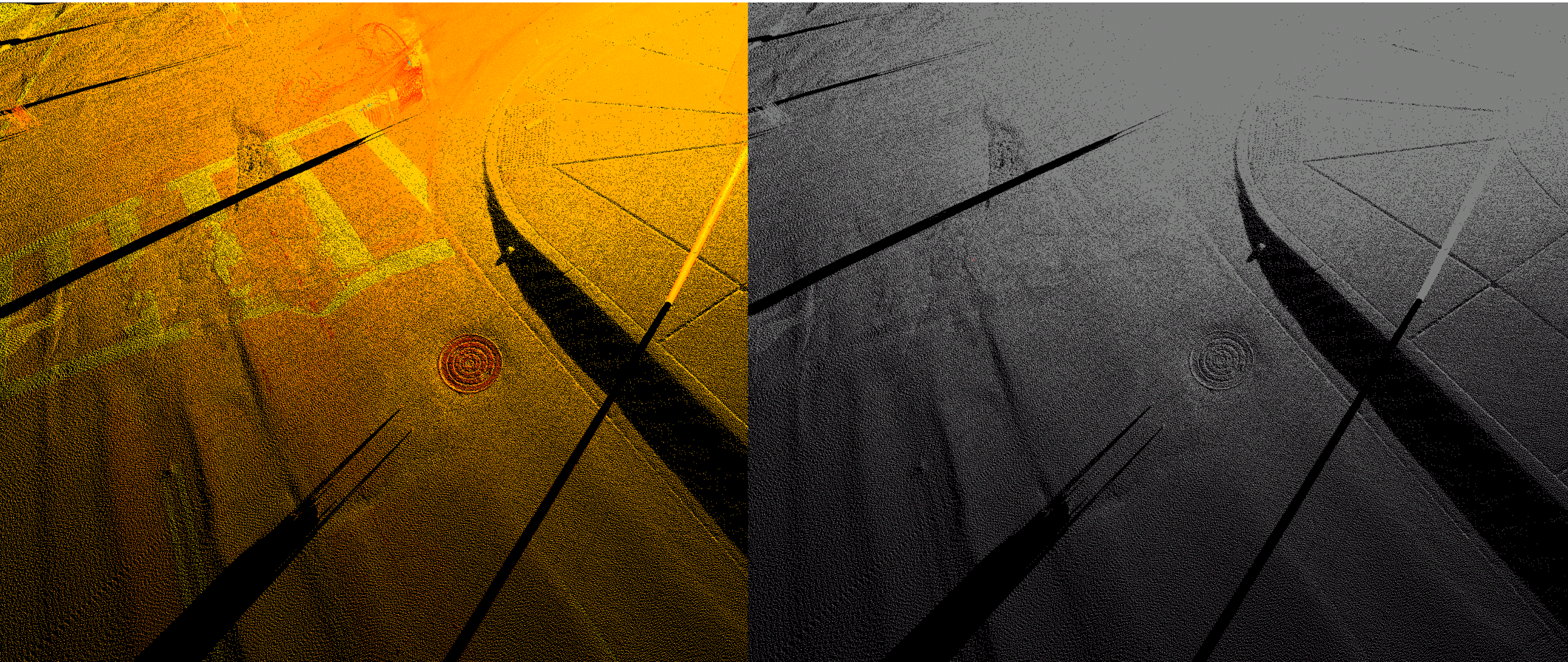


(images not to scale)

TLS Instrument and Survey Parameters

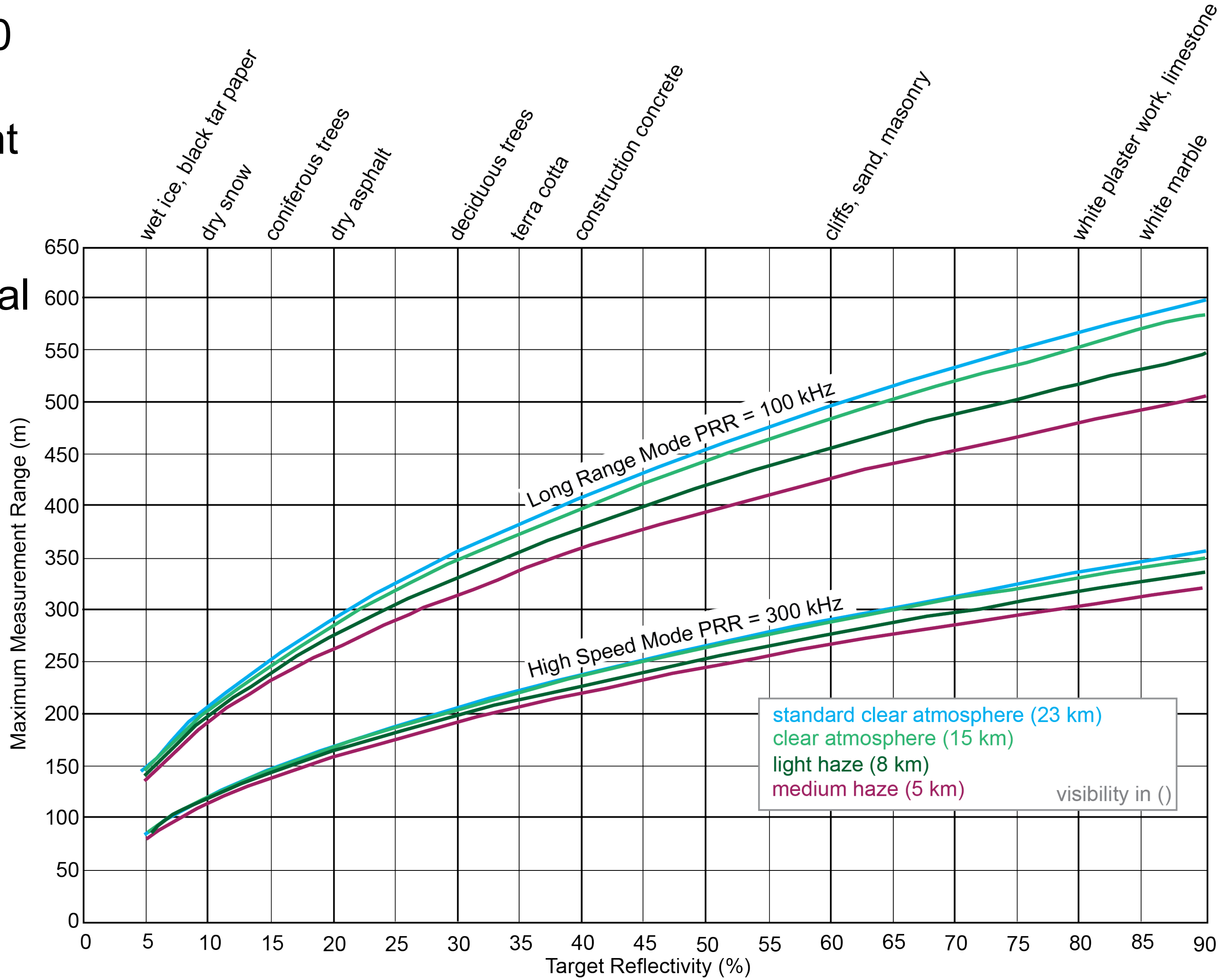
How intensely a laser pulse is returned to the scanner is determined by many factors such as :

- Range
- Angle of incidence
- Atmospheric conditions
- Material properties



TLS Instrument and Survey Parameters

Riegl VZ-400 Maximum measurement range as function of target material



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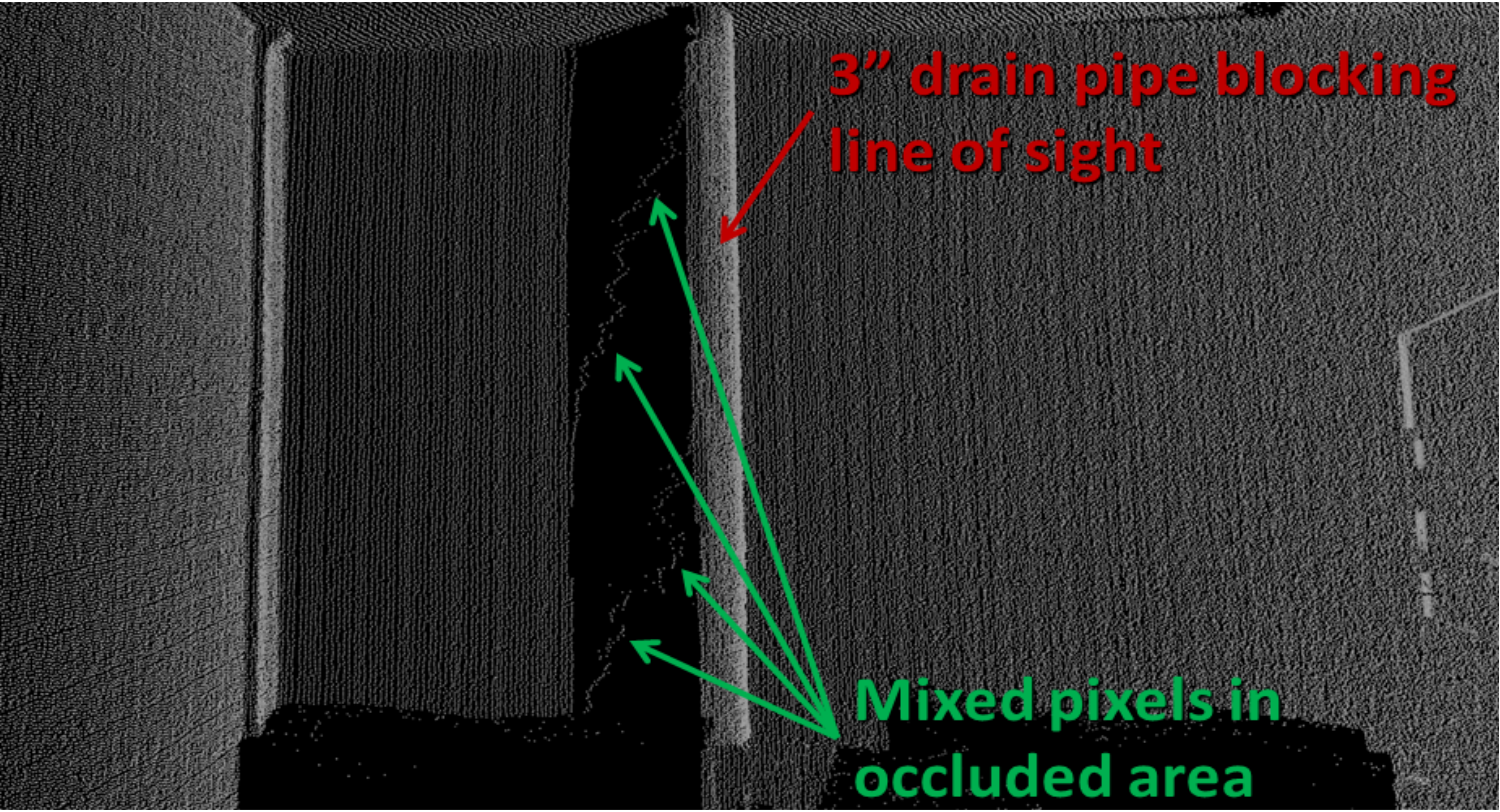
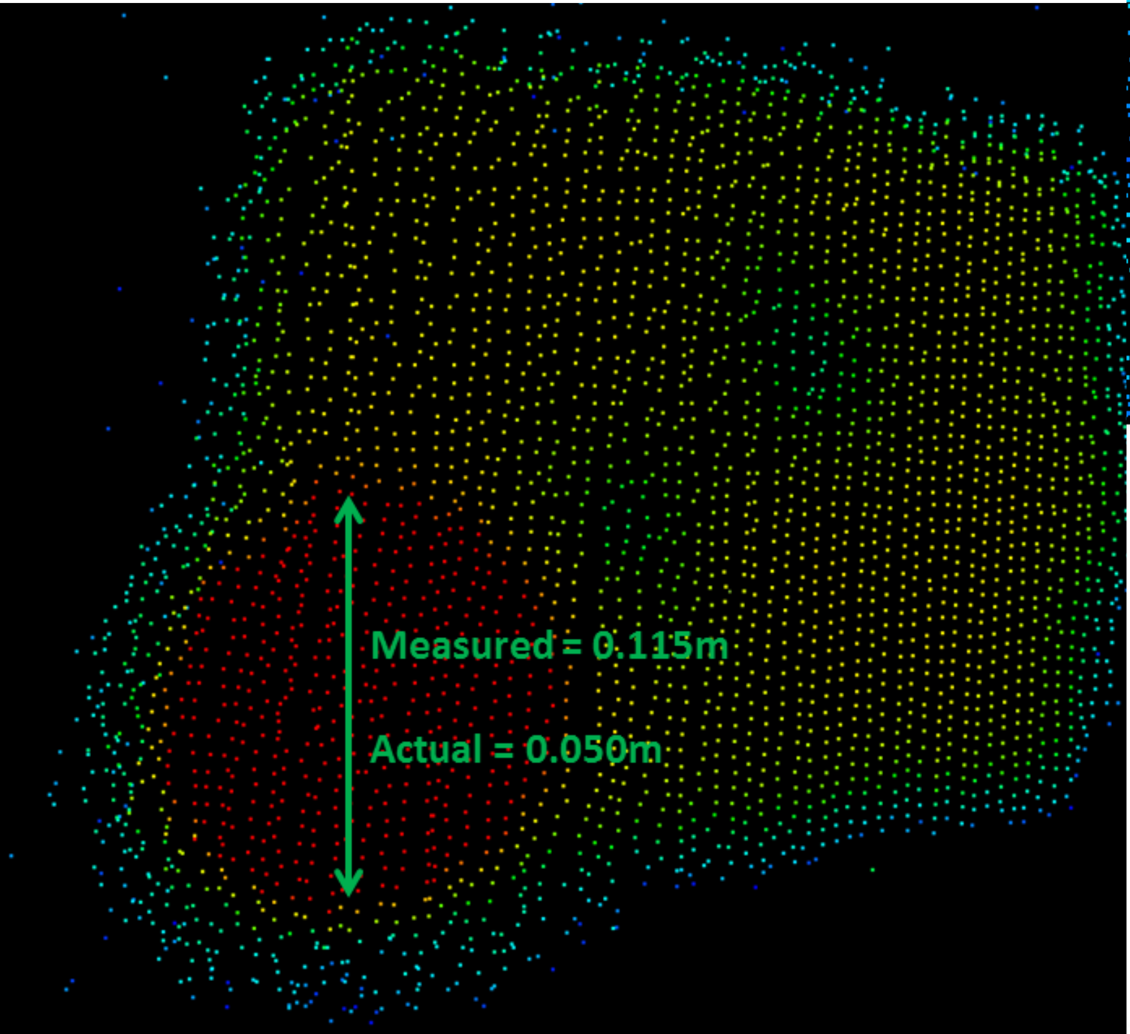
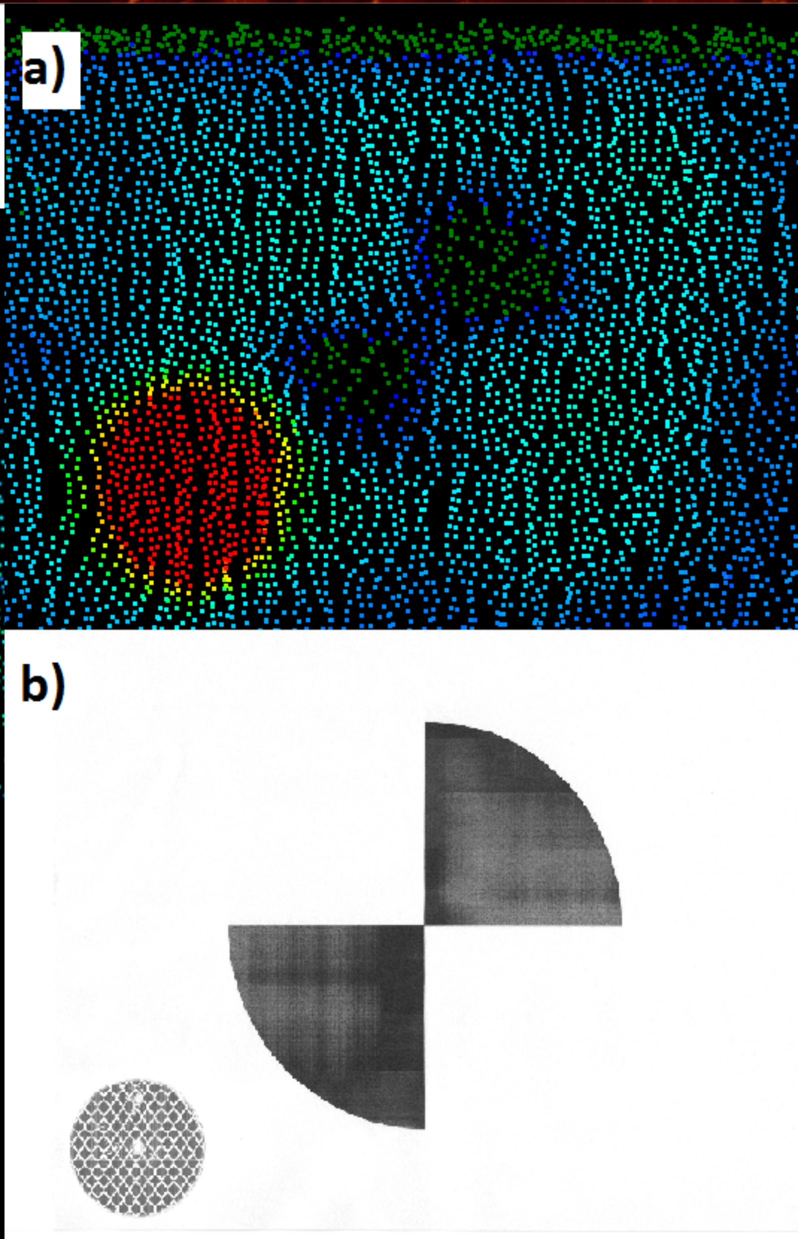
TLS Instrument and Survey Parameters



TLS Instrument and Survey Parameters





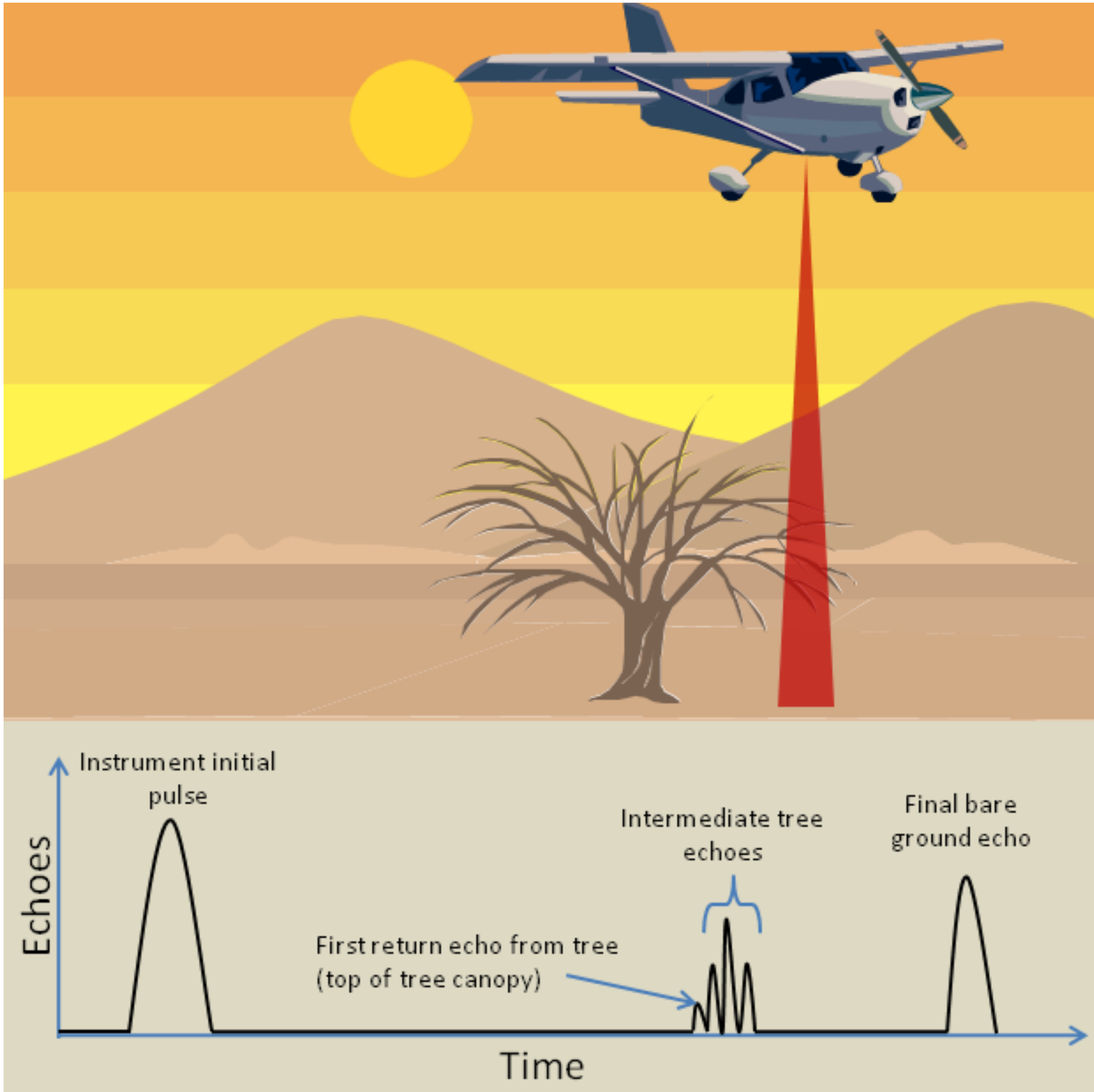
TLS Instrument and Survey Parameters

- Most time-of-flight systems are able to distinguish multiple returns from a single pulse, known as echoes, which provide useful information for filtering data.

- To distinguish each echo, the distance between them must be greater than half the pulse length.

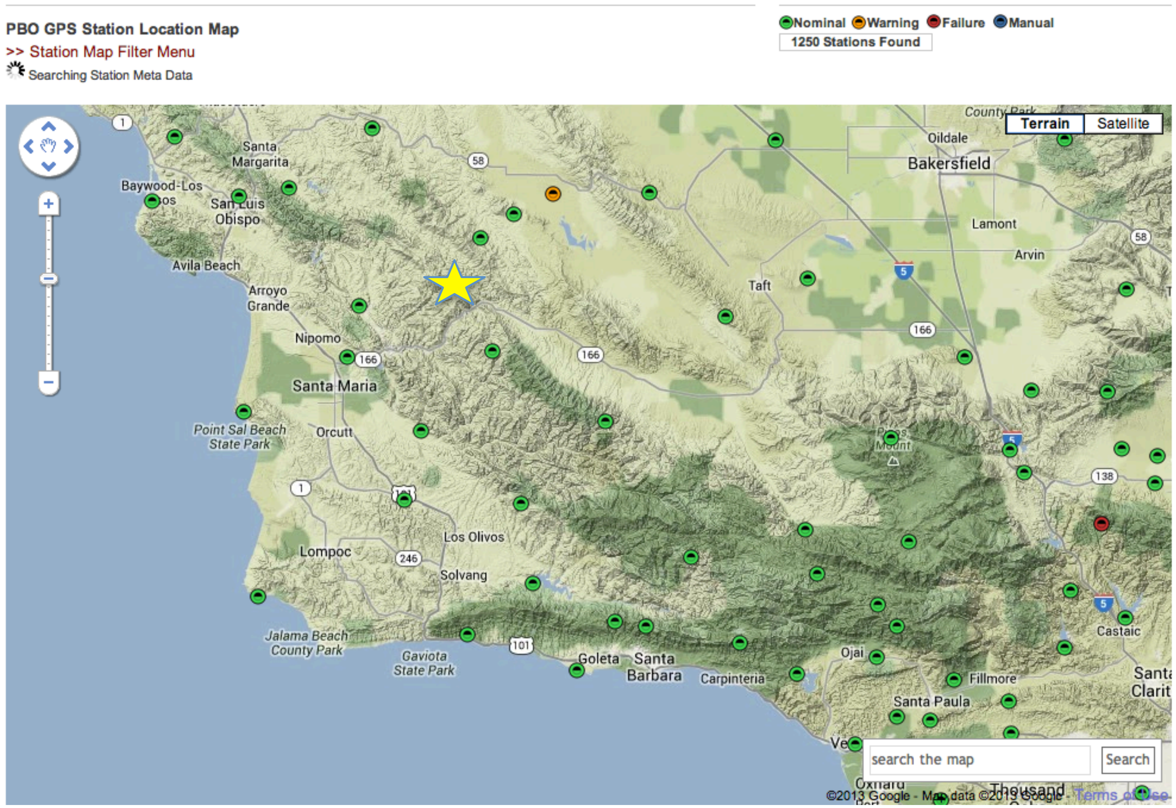
Pulse Length=Pulse Width x Speed of Light/Refractive Index

- Example: if pulse width is 8ns, objects must be greater



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.

Checklist:

- Scanner
- Power supply
- Laptop
- Scanner tripod
- Reflector tripods
- Flat and cylindrical reflectors
- GPS receivers
- Safety gear
- Permit

= 300 LBS!

Basic Field Kit

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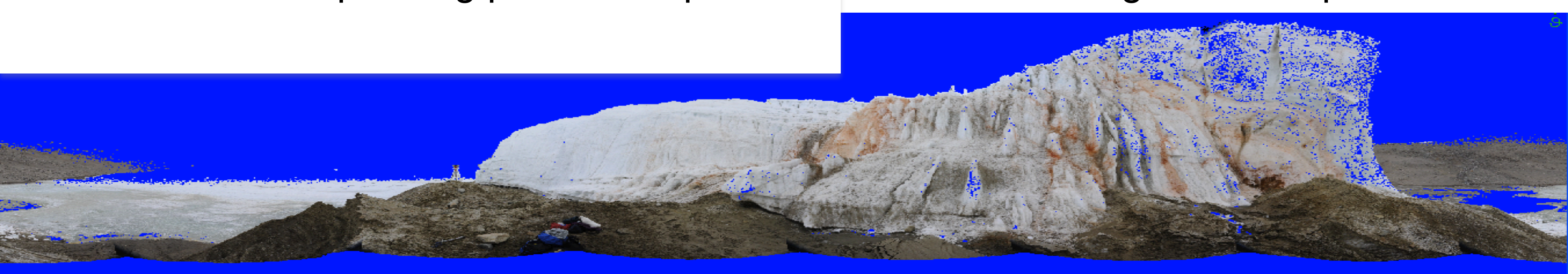
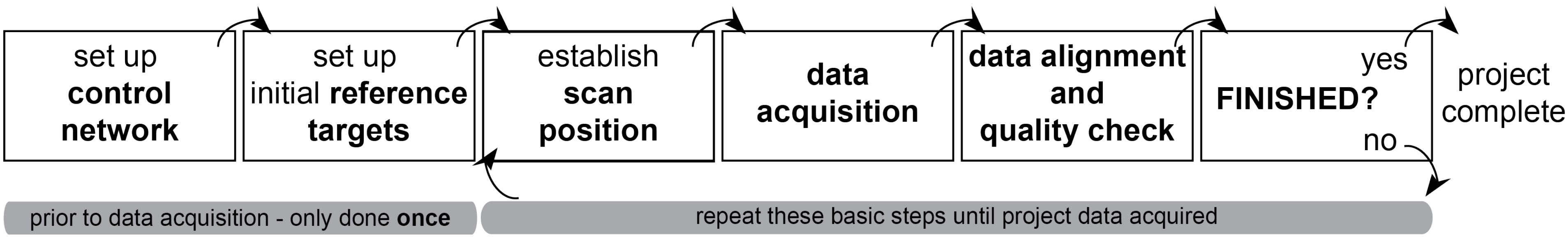
t?

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. This will take one to two 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, but after the target finescan you will find corresponding points with previous scans and co-register scan positions.



Riegl System Work Flow Overview



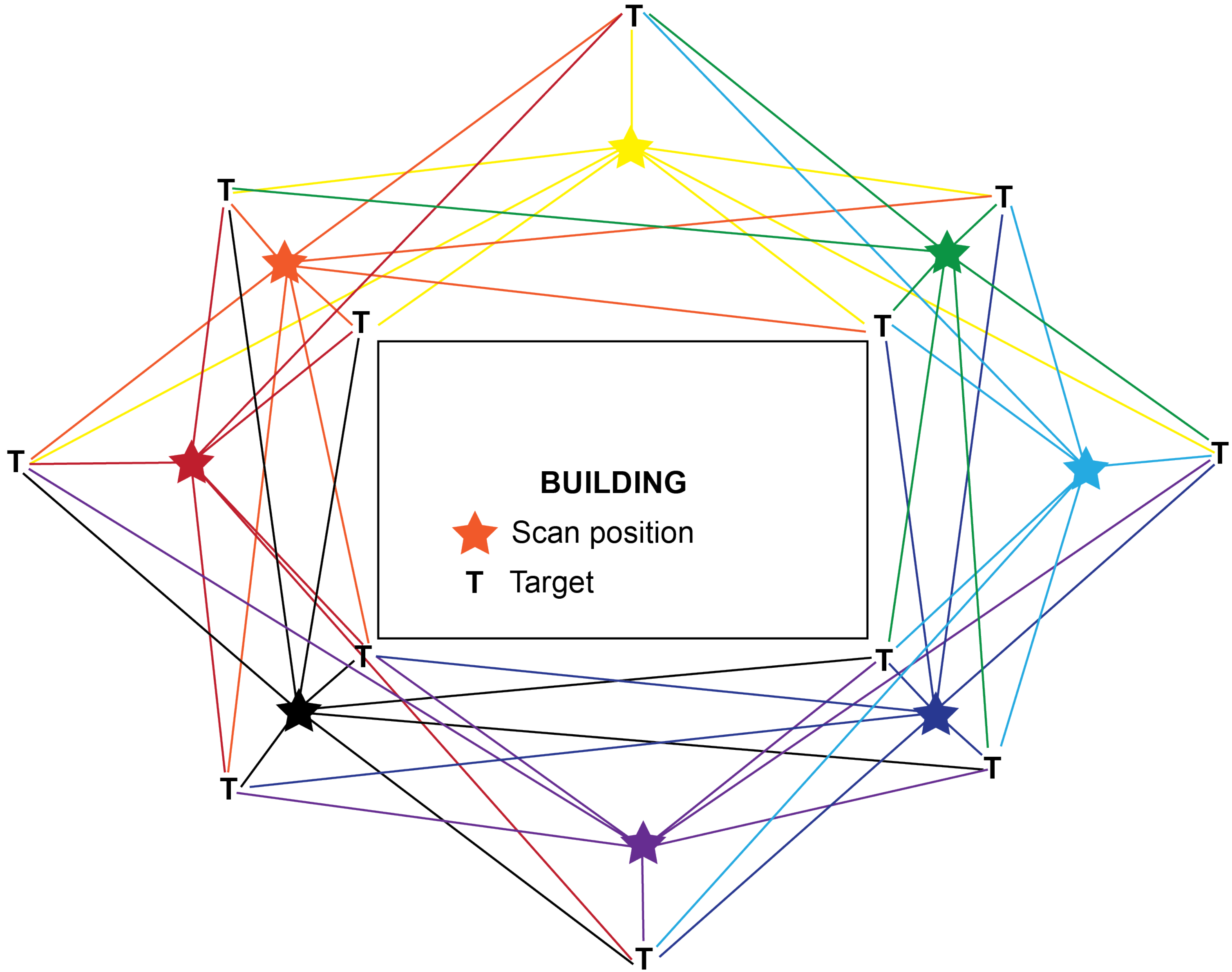
Capture all of the information you can!

- Draw a sketch
  - Target arrangement?
  - Scan positions?
  - GPS locations?
  - Which targets? Offsets?
- Atmospheric conditions
- Who are you working with
- What are you scanning
- Important notes: *Professor tripped over the tripod…*

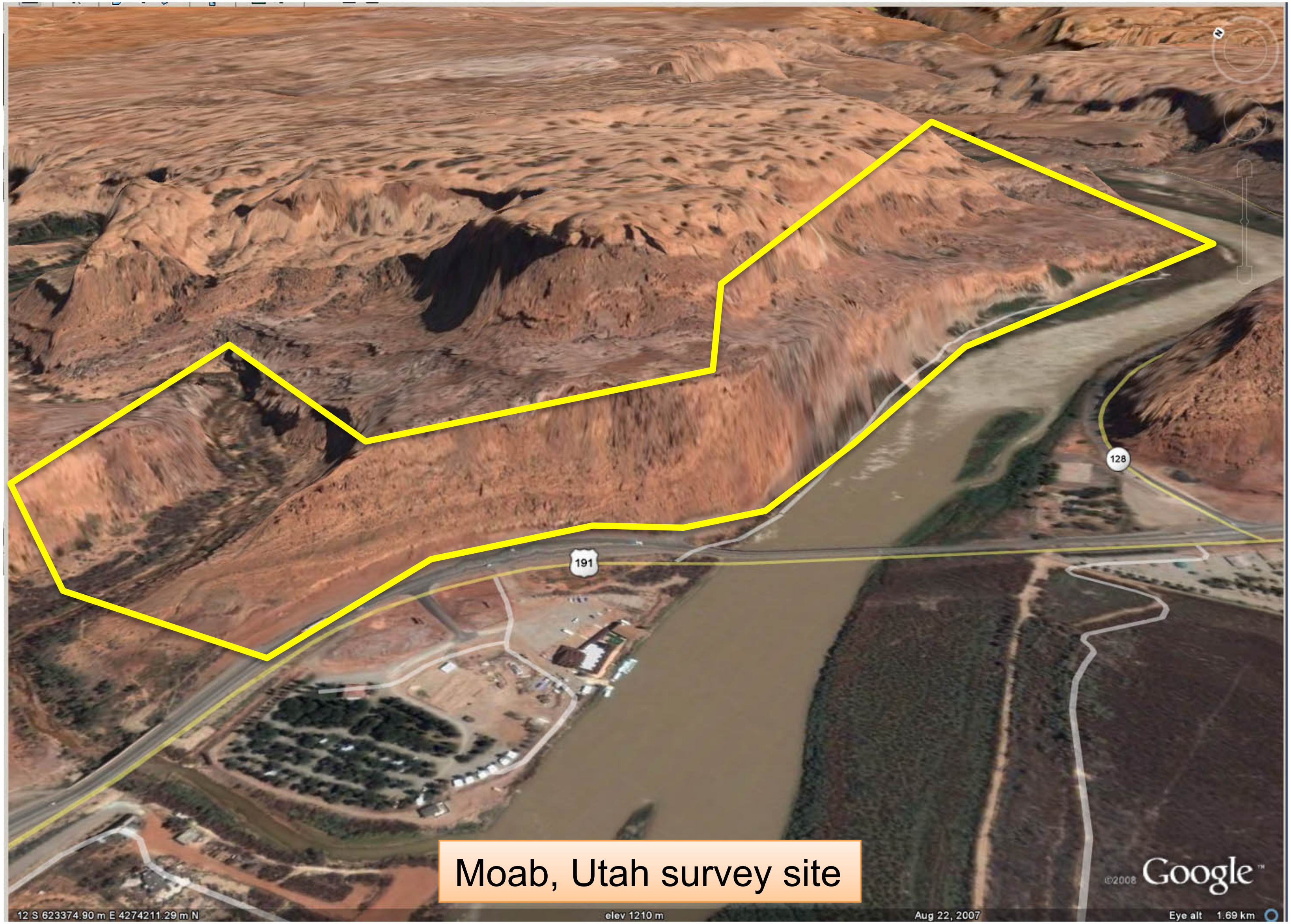
Standard tie-point workflow

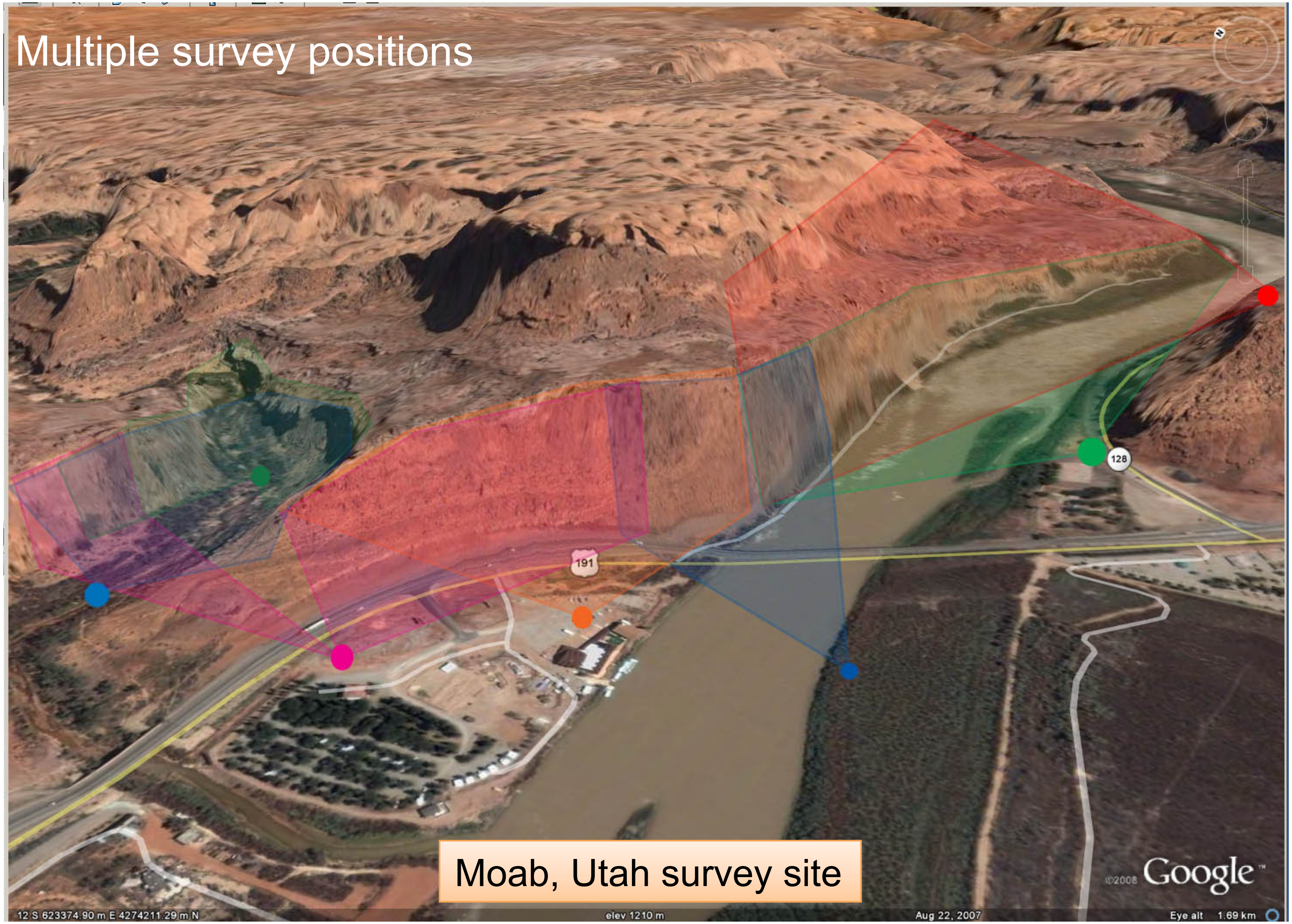
- Reminders – use at least five targets. That is, every scan position should see at least five targets, every target should be seen by at least two scan positions.
- The more targets common to all scan positions, the better.

Geo-referencing

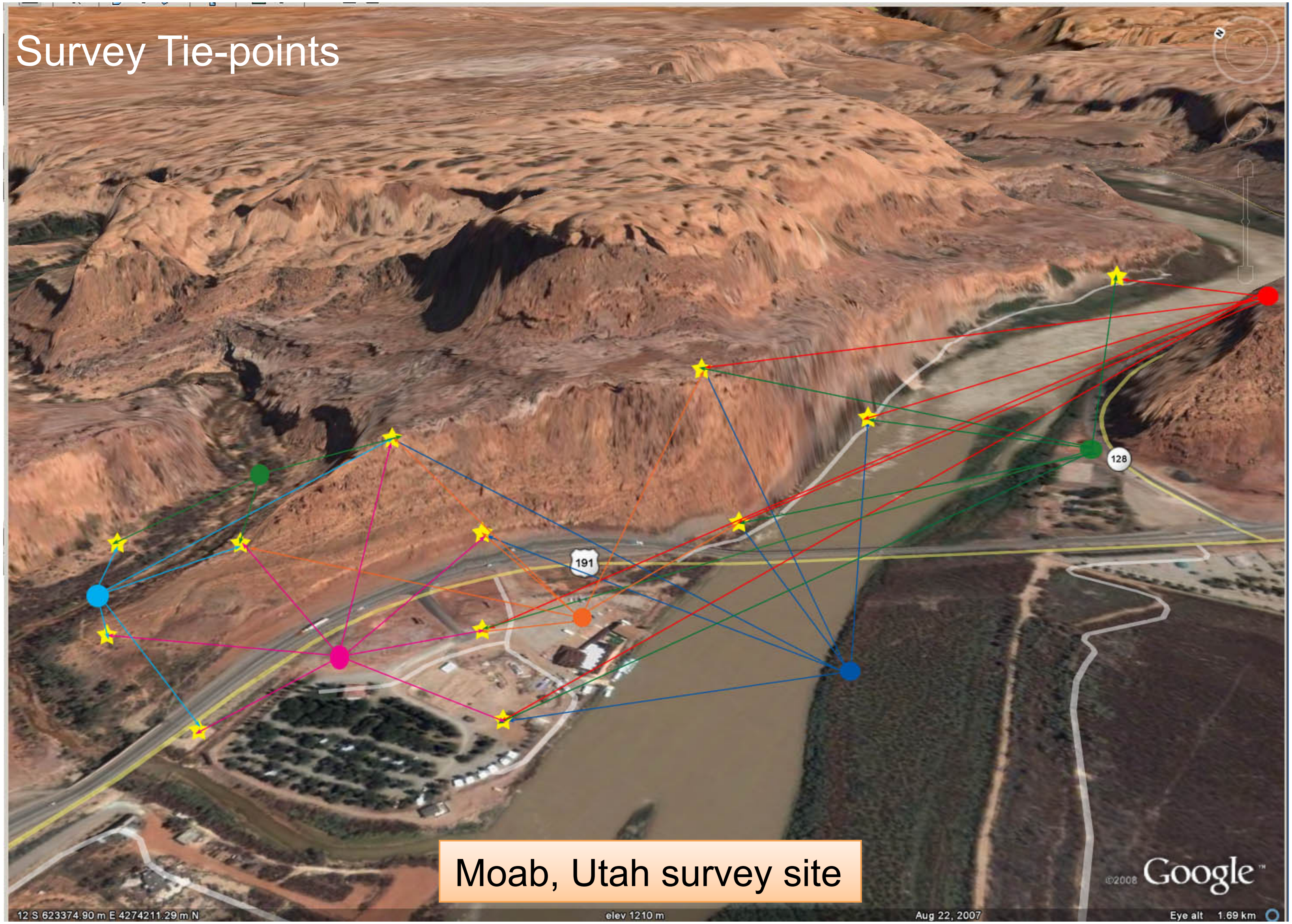


TLS Survey Workflow



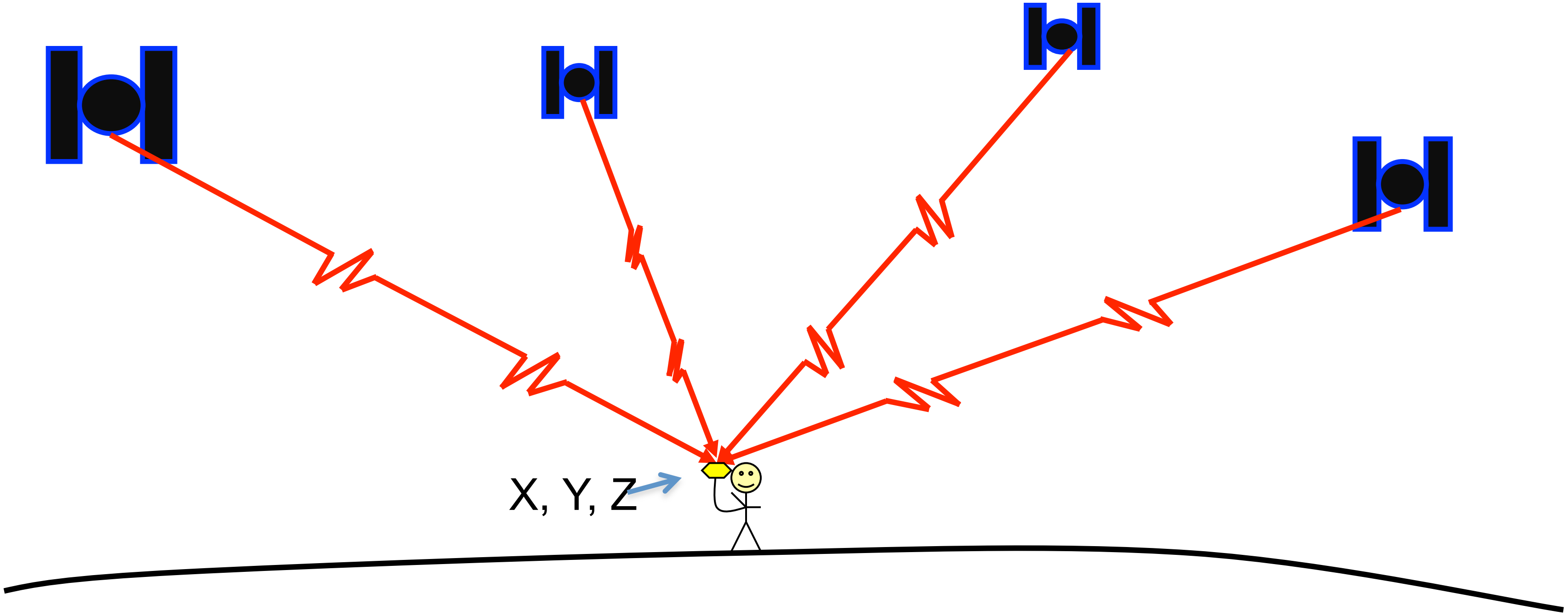

Multiple survey positions
191
128
Moab, Utah survey site
©2008 Google
12 S 623374.90 m E 4274211.29 m N
elev 1210 m
Aug 22, 2007
Eye alt 1.69 km

TLS Survey Workflow



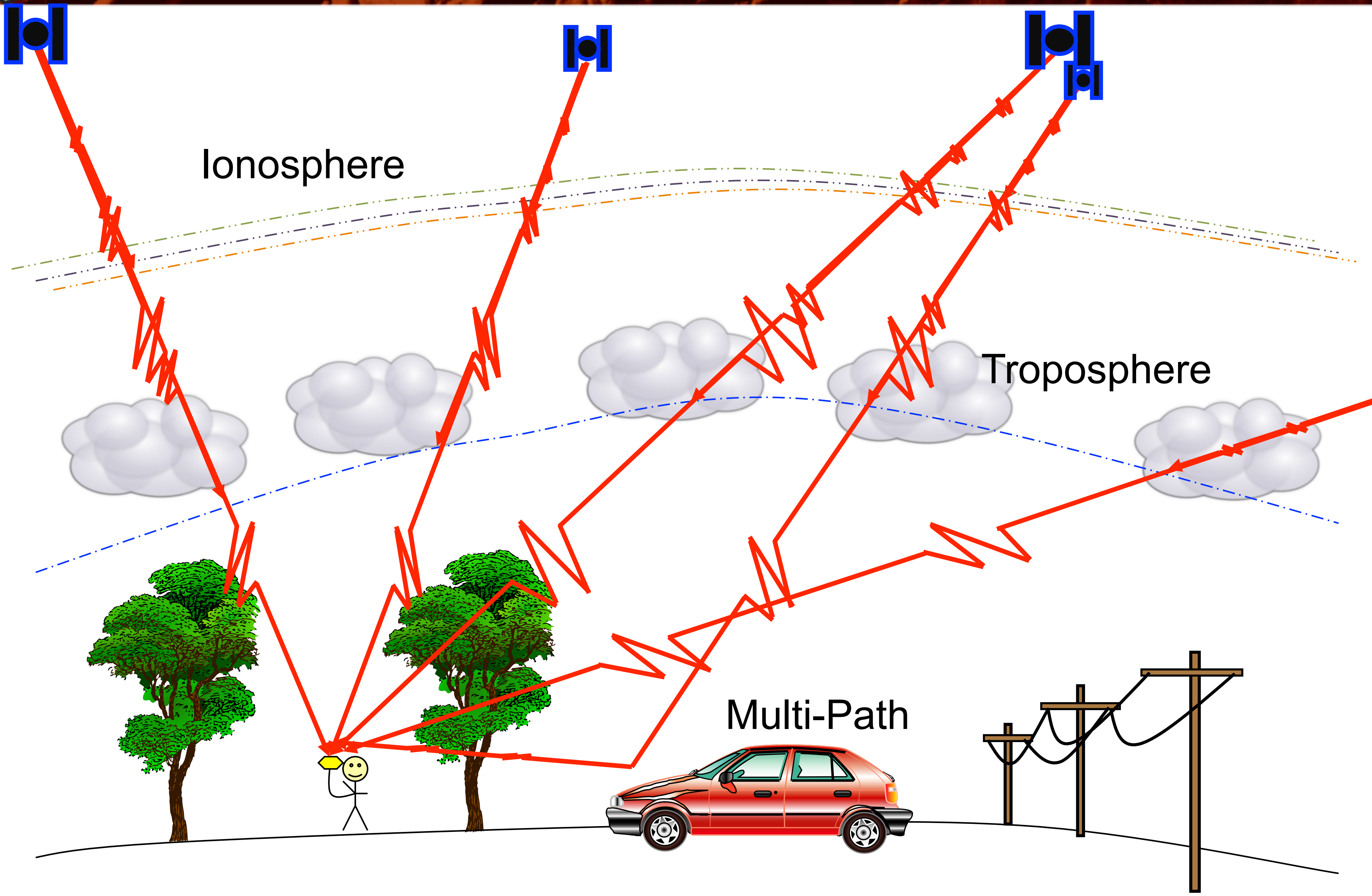
Global Positioning System

- Constellation of thirty-one satellites that each house an atomic clock.
- Precise time information is sent to a receiver on Earth.
- A minimum of four satellites in sky view is needed to obtain a coordinate.



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.


Ionosphere
Troposphere
Multi-Path

GPS solution errors

- Depends on type of survey, baseline lengths, environmental factors (solar flares, multipath), instrument error (clock drift)

Survey type	Occupation Time	Error – horizontal (vertical = 2x)
Static	2 hours – days	0.5 – 1 cm
Fast static	20 minutes – 2 hours	1 – 3 cm
Post-processing Kinematic	20 minutes – 2 hours	2 – 5cm
Real-time kinematic	Seconds – hours	2cm – 5cm (range dependent)

- Scaling errors
  - Atmospheric conditions can vary across a field site – long range scanners can't correct for this.
  - Effect is generally minimal – mm in range calculation over 100's of meters.

What does that leave us with?

Error type	Magnitude
Instrument precision & accuracy	3,5 mm - __?__ cm
Registration/Alignment	0.3 – 3 cm
GPS solutions	0.2 – 5 cm
Scaling (atmospheric)	0.1 – 2 mm
Operator error	?

Best case scenario: **~ 1 cm**

Worst case scenario: **~10-20 cm** … or more

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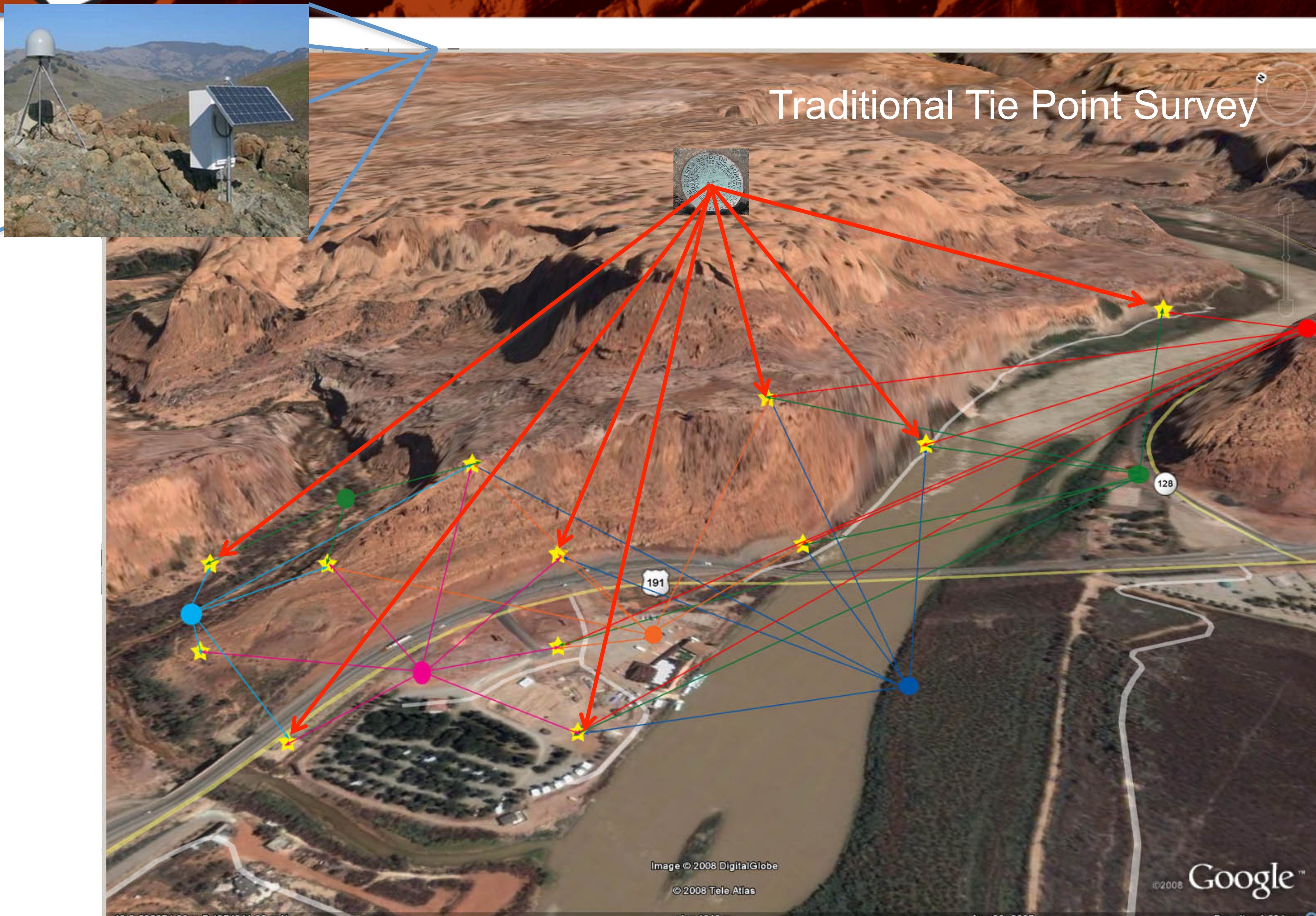
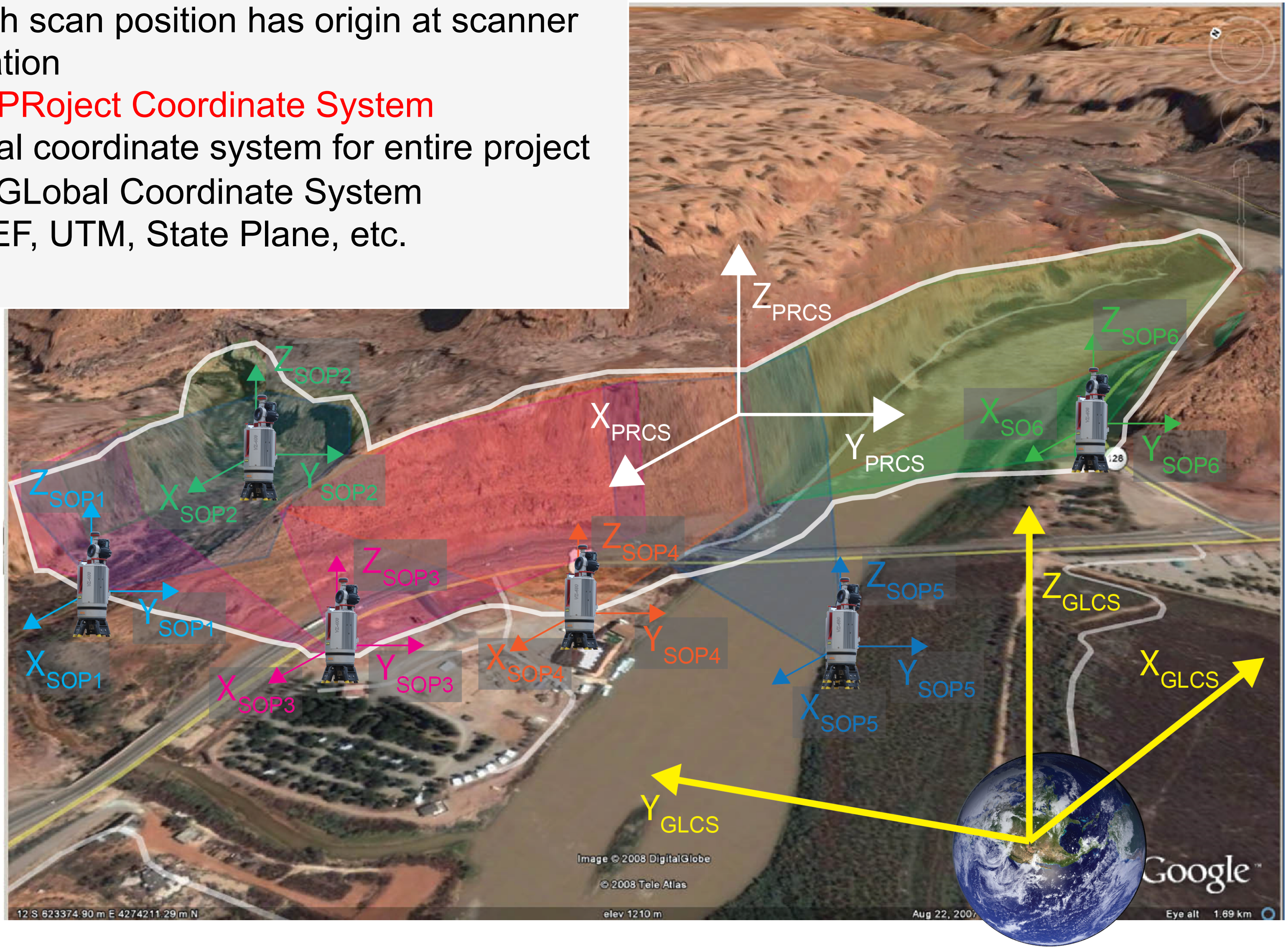
Adding GPS to a TLS Survey



Adding GPS to a TLS Survey

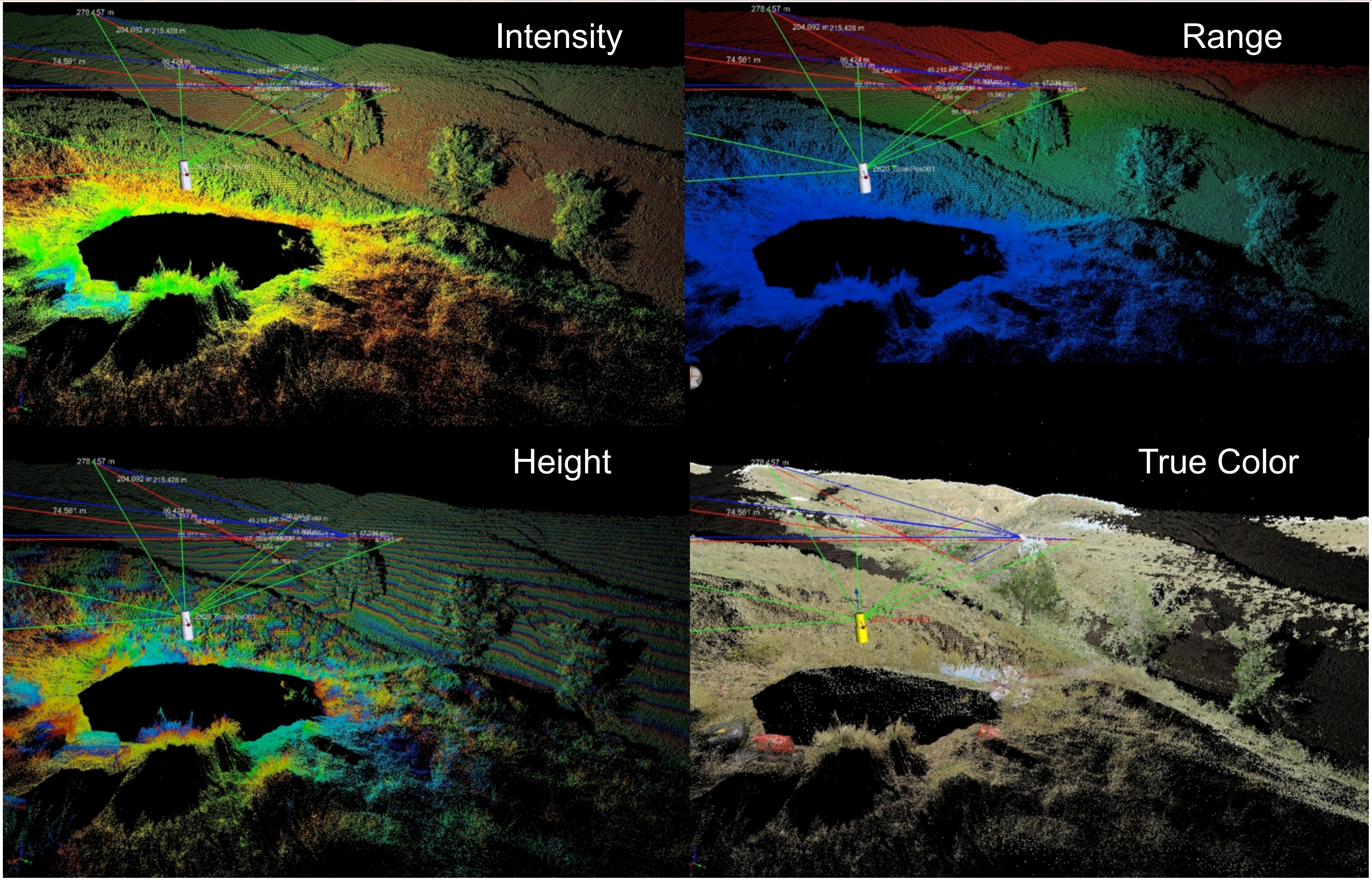
- SOCS – Scanner Own Coordinate System
  - Each scan position has origin at scanner location
- PRCS – PRoject Coordinate System
  - Local coordinate system for entire project
- GLCS – GLobal Coordinate System
  - ECEF, UTM, State Plane, etc.



Point Cloud

- 3D “point cloud” of discrete locations derived from range and orientation of scanner for each laser pulse.
- XYZ position in Cartesian coordinates plus associated point attributes: intensity, RGB, etc.
- 3D point clouds are the basis for subsequent analysis and used to create CAD or GIS models.

Data Visualization



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.