I. GNSS Use in LS Practice, Including Compliance
II. Errors & Least Square Analysis to Aid I. (above)

MSPS 2021 Spring Workshop

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

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Agenda

- What do you survey?
- How do you survey?
- What about standards?
- Do you comply?

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Part I

3

Do You Use GNSS for Boundary Surveys?

- Poll
- Have you been trained in using GNSS?
- How were you trained?
  - Sales team
  - Formal (form manufacturer or college, etc.)
  - Self-taught

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Do You Use GNSS for Boundary Surveys?

- Poll:
- Do you use static GNSS, RTK (including RTN) or total station for most boundary work?
- How does GNSS work?
- Do you factor in the limitations of GNSS?

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The GNSS Makeup

- Segments
  - Space
  - Control
  - User

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The Signals and Codes

- These vary with GPS, Glonass, Galileo and Beidou
- Do you know the details for GPS at least?
  - C/A, P & Y codes
  - L1, L2, L4

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Do You Use Dual Frequency Rxs?

- Do you prefer them?
- If so, why?
- Can you explain the technical differences

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GNSS As a Navigation Tool

- Range/pseudo range
- Trilateration (multilateration)
- Error sources on signal propagation
- Best practices to receive “cleanest” signals
- Redundant measurements
- Long vs. short measurements

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Do You Use GNSS for Boundary Surveys?

- Geodesy
  - Ellipsoid
  - Geoid
  - SPC systems
  - Realizations and epoch dates

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Ellipsoid

- Insert figure

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Geoid

- Insert figure

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Geoid

- What is it?
- What are orthometric heights?

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Geoid Model

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What Standards Apply to Your Work?

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Here Are Some Standards

- Missouri Department of Transportation
  - MoDOT CORS RTN GPS
- MSPS - Missouri Society of Professional Surveyors
- Missouri Board for Architects, Professional Engineers, Land Surve
- American Society of Photogrammetry and Remote Sensing
- Land Surveyor Reference Page
- Virtual Museum of Surveying
- Missouri Standards for Property Boundary Surveys
- United States Public Land Survey Corners
- First and Second Order Horizontal and Vertical Control
- Standards for Surveyor's Real Property Report
- Mapping Survey Standards
- Cadastral Mapping Survey Standards
- The Missouri Coordinate System of 1983

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Missouri State Plane Coordinates

- What is this?
- How do you go from Lat/Long to SPCs?
- Do you care about the mapping angle?
- What is the mapping angle?

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Transverse Mercator

- Central Meridian
- Elevation factor
- Scale factor
- Grid factor

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Transverse Mercator

- Mapping angle
- How do you apply?

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Missouri Standards

- In Standards for Property Boundary Surveys, there's a lot hidden that you as a surveyor is responsible for
- Then…there are other Missouri standards
- Do you know what they are? Have you read them? Do they apply in your work?

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Rules of

Department of Agriculture

Division 90—Weights, Measures and Consumer Protection

Chapter 60—Missouri Standards for Property Boundary Surveys

Or 20 CSR 2030-16.xxx

Title		Page
2 CSR 90-60.010	Application of Standards	3
2 CSR 90-60.020	Definitions	3
2 CSR 90-60.030	General Land Surveying Requirements	3
2 CSR 90-60.040	Accuracy Standards for Property Boundary Surveys	5
2 CSR 90-60.050	Use of Missouri Coordinate System of 1983	5
2 CSR 90-60.060	Approved Monumentation	5
2 CSR 90-60.070	Location of Improvements and Easements	5

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Standards Apply to Boundaries

- Which implies they also apply to coordinate values and accuracies

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When and How Are MO SPCs Used?

- 2 CSR 90-60.040 (2)B

(B) The positional uncertainty of any coordinates shown on the plat relative to the control that is held fixed, shall not exceed 50 ppm or 0.01 foot for distances less than 2,000 ft at the 68% confidence level (1 sigma).

- URBAN

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When and How Are MO SPCs Used?

- What is the accuracy of your coordinate values (SPCs)?
- Do you test them against a published monument?
- How do you make redundant (independent) measurements?

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When and How Are MO SPCs Used?

- 2 CSR 90-60.040 (3)B

(B) The positional uncertainty of any coordinates shown on the plat relative to the control that is held fixed, shall not exceed 100 ppm or 0.01 foot for distances less than 1,000 ft at 68% confidence level (1 sigma).

- RURAL

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When and How Are MO SPCs Used?

- How do you evaluate the accuracy of your shots?
- Are you checking accuracy (or precision)?

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What About Compliance?

- It may be more than what's on the surface of the property boundary survey standards
- 2 CSR 90-60.030 (D) [Do MO SPCs suffice?]

  (D) The direction of boundary lines shall be shown by angles, azimuths, or bearings with the directional reference system clearly described on the plat

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What About Compliance?

- It may be more than what's on the surface of the property boundary survey standards
- 2 CSR 90-60.030 (F) [Do MoDOT RTK & Grid distances suffice?]

  F) Complete dimensions (distances, directions, & curve data) of all parcels surveyed or created. All linear measurements shall be shown as horizontal distances at the ground surface in feet or meters.

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Grid v. Ground

- Do you publish grid or ground distances?
- If ground, do you "scale up" your coordinates or do you just multiply them?
- Do you use a "centroid" to multiply distances?
- Whatever you do, do you state it on the plat?

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What About Compliance?

- It may be more than what's on the surface of the property boundary survey standards
- 2 CSR 90-60.030 (G) [Geoid/Ellipsoid/Geoid model meta data?]

(G) All vertical measurements shall be shown as elevations above an established or assumed datum in ft or m. When elevations are shown, a clearly defined datum shall be shown, including location and elev of the BM used to establish project datum

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Elevation Accuracy

- Are you using ellipsoidal heights?
- Orthometric heights?
- Which geoid model if you use one?
- If using MoDOT VRS do you check in on reliable benchmarks?
- Do you leave passive marks behind?

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What About Compliance?

- Are you using a meaningful basis of bearing?
- Before you answer consider your positioning uncertainties and the angular error in azimuth or bearing of the line you are using

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Example For Bearing Reference

- 500 ft line
- Positioning accuracy @ 1 σ: ±2 cm (0.07 ft)

$$\theta = tan^{-1}\frac{2\times 0.07}{500} = 58''$$

Is this an acceptable process? Complies with standards?

But There's More

- Do you publish epoch date?
- Do you publish the realization
- Do you know what these are for today?

…And More!

- If you based your survey on GNSS observations and don't worry much because now you are doing the topographic map…
- Do you sign and seal those maps?
- Compliance with mapping standards and control survey standards?

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Or 20 CSR 2030-18.xxx

Rules of

Department of Agriculture

Division 90—Weights, Measures and Consumer Protection

Chapter 62—First and Second Order Horizontal and Vertical Control

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2 CSR 90-62.020 & 62.030

- 1st and 2nd order control is to be used to meet the needs of mapping, geographic information systems, land information systems, property boundary surveys, and design surveys
- To…qualify as 1st or 2nd order control, it must be accepted and published by Dept of Ag or NGS

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2 CSR 90-62.050

- Direct connect to stations 5 km or less from any new station
- At least three existing stations
- Two separate occupations
- Etc. (by the way this all is static observations)

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Boundaries Referenced to Grid N

- Do you know what you are implying when you do this?
- Horizontal control – there's a spec for that!
- GPS Survey guidelines – there's a spec for that!

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Rules of

Department of Agriculture

Division 90—Weights, Measures and Consumer Protection

Chapter 64—Mapping Survey Standards

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Topographic Survey Certification

- There's a spec for that! [2 CSR 90-64-020]
- Are you meeting the test that your certification implies
- What if you're using drones?
- Do you do "ground truthing"?
- Do you use the RMS chart?
- Sample (test) data set?

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64.020

(1) Horizontal Accuracy.

(A) Class I. The root mean square (rms) error of a map product shall be less than 0.01 of one inch (1") on the map or in the case of a metric map, 0.025 of one centimeter (1 cm) on the map.

EXAMPLE (Customary Units)

Scale	Limiting rms Value in Feet
1"= 20'	0.2'
1"= 50'	0.5'
1"= 100'	1.0'
1"= 200'	2.0'
1"= 400'	4.0'
1"=1000'	10.0'
1"=2000'	20.0'

There's a similar table in SI Units

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64.020 (1)

(B) Class II. The rms shall be twice that required for Class I.

(C) Class III. The rms shall be 3 times that required for Class I.

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64.020 (2)

- (2) Vertical Accuracy.
  (A) Class I. For Class I maps rms error in elev shall be less than 1/3 of the indicated contour interval for well-defined points only, and 1/6 of C.I. for spot heights.
- (B) Class II. The rms error may be twice that required for Class I.
- (C) Class III. The rms error may be 3 times that required for Class I.

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64.020 (3)

- (3) Mixed Accuracy. A map may be compiled that complies with one class of accuracy in elevation and another in planimetry.

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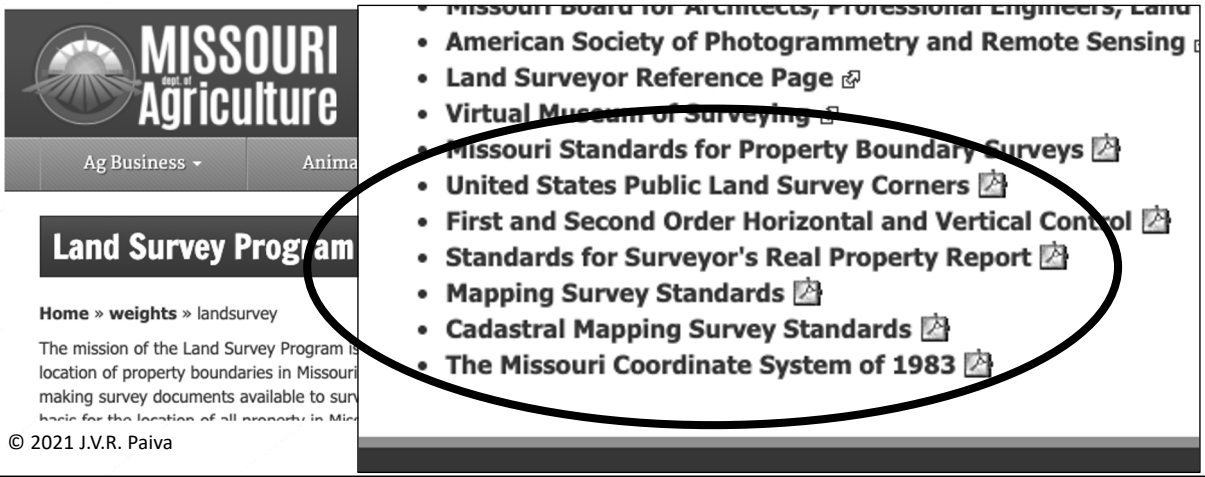
Where Do I Find These other Standards?

- https://agriculture.mo.gov/weights/landsurvey/



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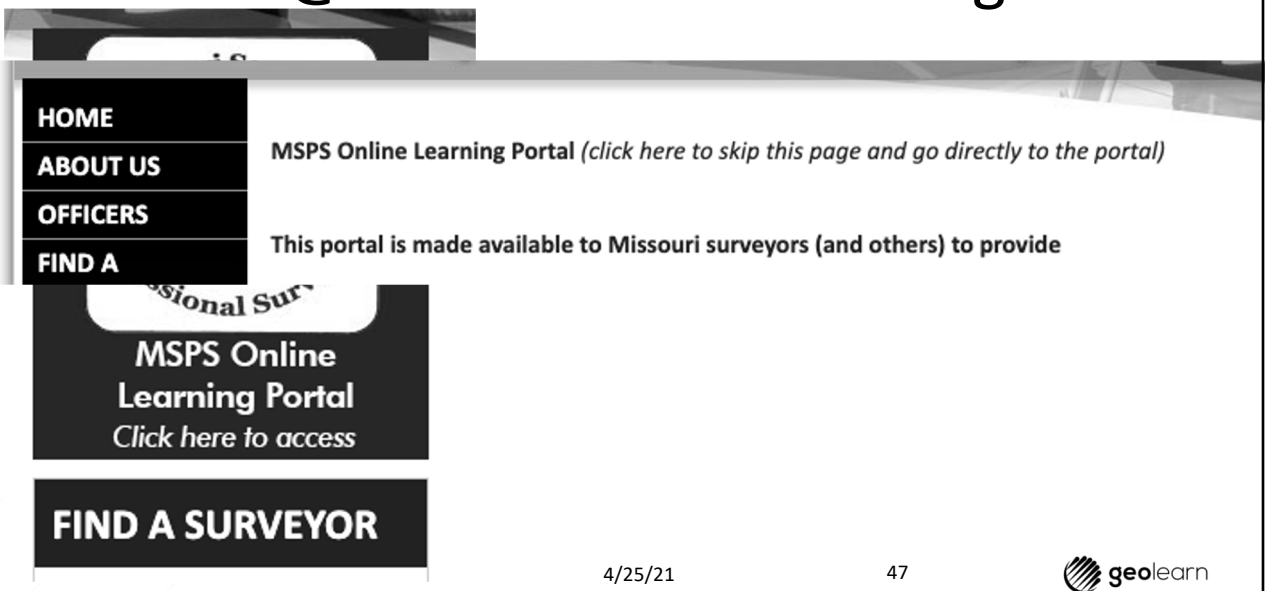
Courses @ MSPS Online Learning Portal



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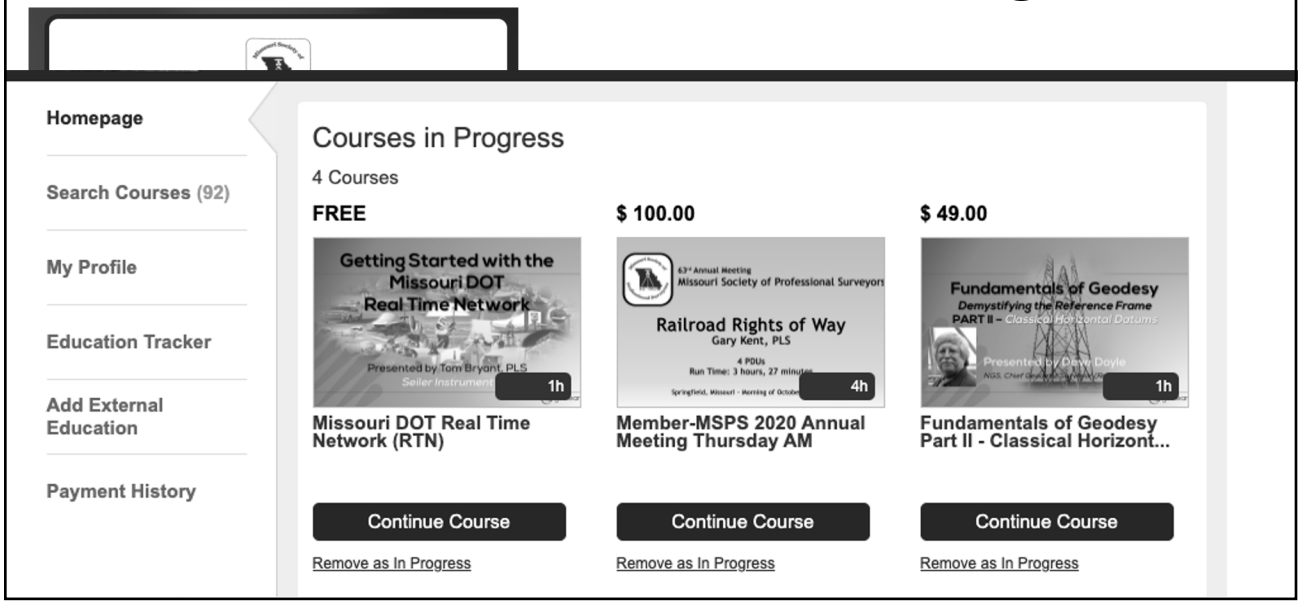

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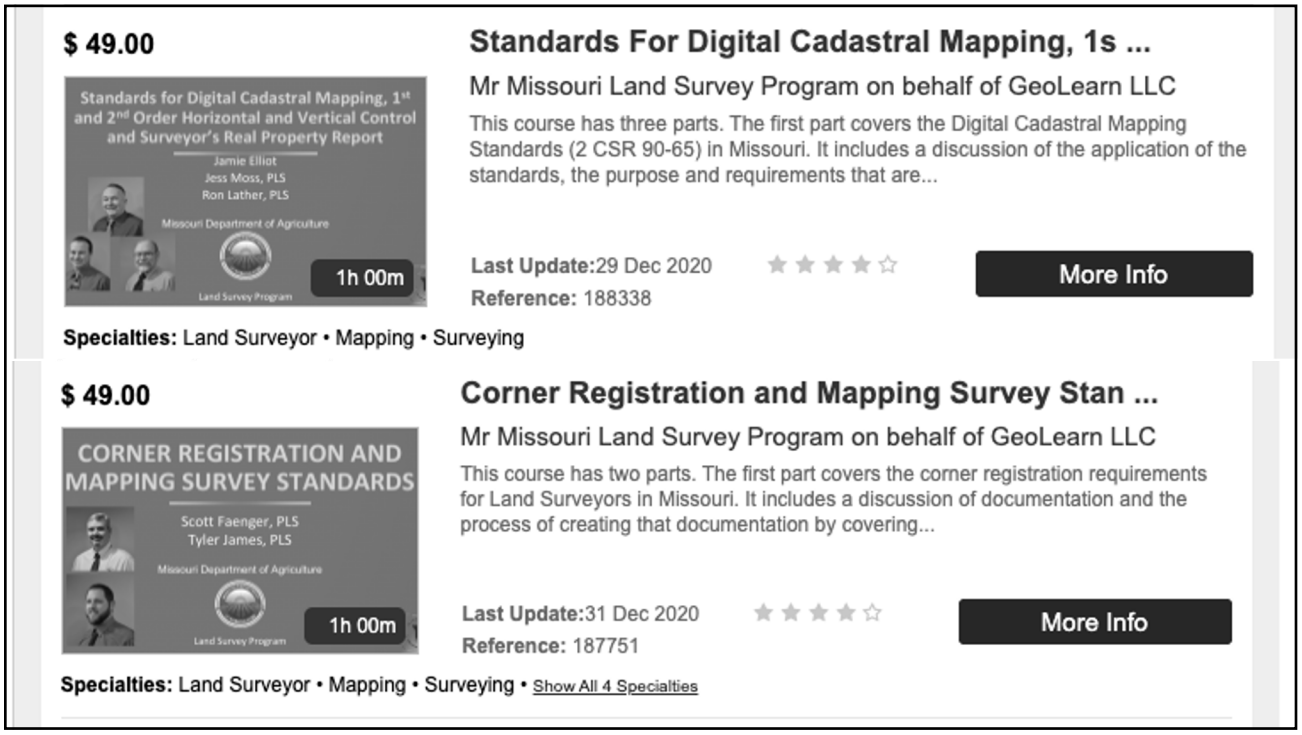
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Mr Missouri Land Survey Program on behalf of GeoLearn LLC
This course has three parts. The first part covers the Digital Cadastral Mapping Standards (2 CSR 90-65) in Missouri. It includes a discussion of the application of the standards, the purpose and requirements that are...
Standards for Digital Cadastral Mapping, 1st and 2nd Order Horizontal and Vertical Control and Surveyor's Real Property Report
Jamie Elliot
Jess Moss, PLS
Ron Lather, PLS
Missouri Department of Agriculture
Land Survey Program
1h 00m
Last Update:29 Dec 2020
Reference: 188338
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Scott Faenger, PLS
Tyler James, PLS
Missouri Department of Agriculture
Land Survey Program
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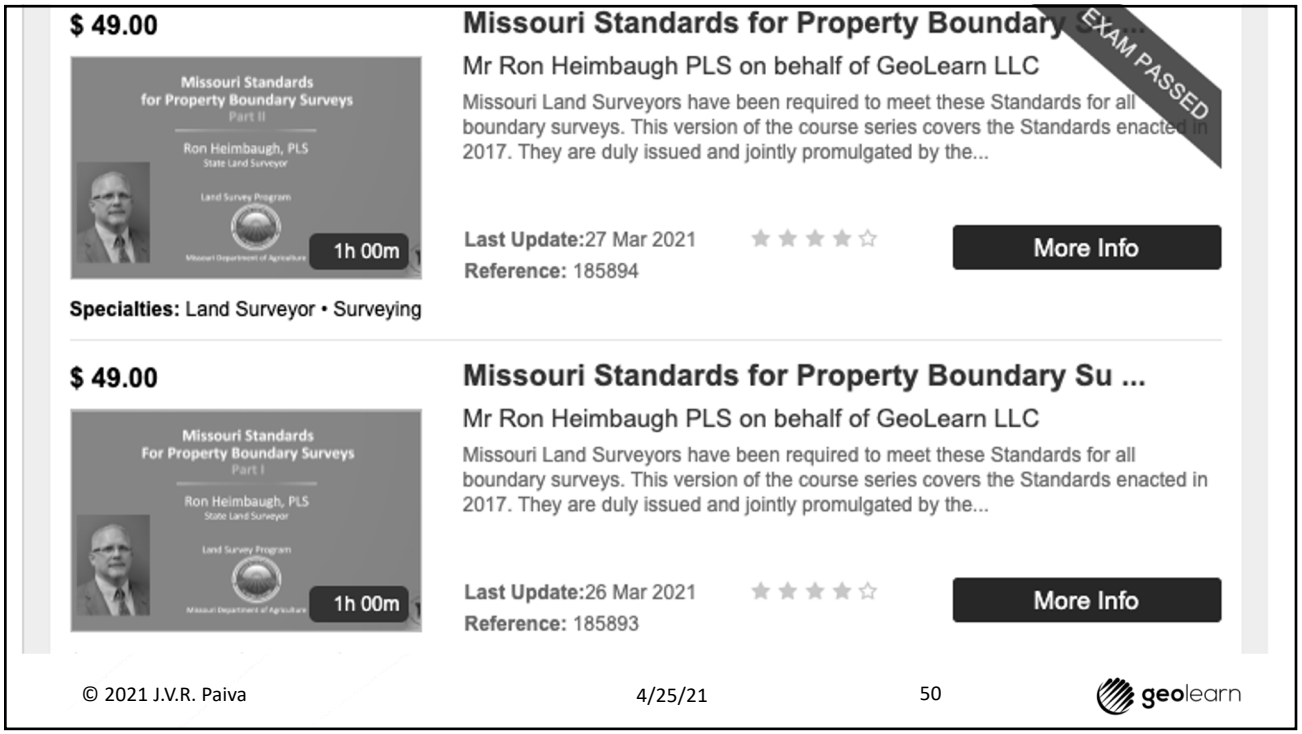
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State Land Surveyor
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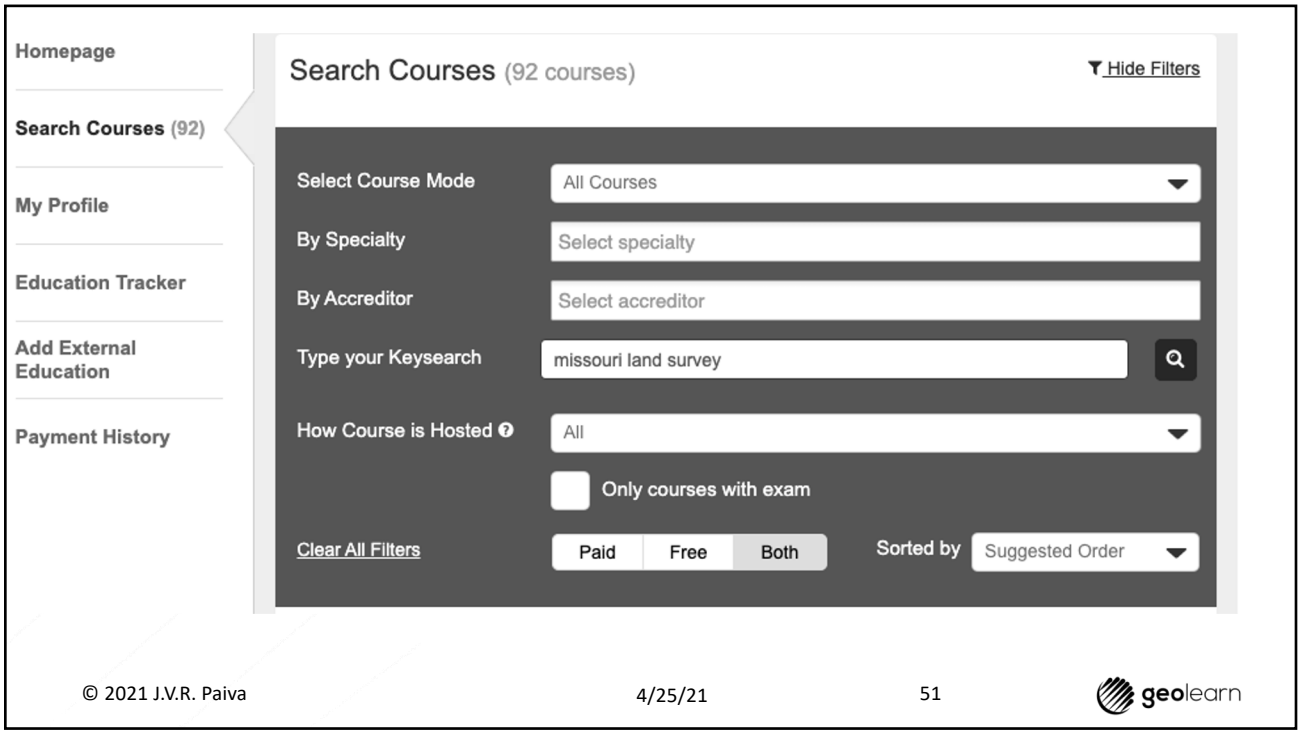

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Part II

- What instrumentation do you use?
- Static GNSS
- RTK (including RTN)
- Total station
- Something else?

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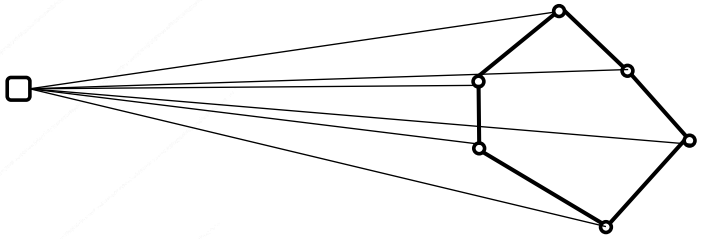
Do You Close Your Surveys?

- What are you supposed to do?
- How do you do it with RTK? (It's hub and spoke surveying, don't forget)



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What Errors & Blunders Are Overlooked?

- But wait, let's briefly review errors and mistakes
- Random
- Systematic
- Blunder = mistake ≠ "human error"

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Random Errors With GNSS

- Receiver phase measurement
- Clock errors
- Troposphere
- Ionosphere
- Multipath
- Pole/antenna/height/wrong specs/bubble

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Random Errors With Total Station

- Angle measurement error
- Distance measurement error
- Error in centering and leveling of instrument
- Error in centering and leveling of pole
- Atmospheric errors

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Systematic Errors With GNSS

- Antenna phase center
- Bent/warped pole
- Inaccurate optical plummet
- Height of antenna issues

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Systematic Errors With Total Station

- Optical plummet
- Leveling
- Prism constant (large and small)

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Blunders With GNSS

- Setting up/observing wrong point
- Geoid/ellipsoid issues
- Forgetting to measure antenna height or assuming zero

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Blunders With Total Station

- Forgetting to level and/or center
- Cracked prism
- Incorrect constants at instrument or prism
- Assuming instrument/prism height to be zero
- Observing wrong point

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"I Don't Need to Adjust My Surveys"

- What are you saying if you say or think that?
- When you don't measure the last angle/ distance in a traverse, you are placing all the error in the missing distance and angle
- If you close and don't adjust, you are doing the same thing!

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Better Processes for Closing with RTK

- Different base stations
- Different initializations
- Re-observe some of the points (but do it scientifically)
- Observe known, reliable control
- Re-observe with different constellation

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Better Processes for Closing With Static GNSS

- First, have independent observations
- Observing 3 points with 3 receivers in one go
- After you have independent observations, you can calculate angles in your triangles using law of cosines and law of sines

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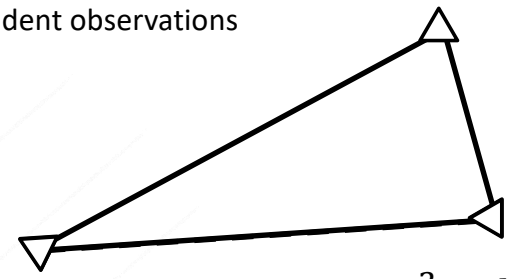
Independent Observations

One occupation; only two independent observations



Second observation creates the independent measurement

$$c^2 = b^2 + a^2 - 2 * a * b * cosC$$

$$\frac{a}{sinA} = \frac{b}{sinB} = \frac{c}{sinC}$$

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Adjustment Techniques

- Compass
- Your professional judgment
- Least squares

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If Learned and Used Properly…

- Least squares is the best “professional judgment” technique

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How To Learn to Use Least Squares?

- Apply it all the time
- Create fictitious surveys
- But…don't use manufacturer's spec for angle, distance and positioning accuracy!

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Questions?

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About seminar presenters

Mr. D. Ryan McDowell is a Professional Land Surveyor licensed in the States of Missouri, Arkansas, Kansas, Colorado and Kentucky. He has nearly 20 years of experience working for both the public and private sector clients and is accustomed to managing extremely large surveying projects from proposal stage to final deliverables. Ryan was born and raised in Kentucky and received his Bachelor's degree from highly regarded Transylvania University in Lexington, KY and is proud to have been bestowed the notable honor of a Kentucky Colonel. Mr. McDowell has furthered his post-baccalaureate education at St. Louis Community College and the University of Wyoming earning 30 credit hours in Land Surveying courses. In addition, in 2018, Mr. McDowell received a Graduate Certificate in Survey Engineering from the University of Maine, during which time he completed advanced graduate level surveying classes on LiDAR, photogrammetry, geodesy and advanced computations and continues to further his Professional education. In 2018 he completed the professional program in UAS operations from Embry-Riddle Aeronautical University, and holds a FAA Part 107 Remote Pilot license. He is currently working towards his CFeds Certification and will sit for his Project Management Professional (PMP) Certification in 2021.

McDowell has completed hundreds of surveying projects involving boundary and right of way determinations for extremely large transmission, transportation and infrastructure projects. He is confident in leading surveying teams across the nation to complete the complexities often required with large scale surveying projects. In addition to his professional commitments, Ryan McDowell is active in many state level societies and has served in many leadership positions. He is married, has three kids, serves as a youth soccer coach, scout leader, and enjoys cooking on a competitive BBQ team within the Kansas City Barbeque Society.

Ryan worked as a Project Manager for Surveying and Mapping, LLC at their St. Louis, MO office where he leads the Geospatial Division covering Mobile LiDAR, Aerial Mapping, UAS LiDAR/Photogrammetry/ Inspections, as well as Terrestrial Scanning for major infrastructure projects.

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 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.

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