MSPS "Spring Workshop" 2020

Common Mistakes & Blunders

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Get Something Straight

- Mistake is a blunder

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Error

- Comes from three sources
  - Personnel (call personal errors)
  - Nature (called natural errors)
  - Instrumentation (called instrumental errors)
- Two Types
  - Systematic
  - Random

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When You Make Measurements

- Natural, personal and instrumental errors, whether random or systematic are ERRORS
- But when you introduce a discrepancy because you didn't sent the prism constant correctly…
- That is a MISTAKE or BLUNDER
- So don't call it an error

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One Other Thing: Probability

- Or confidence in measurements
- If I ask you how well can you position a point, what answer do you give me?
- Doesn't matter the technology or conditions, just give me an answer

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Standard Deviation

- Uncertainty range that can be expected 68% of the time, due to random errors
- So if you have an instrument that has a standard deviation of ±10" per angle, you can expect the angle you write down to be different from the correct value by up to 10" in either direction, about 2/3 of the time

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What Surveyors Forget

- Any analysis of data that we (should) do assumes that the error is random

1. Generally small errors
2. Equal chance of positive or negative errors
3. Probability of large errors is low

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So Before Doing Error Analysis

- Remember that it is RANDOM error analysis
- This means that all systematic errors and mistakes must be removed from the data
- Otherwise, results of analysis are meaningless

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Checking Between Two Monuments

- Given: distance between monuments A and B is 4,529.32 ft
- Uncertainty at A, 95% confidence is ±0.15 ft
- Uncertainty at B, 95% confidence is ±0.20 ft
- With your static GNSS system you measure this line and get a number, but it doesn't match
- GNSS spec is ±(1 cm + 2 ppm) standard deviation
- How to figure out whether your number fits?

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Uncertainty in Your Control

- Random error combines as the square root of the individual terms squared and summed, in other words
- $E_{total} = \sqrt{E_1^2 + E_2^2 + \cdots \cdots E_n^2}$
- So for line AB, based on published uncertainty we can expect uncertainty in the distance to be $\sqrt{0.15^2 + 0.20^2} =$ 0.25 ft
- This is at the 95% confidence level
- If we want std deviation, 68% confidence, we divide by 2 (actually 1.96, but OK to round to 2), so $\sigma = 0.125\ ft$

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But Our Measuring System is Not Perfect

- It has defects; manufacturer tells us that each position has uncertainty of ±(1 cm + 2 ppm), which converts to
- 0.033 + 0.009 = ±0.042 ft per end point with 68% confidence
- So our result has uncertainty of $\sqrt{0.042^2 + 0.042^2}$
- This can be simplified, if you wish, to $\sqrt{2}\times 0.042 = 0.059\ ft$
- So your "measuring tape" you've stretched between A and B has an uncertainty of 0.059 ft at 68% confidence

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…And Our Control is Not Perfect

- Our control is only good to 0.125 ft standard deviation
- To figure out how much our measured distance should fit within, we use the same equation again
- $uncertainty\ of\ fit = \sqrt{0.125^2 + 0.059^2}$ = 0.138 ft
- So we can have a measurement that is within the range of ±0.138 ft of the inversed distance between control of 4529.32 and still call it good!

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You're a Surveyor

- KNOW what you are talking about
- Or don't talk ☺

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So How Did "They" Survey?

- Depends on the "Them"
- Depends on the "When"

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How Far Back Do You Want to Go?

- Compass and chain
- Theodolite and EDM (includes total stations)
- GNSS (static and RTK, includes RTN, as in MO DOT, etc. for RTN and OPUS for static observation)

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It Is Always Helpful to Analyze Work

- When following a description, if it doesn't close, what could have happened?
- Most obvious things to check include
  - Typos
  - Transcriptions
  - Calls out of order
  - Missing final or other call (thence to the POB)

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We Could Also Have

- Odd directions
- Odd distances
- Odd commencement points
- Odd POBs
- Odd monuments
- Deceased witness trees (or ”successors”)
- Etc.

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We Like to Point Out…

- Other people's mistakes or even honest errors
- But what about our own?

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So…The Easiest Example

- Four sided figure, 1,000 ft on a side, roughly square
- You survey along with your total station
- You come to a monument
- You fall 0.2 ft north and 0.1 ft east
- Obviously you are right, so set "your" monument as the correct one

No!

- Lots to think about including what Cooley said
- …and the fact that in an original survey, monuments, once set, settle the location question
- You, the follower, has the duty to only find where the original monuments were set

NOT

- To correct them (the original monuments)

Remember

- Original survey is a measurement task
- Retracement is an evidentiary exercise

Cooley's Words

- "…when one or more corners is extinct…, all parties have acquiesced to lines based on points that may not be trustworthy…."

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Cooley continued

- …but to bring discredit, when people concerned do not question them… "breeds trouble in the neighborhood…"
- "…often subjects the surveyor to discredit…"
- "…long acquiesced line may be better evidence of the real line that any survey made after the monuments have disappeared."

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Coming Back to Our Example

- 1,000 ft shot
- 5” total station
- EDM spec: ±(3 mm + 2 ppm)
- Angle accuracy in one shot is approximately ±0.03 ft cross error
- Distance error (inline) in one shot approx. ±0.01 ft

So That’s IT, Right?

- Not really
- First of all, have you checked in at previous monuments?
- Then…what about your work?
- “Moi?”

How Reliable is Your System?

- Total station adjustments for angle
- Total station adjustments for distance
- Prism constant
- Target quality
- Tripod stability
- …continued

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System…

- What’s your start point and its reliability?
- What’s your “to” point and its reliability?
- Optical plummet on instrument
- Level bubble on instrument
- How is your target plumbed and leveled?

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When You Add It All Up

- Good question, how do you add it all up?
- In this case uncertainty is probably in the range of 0.05 to 0.10 feet for good quality crew and system

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Taking Just One Example

- Prism/target pole
- How does it work?
- What do you use it for?
- How often do you inspect it?
- How often do you adjust it?

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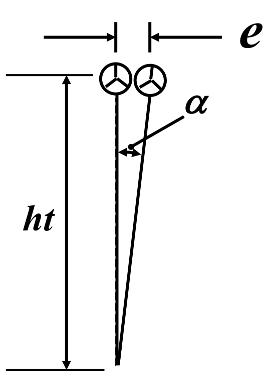
A Big Question: Bubble Sensitivity

- Bubble is rated (whether circular or linear) as angle change when moved out of plumb for every 2 mm of bubble movement
- Typical circular vials poles: 60, 40, 30 minutes
- Tribrach circular vials: 10, 8 minutes
- Total station linear vials: 40, 30, 20 seconds

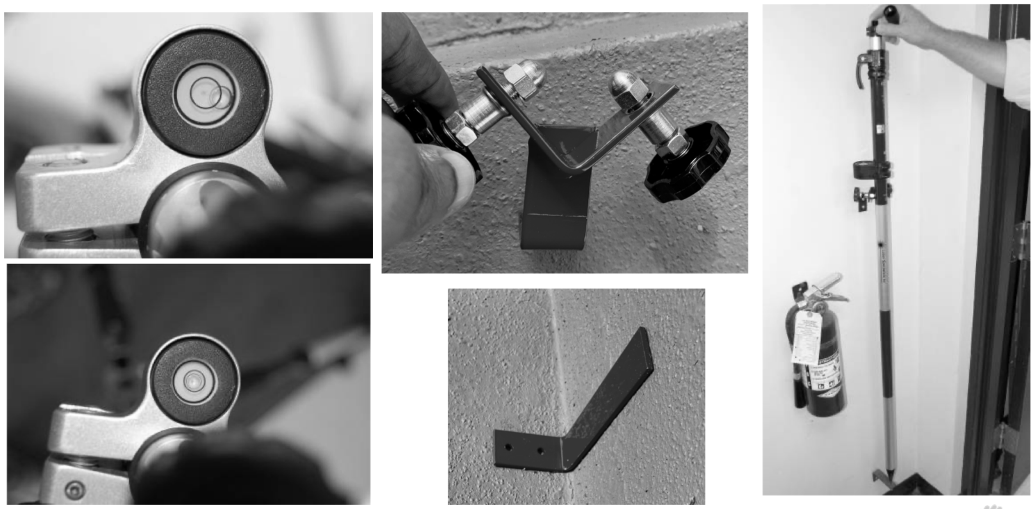
Importance of Prism Pole Circular Vial Adjustment



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

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

Prism Pole Bubble Check and Adjust



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Estimating Your System

- Break it down
- Estimate magnitude of each contribution of error on an estimated standard deviation basis
- Take square root of sum of the squares

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Conditions Causing 0.01 ft Error in 100 ft.

(calibrated steel tape)

Tape Length	0.01
Temperature	15° F
Tension (pull)	5.4 lbs
Sag	7.5” at center
Alignment	1.4 ft at one end/7.5” at center
Tape Not Level	1.4 ft diff in elevation
Plumbing	0.01
Marking	0.01
Interpolation	0.01

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Possible Errors Using Common Procedures

Standard 100 ft measurement with calibrated tape

Source	Error (ft.)	$Error^2$
Tape Length	Known	0.000000
Temp (10° F error)	0.006	0.000036
Tension (5 lb error)	0.009	0.000081
Alignment (0.05 ft)	0.000	0.000000
Tape Not Level (0.5 ft)	0.001	0.000001
Plumbing	0.005	0.000025
Marking	0.001	0.000001
Interpolation	0.001	0.000001
SUM	0.023	0.000145

1: 8,000 OR
120 PPM

Sq Rt of [Sum of $Errors^2$] = 0.012 ft

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Possible Errors Using Common Procedures

Calibrated EDM (100 ft; accuracy 3 mm + 3 PPM)

Source	Error (ft.)	Error^2
Length	Known	0.000000
Temp (10^o F error)	5 PPM = 0.0005	0.00000025
Pressure (1" Hg)	5 PPM = 0.0005	0.00000025
Centering w/pole	0.03	0.0009
Centering w/O.P.	0.005	0.000025
Mfr's error const.	0.003	0.000009
Mfr's error scale	3 PPM = 0.0003	0.00000009
SUM	0.0393	0.000093459

1: 3,000 OR
306 PPM

Sq Rt of [Sum of Errors^2] = 0.0306 ft

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Possible Errors Using Common Procedures

Calibrated EDM (5,000 ft; accuracy 3 mm + 3 PPM)

Source	Error (ft.)	Error^2
Length	Known	0.000000
Temp (10^o F error)	5 PPM = 0.025	0.000625
Pressure (1" Hg)	5 PPM = 0.025	0.000625
Centering w/O.P.	0.005	0.000025
Centering w/O.P.	0.005	0.000025
Mfr's error const.	0.003	0.000009
Mfr's error scale	3 PPM = 0.015	0.000225
SUM	0.078	0.001534

1: 127,000 OR
8 PPM

Sq Rt of [Sum of Errors^2] = 0.03917 ft

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Possible Errors Using Common Procedures

RTK GPS (pole w/bipod) 2,500 ft baseline ±(1 cm + 2 PPM)

Source	Error (ft.)	Error^2
Length	Known	0.000000
Tropo delays	0.0025 m = 0.008 ft	0.000067
Centering w/O.P.	0.005	0.000025
Centering w/O.P.	0.005	0.000025
Mfr's error const.	0.01 m = 0.03281	0.001076
Mfr's error scale	2 PPM = 0.005	0.000025
SUM	0.05581	0.001218

Sq Rt of [Sum of Errors^2] = 0.0349 ft

1:72,000 OR
14 PPM

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But GNSS Doesn't Have Such Complications?

- Think again
- The easier the black box technology, the harder to understand how it works
- The harder to understand how errors are propagated
- So errors are harder to mitigate

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Faulty GNSS RTK Initialization

- RTK is not perfect
- Manufacturer’s spec doesn’t duplicate real life
- What’s there in real life that’s not in the test?
- Multipath
- Shadowing resulting in smaller number of satellites
- Latency
- Space weather
- Do you look at skyplots anymore?

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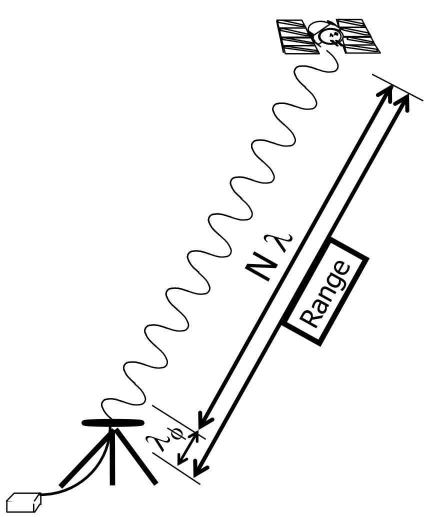
The Integer Ambiguity



- Receiver measures partial wavelength when it first locks on
- Partial, circularly polarized phase is read like a clock
- Receiver counts successive cycles after this
- Receiver does not know whole number of wavelengths (behind that first partial one) between it and SV

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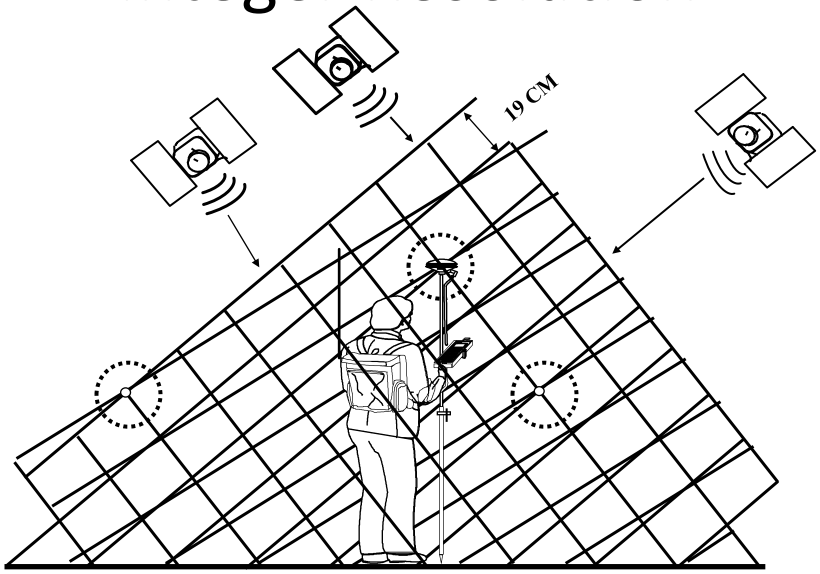
Integer Resolution



Faulty Initialization Mitigation

- Occupy all points or key points or control points more than once
- When you do the re-occupation, break lock and re-initialize
- Occupy known control set by either/and other different methods, different bases, different time of day; usually guarantee of different constellation

Faulty Initialization Mitigation

- Static GNSS is accurate because satellites move large distances during observation (~6,500 mph)
- Relatively small satellite movement with RTK/RTN even 3-5 minute occupations

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Using Steel Tape to Calibrate EDM

- Don’t do it!
- Enough said

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Optical Plummet on Tribrach

- Either optical or laser
- Equipment: tripod, “hockey puck,” tribrach AND the tribrach you are checking/adjusting
- Set up tribrach on tripod indoors, firm footing, but <u>leveling</u> not needed

Optical Plummet on Tribrach

- Put hockey puck in tribrach, then tribrach to be checked upside-down on hockey puck
- Observe mark on ceiling with reticle, rotate tribrach 180°
- Any observed movement is TWICE the error in the plummet

Talk to The Repair Techs

- Not unusual to see O.P. tribrachs with errors of several tenths of a foot!

Combining Random Errors

$$\sigma_{derived} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \ldots + \sigma_n^2}$$

Random Error of Repeated Operations

$$\sigma_{derived} = \sigma_{single}\sqrt{n}$$

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SO…

- When you determine you have made a “finding” based on measurements,
- ALWAYS question every part of how you arrived at the finding
- Be as skeptical of your own work as that of your predecessors

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The Fancier It Gets, the Harder It Is

- Retracing descriptions is not a competition to see who is more accurate
- Being the original surveyor carries awesome responsibility
- Either way, DO YOUR JOB, leave your "footsteps," imagine *anyone* following you

Thank You!

- Questions: write joepaiva@geo-learn.com

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. Because of this interest in drones, Joe is an FAA-licensed Remote Pilot.

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., assistant professor of civil engineering at the University of Missouri-Columbia, and 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 is a Registered Professional Engineer and Professional Land Surveyor, was an NSPS representative to ABET serving as a program evaluator, where he previously served as team chair, and commissioner, and has more than 30 years experience working in civil engineering, surveying and mapping. Joe writes for *POB*, *The Empire State 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 volunteer professional responsibilities include 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.

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