Am I Getting What I Thought I Was Getting?

Instrumentation

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Joseph V.R. Paiva, PhD, PS, PE

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In this Presentation

- Discussion of instrumentation
- What the manufacturer tells you
- Interpreting what the mfr tells you
- Understanding how you/your team uses the technology
- Monitoring instrumentation

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Most Commonly Used

- Total Stations (including robots)
- Automatic Levels
- GPS/GNSS
- LiDAR Scanners (maybe?)
- sUAS (maybe?)
- Steel tapes (maybe?)
- Cloth/fiberglass/etc. tapes (I hope)

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Total Stations

- Basically theodolite with EDM built-in
- Telescope carries a lot of “responsibility”
- Reticle for angle measurement, EDM for distances, target seeking/locking for robotic, laser pointer for layout work

Basically, a lot that can go out of kilter

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Automatic/Digital Levels

- Telescope (so there's a reticle)
- Compensator to ensure LOS is horizontal
- If digital there's a system to "read" the rod
- With digital also electronic data capture and possibly workflow assistance
- Let's not forget the rod

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GPS/GNSS

- Highly automated
- Set up, turn on, turn off, process data in field or in office
- With real-time, monitoring by team is necessary to avoid GIGO

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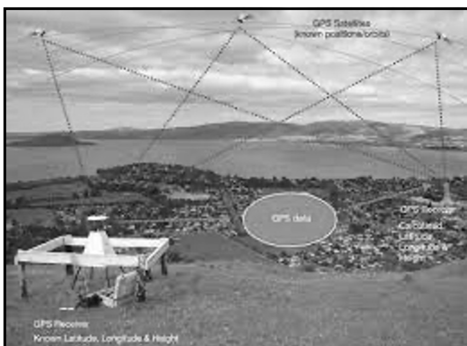

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LiDAR

- What do we know about it?

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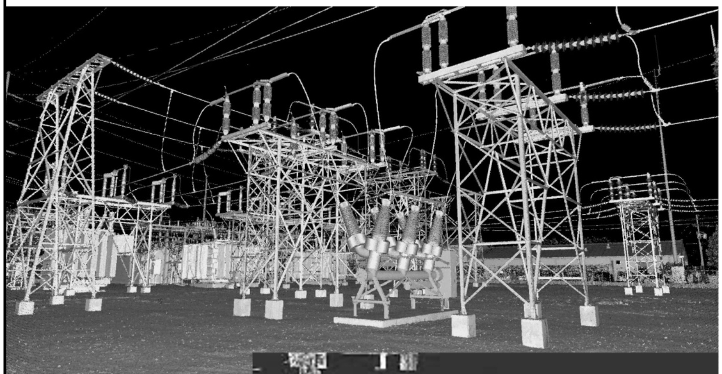

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sUAS

- What do we know about it?

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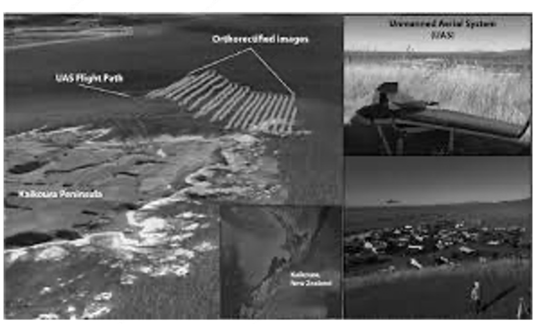

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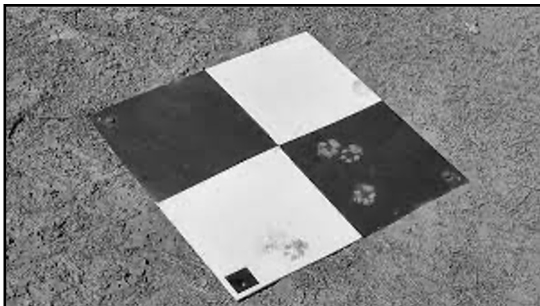

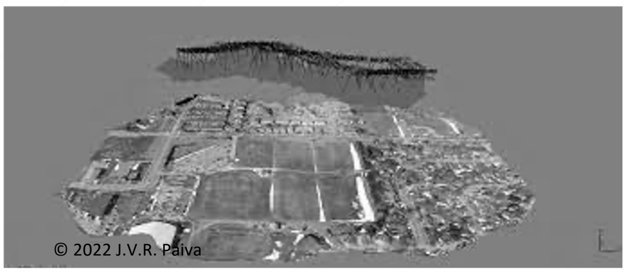

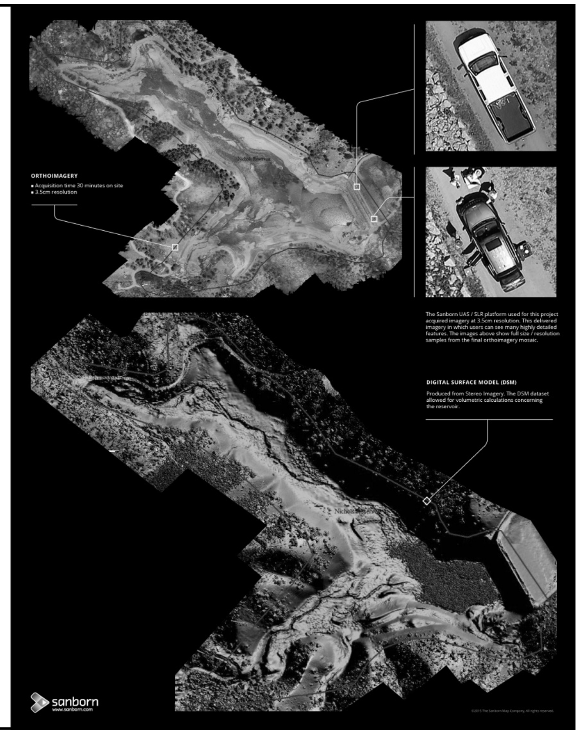

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Steel Tapes

- Why?
- How do they work?
- What are the limitations

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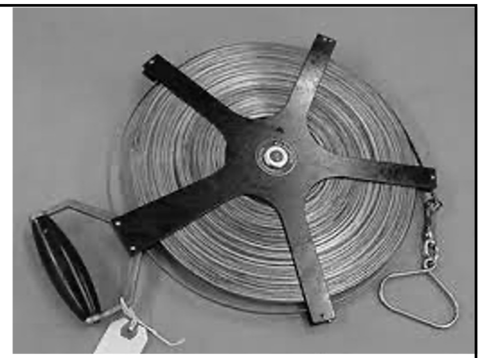

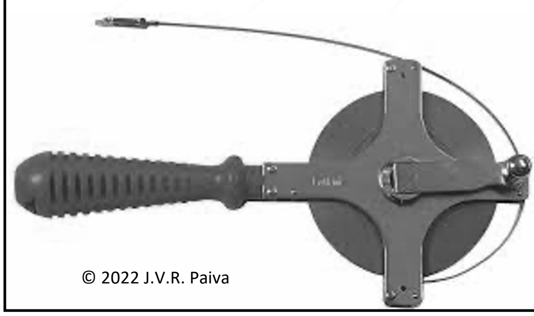

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Non-metallic tapes

- What are they used for?
- Do they need to be accurate?
- Is there any kind of "care and feeding" for these?
- How is the surveying team trained to use these?

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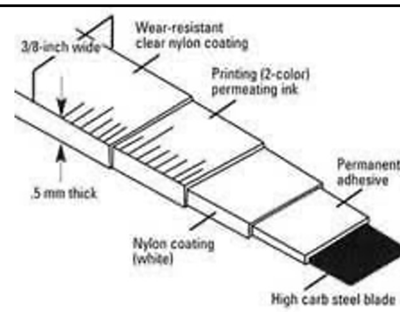
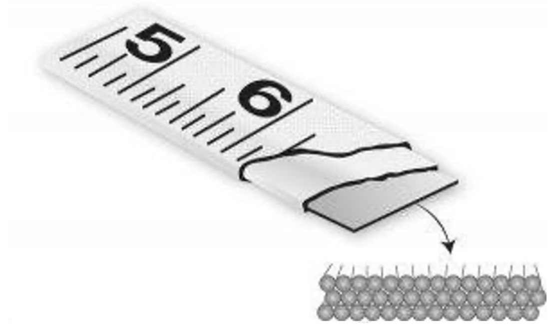
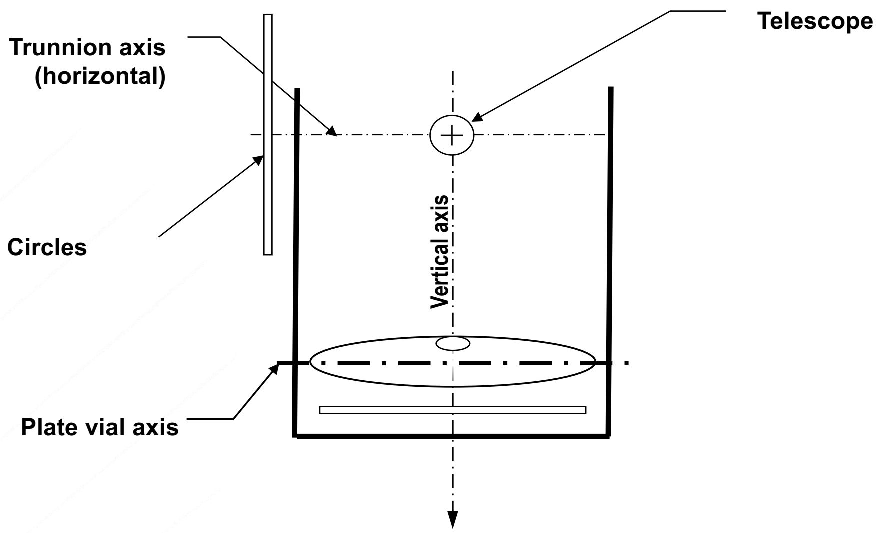
Types of Non-Metallic Tapes

- Cloth
- Fiberglass
- Combo
- Various types of plastic with or without reinforcing fibers
- Nylon clad steel tapes





Basic Alignment of Theodolite



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Check Bubbles

- Spec is x” per 2 mm of bubble travel
- Find reversing point for use by field teams
- Avoid direct sun on bubble
- Compensator IS THE BUBBLE on some instruments
- Requires reading manual to properly understand it to use it

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Check Reticle Alignment

- Point at target
- Record H & Z readings
- Invert telescope, repeat readings
- Do they differ? If so, Δ is twice the error
- Repeat 5 to 10 times and average to get a reasonable conclusion

Check EDM Alignment

- Best done in shop where they have an IR camera (if EDM is IR)
- Center of EDM beam must align with reticle
- Many cm in distance error is possible if this is not properly aligned to reticle

Auto-Pointing Alignment Check

- Auto-point to target
- Visually check reticle position
- Out of alignment condition is easy to determine
- DO NOT LET THIS ONE GO!

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Laser Pointer Check

- Similar to auto-pointing check
- You cannot let this one go either if you do layout work with this, especially in robotic mode

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Height of Standards Check

- Sight solid, unmoving point at least 15° above horizontal (more is better)
- Then drop down and sight point on ground 100-150 ft away, mark it
- Invert telescope and repeat to see if you hit the ground point
- Any miss indicates that even if instrument is leveled, telescope is not tracking a vertical line

Now, About Angle Accuracy

- What is mfr's spec? How stated?
- If it is DIN or ISO, ±3", for example is not what you think it is
- The spec is the uncertainty (standard deviation) for ONE direction
- Angle is TWO directions, so multiply spec value by 1.4 to get uncertainty in angle measured F1/F2

EDM Accuracy

- What is mfr's spec? How stated?
- Many times confidence level is not indicated
- Manufacturer's advertising is created by people who really don't know
- So, distrust and verify

EDM Accuracy by Range

Accuracy	100 Ft.	1100 Ft.	2200 Ft.	3300 Ft.
±(2mm+2ppm)	±2.1mm=0.007ft	±2.7mm=0.009ft	±3.3mm=0.011ft	±4mm=0.013ft.
±(2mm+3ppm)	±2.1mm=0.007ft	±3.0mm=0.010ft	±4.0mm=0.013ft	±5mm=0.016ft.
±(3mm+2ppm)	±3.1mm=0.010ft	±3.7mm=0.012ft	±4.3mm=0.014ft	±5mm=0.016ft.
±(3mm+3ppm)	±3.1mm=0.010ft	±4.0mm=0.013ft	±5.0mm=0.016ft	±6mm=0.020ft.
±(3mm+5ppm)	±3.2mm=0.010ft	±4.7mm=0.015ft	±6.3mm=0.021ft	±8mm=0.026ft.
±(3mm+10ppm)	±3.3mm=0.011ft	±6.3mm=0.021ft	±9.7mm=0.032ft	±13mm=0.042ft.
±(5mm+2ppm)	±5.1mm=0.017ft	±5.7mm=0.019ft	±6.3mm=0.021ft	±7mm=0.023ft.
±(5mm+3ppm)	±5.1mm=0.017ft	±6.0mm=0.020ft	±7.0mm=0.023ft	±8mm=0.026ft.
±(5mm+5ppm)	±5.2mm=0.017ft	±6.7mm=0.022ft	±8.3mm=0.027ft	±10mm=0.033ft.

EDM Baseline

- Rigorous field process
- Easy to make mistakes
- Long and tedious
- Evaluate scale and constant errors
- Standard deviation

- *Use of Calibration Base Lines* NOAA Technical Memorandum NOS NGS-10
- Computation using "CALIBRAT"

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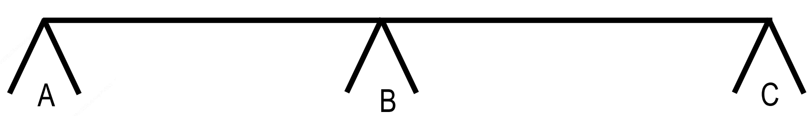
Determining Prism & Instrument Constants



AB + BC should equal AC

If error exists (***e***), then

it will be in each of the measurements, thus

AB + BC – AC = ***e***

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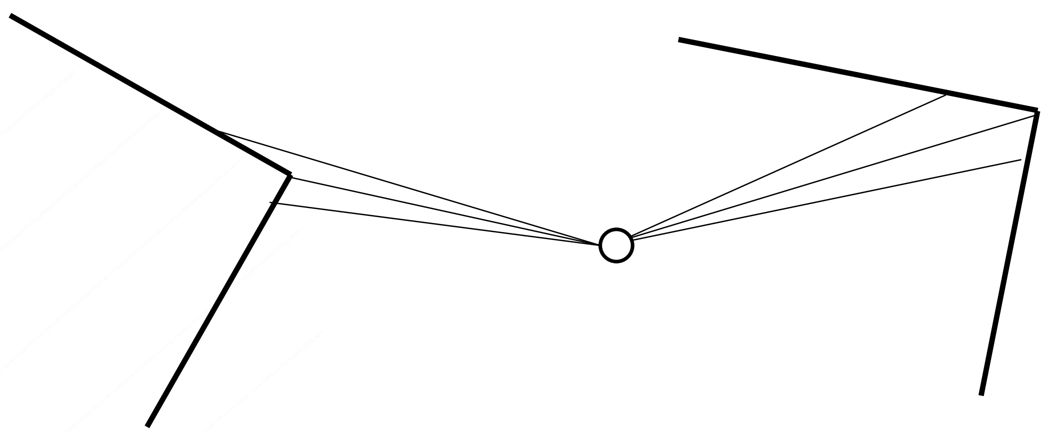
Prismless EDM Operation



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Auto/Digital Levels

- Compensator accuracy and maintenance
- Do you teams know how to do simple checks?
- KNOW two-peg test
- Process using balanced sighting distances is important when running loops

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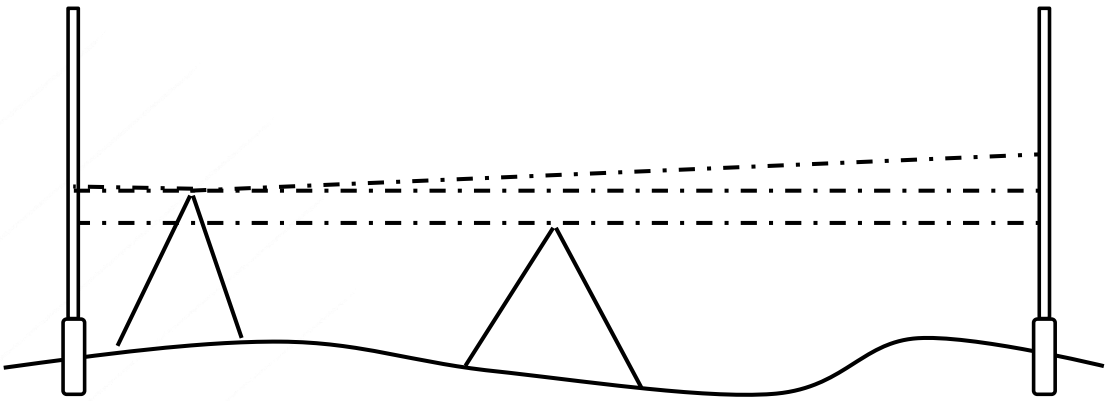
Two-Peg Test

Δ elev determined from center is accurate

Setup near one peg allows calculation of what should be observed on distant peg



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GPS/GNSS Error Sources

- Systematic errors called “biases”
- Can originate at satellites
- Can originate at receiver
- Can be from signal propagation

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Other GPS/GNSS Error Sources

- Base station location (ha!)
- Antenna height
- Effect of geoid
- Phase and range measurement errors
- Atmospheric attenuation of signal
- Phase center errors

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More Errors

- Satellite (space segment) errors – ephemeris, clock, etc.)
- Receiver (user segment) errors – clock, multipath, phase center, rx measurement noise
- Ionosphere, troposphere
- Geometry (DOP)

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Also…

- Network design
- Meaningless measurements because they are NOT independent
- Most flagrant errors caused by not understanding that GPS does NOT measure rover's position—it resolves VECTOR between base and rover

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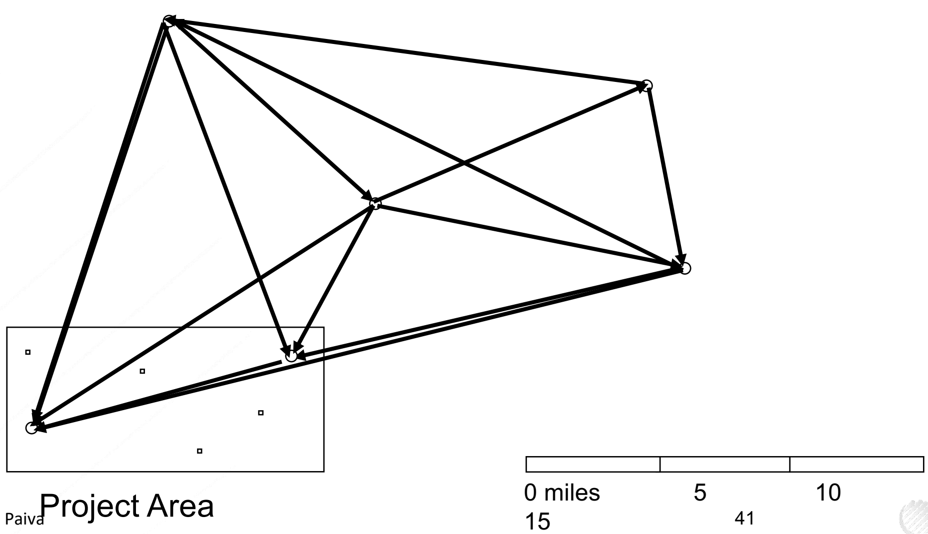
GPS Mistakes vs. Good Technique



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GPS Checking

- Use independently adjusted network or use carefully thought-out procedures to set up your own
- Couple of short to medium-sized lines within easy reach to do quick checks of RTK and static obs
- Observe the network (should be a braced quadrilateral optimally) periodically

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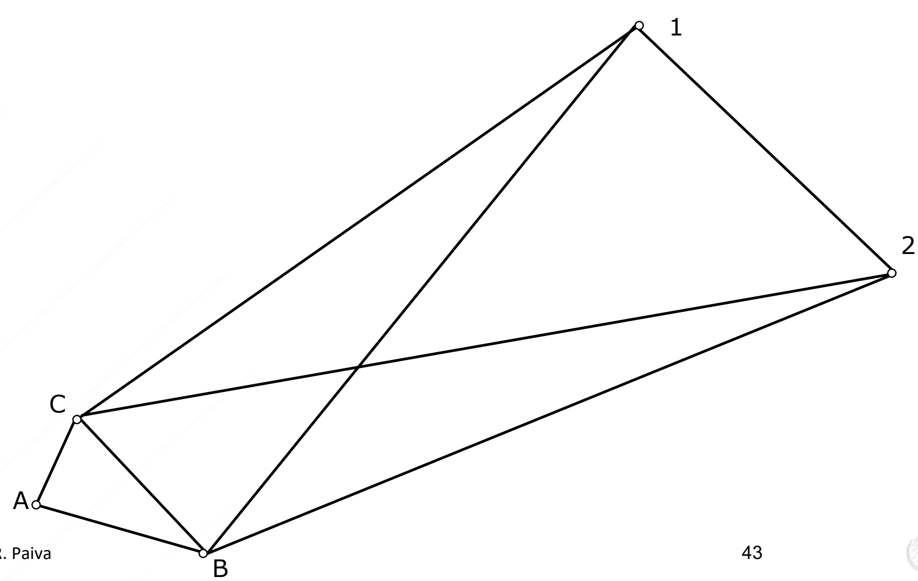
Suggested GPS Test Network



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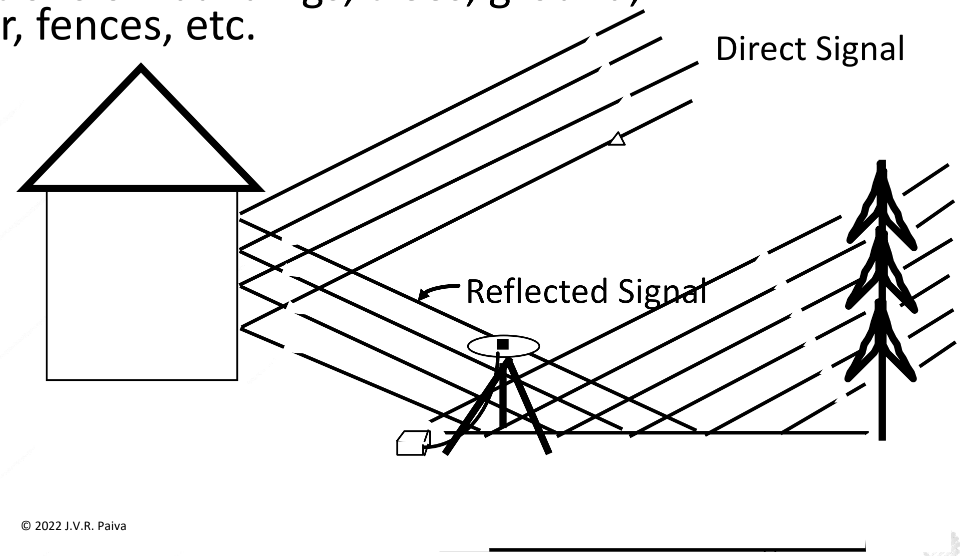
Multipath

Reflections off buildings, trees, ground, water, fences, etc.



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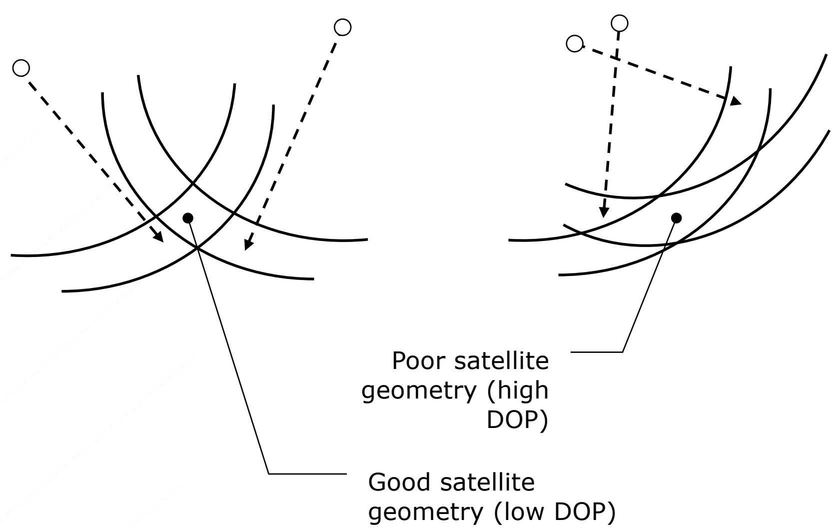
Satellite Geometry



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Geometry Considerations

- PDOP, HDOP and VDOP should be checked periodically
- Before surveying look at values
- But remember "shading" can change what you expected so look at it while surveying too
- Vertical positioning is always a poor intersection—vertical accuracy worse than horiz by multiplier of 1.5 to 2

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Elevation vs. Altitude

- GPS altitude is height above WGS-84 ellipsoid
- Elevations are height above mean sea level
- Sea level, unlike the ellipsoid is a non-smooth undulating surface
- In US "geoid separation" can be up to 100 m

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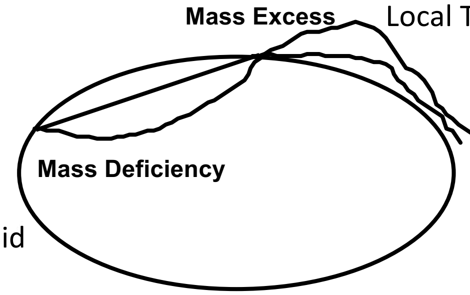
Ellipsoid, Geoid, Topography



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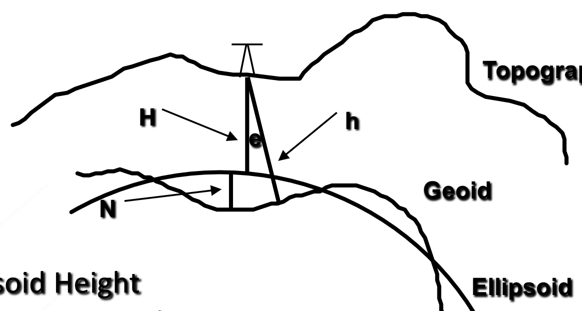
Geometric Relationships



H = Ellipsoid Height
h = Orthometric Height
N = Geoid Undulation

H = h + N
e = Deflection of the vertical

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Coordinate Systems

- GPS measures in WGS-84 Cartesian
- Surveyor could be using SPCs, UTMs, other systems
- Converting from "native" GPS system to surveyor's system can be fraught with errors (and mistakes)
- "Localization," "calibration," "transformation" add problems of their own

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LiDAR

- Have check shapes (planes, spheres, hemispheres, cylinders)
- Use different ranges (dist to objects)
- Find out about compensator
- Your software may indicate problems because of difficulty "stitching"
- Use targets (control): moving from scan to scan

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sUAS

- Ground control
- Independent check points
- Check out the drone for vibration (various sources)
- Be sure the camera is not too wide angle and has good enough quality to resolve the ground

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"Other Stuff"

- Accessories, peripherals, whatever

Optical plummet
Antenna pole bubble
Antenna cables
Antenna pole straightness
Tripod stability
Tribrach bubble
Antenna pole height

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How Much is the Error?

- Typical level vial sensitivity can vary on prism poles from 10 to 60 minutes
- The level spec refers to the angle change to move the position of the bubble 2 mm
- If 30 minutes, and the bubble is 2 mm out-of-center…
- Prism on top of 6 ft pole is out of plumb 0.05 ft
- How to calculate?

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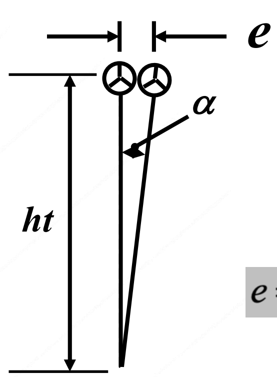
Calculating Prism/Antenna Pole Error



$$\alpha = \tan^{-1} \frac{e}{height}$$

$$e = height \times \tan \alpha = 6\,ft \times \tan 30' = 0.052\,ft$$

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Level Vial Centering/Adjustment

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Optical Plummets

- If not rotatable, watch out!
- Know how to check
- Know how to adjust
- Errors in excess of 0.1 ft per setup not uncommon
- These apply to optical and laser plummets, no matter what “they” tell you there is no difference!

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Better Option for O.P. Tribrachs

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For ALL Technology

- Specs are often published for ideal conditions, assuming “the surveyor understands how to interpret the spec for their application”
- There are many things YOU are responsible for
- Even if you do them perfectly, chances are you are causing published accuracy potential to deteriorate

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What Things?

- Weather (how you shield technology for it, or compensate for its effects)
- Other environmental conditions: vibrations, ground condition
- Support: Tripod, tribrach, target, prism/antenna pole, prism, cables, etc.

Thank You

About seminar presenter Joseph V.R. Paiva

Dr. Joseph V.R. Paiva, is principal and CEO of GeoLearn, LLC (www.geo-learn.com), an online provider of professional and technician education since February 2014. He also works as a consultant to lawyers, surveyors and engineers, and international developers, manufacturers and distributors of instrumentation and other geomatics tools, as well being a writer and speaker. One of his previous roles was COO at Gatewing NV, a Belgian manufacturer of unmanned aerial systems (UAS) for surveying and mapping during 2010-2012. Trimble acquired Gatewing in 2012.

Selected previous positions Joe has held includes: managing director of Spatial Data Research, Inc., a GIS data collection, compilation and software development company; senior scientist and technical advisor for Land Survey research & development, VP of the Land Survey group, and director of business development for the Engineering and Construction Division of Trimble; vice president and a founder of Sokkia Technology, Inc., guiding development of GPS- and software-based products for surveying, mapping, measurement and positioning. Other positions include senior technical management positions in The Lietz Co. and Sokkia Co. Ltd., assist. professor of civil engineering at University of Missouri-Columbia for 11 years, partner in a surveying/civil engineering consulting firm.

Joe has continued his interest in teaching by serving as an adjunct instructor of online credit and non-credit courses at the State Technical College of Missouri, Texas A&M University-Corpus Christi and the Missouri University of Science and Technology. His key contributions in the development field are: design of software flow for the SDR2 and SDR20 series of Electronic Field Books, project manager and software design of the SDR33, and software interface design for the Trimble TTS500 total station. He holds several patents.

He is a Registered Professional Engineer and Professional Land Surveyor, was an NSPS representative to ABET serving as a program evaluator, where he also served as team chair and commissioner, and has more than 30 years experience working in civil engineering, surveying and mapping. Joe writes for has written for many publications including *POB*, *The Empire State Surveyor,* and the *Missouri Surveyor,* and many other publications and has been a past contributor of columns to *Civil Engineering News*. He has published dozens of articles and papers and has presented over 150 seminars, workshops, papers, and talks in panel discussions, including authoring the positioning component of the Surveying Body of Knowledge published in *Surveying and Land Information Science*. Joe has B.S., M.S. and PhD degrees in Civil Engineering from the University of Missouri-Columbia. Joe's past volunteer professional responsibilities have included president of the Surveying and Geomatics Educators Society (SaGES) 2017-19 and various *ad hoc* and organized committees of NSPS, the Missouri Society of Professional Surveyors, ASCE and other groups.

GeoLearn is the online learning portal provider for the Missouri Society of Professional Surveyors, and several other surveying professional societies in including New York and Oklahoma.

Dr. Paiva can be reached at joepaiva@geo-learn.com or on Skype at joseph_paiva.

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