

Understanding Least Squares Adjustment For Conventional Measurements

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Maryland Society
of **Surveyors**



Topics to Be Covered:

- 2016 Accuracy Standards for ALTA/NSPS Land Title Surveys
- What is a least squares adjustment.
- How does least squares work.
- Define some terms in the field of statistics.
- Advantages of a least squares adjustment.
- The process of setting up a least squares adjustment.
- What are positional tolerances and how do they work.

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2005 Accuracy Standards for ALTA/NSPS Land Title Surveys

- Allowable Relative Positional Accuracy for Measurements Controlling Land Boundaries on ALTA/ACSM Land Title Surveys

$$=0.07 \text{ feet (or 20 mm) + 50 ppm}$$

Accuracy Standards for
ALTA/ACSM Surveys



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2016 Accuracy Standards for ALTA/NSPS Land Title Surveys

- Relative Positional Accuracy may be tested by:
- Comparing the relative location of points in a survey as measured by an independent survey of higher accuracy or
- The results of a minimally constrained, correctly weighted least square adjustment of the survey.

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The Purpose of the Adjustment Process:

- To develop final survey values that are accurate and therefore as close to the truth as possible.
(Since we never know the truth, this is not easy.)
- To evaluate and measure the confidence in the results.
- To determine how accurate each value is.

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Least Squares (Simplified):

- The best value from a set of measurements, is the one that will change any single measurement in the set the least.

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Taped Distance Example:

DIST	DIFFERENCE FROM ADJ.	DIFF ²	DIFFERENCE FROM ADJ.	DIFF ²	DIFFERENCE FROM ADJ.	DIFF ²
500.01	+0.01	0.01	0.00	0.00	-0.02	0.04
500.02	+0.02	0.04	+0.01	0.01	-0.03	0.09
499.99	-0.01	0.01	-0.02	0.04	0.00	0.00
499.98	-0.02	0.04	-0.03	0.09	-0.01	0.01
500.00	0.00	0.00	-0.01	0.01	+0.01	0.01
499.99	-0.01	0.01	-0.02	0.04	0.00	0.00
500.01	+0.01	0.01	0.00	0.00	+0.02	0.04
500.00	0.00	0.00	-0.01	0.01	+0.01	0.01
500.00	0.00	0.00	-0.01	0.01	+0.01	0.01
Totals:		0.12		0.21		0.21
Most probable value chosen	500.00		500.01		499.99	

The arithmetic mean of 500.00 in the set of measurements will have the least change for any single measurements.

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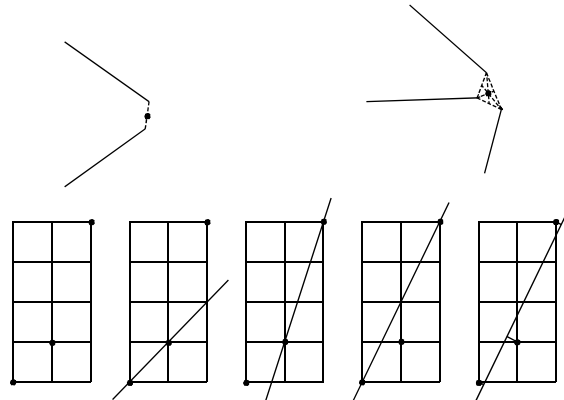
Least Squares Should Be Used When:

- A geometric figure is measured so that there is more than one solution possible.
- So that the difference between the adjusted and observed measurements are minimized and a value closer to the truth is obtained.
- When you would like to know how the various possible errors can accumulate and what their size will be.

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How Least Squares Works:



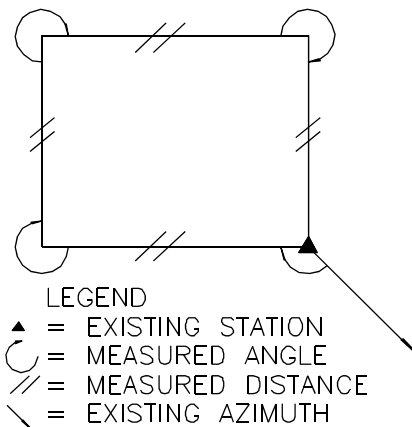
When a geometric figure is measured so that there is more than one solution possible, adjustments are made so that a value closer to the truth is hopefully obtained.

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A Traverse Must Close for Adjustment to Be Possible:

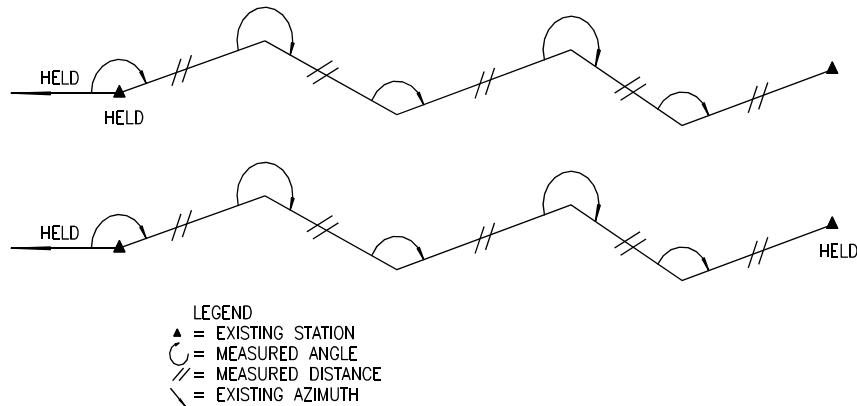
Survey traverses must at a minimum begin and end at a point or points of known position and have orientation.



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Traverse Example:



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Precision Vs. Accuracy:

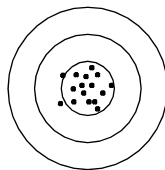


Fig #1

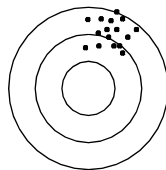


Fig #2

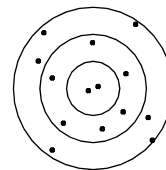


Fig #3

Grouping of rifle shots

- Figure #1 & #2 shots are precise.
- Figure #1 & #3 shots are very accurate.
- Figure #1 shots are precise and accurate.
- Figure #2 shots are precise not accurate.
- Figure #3 shots are accurate not precise.

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Precision Vs. Accuracy Example:

Measurements on a 700.00 ft. calibrated baseline

Precision (Repeatability)		Accuracy (Truth)	
700.20		700.02	
700.21		700.02	
700.19	mean	700.03	mean
700.20	700.20	699.98	700.00
700.20		699.97	
700.20		700.00	
700.21		700.00	

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The Process of Measurements and Their Errors:

All measurements have errors

- Blunders or Mistakes
- Systematic Errors
- Random Errors

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Causes of Systematic Errors

- Instruments not being properly calibrated or adjusted
- Environmental conditions

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Random Error Causes

- The inability for anyone to perceive anything with exactness.
- Unpredictable fluctuations in environmental conditions.
- Unpredictable instrumental fluctuations.

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Words to Live By

- There is good luck and bad luck in all survey measurements, but if errors are not controlled and managed you will not have good luck.

• Alan Dragoo

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Statistics for Surveyors:

A mathematical process that can be used to evaluate the quality of measurements.

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Definitions & Concepts of Statistical

Terms:

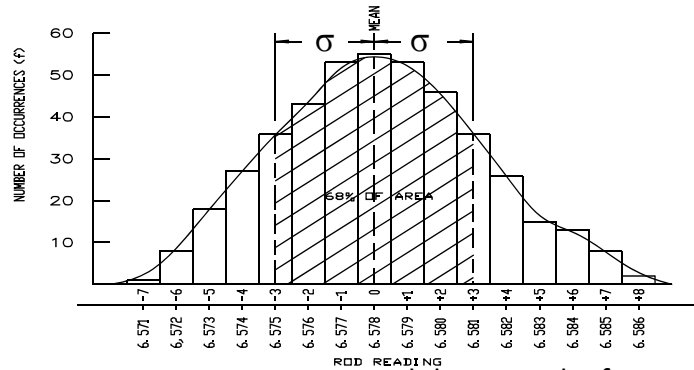
- Mean
 - The true value of any measurement is never really known.
 - For any set of measurements that has had the blunders and systematic errors removed the arithmetic mean is the best most probable value, to represent the true value.
- Residual
 - The difference between a single value in a set of measurements from what is accepted as true.

Definitions & Concepts of Statistical Terms Continued:

- Laws of Probability State
 - Large errors seldom occur
 - Small errors occur more often
 - There is an equal chance of positive errors as negative errors

Definitions & Concepts of Statistical Terms Continued:

When blunders and systematic errors have been eliminated



The more measurements are repeated the more the frequency of reoccurring measurements plotted on a graph represent a bell shape curve.

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Definitions & Concepts of Statistical Terms Continued:

- Standard Deviation: σ_s
 - The name used to define the \pm uncertainty of a single measurement of a set, to a defined level of confidence.
- Standard Deviation 1 sigma level: σ_s
 - 68.3% of a set of measurements fall \pm This value from the arithmetic mean.

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Definitions & Concepts of Statistical Terms Continued:

- Standard Deviation:

$$\sigma_s = \pm \sqrt{\frac{\sum v^2}{n-1}}$$

V = residual

n = number of observations

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Definitions & Concepts of Statistical Terms Continued:

- Calculation of standard deviation: σ_s

Obs #	Reading	v (residual)	v ²
1	46.7"	-1.1"	1.21"
2	45.2"	-0.4"	0.16"
3	45.9"	+0.3"	0.09"
4	45.2"	-0.4"	0.16"
5	46.2"	+0.6"	0.36"
6	47.4"	+1.8"	3.24"
7	43.0"	-2.6"	6.76"
8	45.2"	-0.4"	0.16"
Mean:	45.6"	Total:	12.14"

$$\sigma_s = \pm \sqrt{\frac{12.14}{7}} \quad \sigma_s = \pm 1.32"$$

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Definitions & Concepts of Statistical Terms Continued:

- Standard Deviation of the mean: σ_m
 - The \pm uncertainty of the mean of a set of measurements, to a defined level of confidence.
 - The σ_m is relative to the true value for a set of measurements that have had all blunders and systematic errors removed.

$$\sigma_m = \frac{\sigma}{\sqrt{n}} \quad n = \text{Number of observations}$$

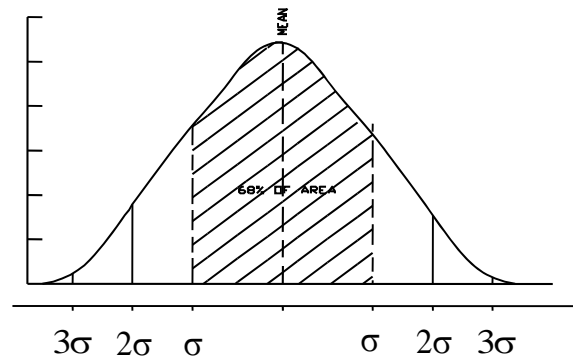
Definitions & Concepts of Statistical Terms Continued:

- Standard Deviation of the mean:

There is a 68.3% chance of being within $\pm \sigma_m$ of the unknown true value.

Definitions & Concepts of Statistical Terms Continued:

- Standard Deviation with various levels of confidence.



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Definitions & Concepts of Statistical Terms Continued:

- Levels of confidence:

Name of error	Value	% Certainty
Probable or CEP	0.6745 σ	50%
Standard Deviation	1 σ	68.3
90% Error	1.6449 σ	90%
Two Sigma or 95% Error	2 σ	95%
99% Error	2.5 σ	99%
Three Sigma	3 σ	99.70%

(Note: Actually, the 95% error is closer to 1.96 σ , but 2 σ is often accepted as a convenient conversion.)

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Confidence & Standard Error Relationships

- If you want more certainty that your measurements don't fall outside of your tolerance level, inflate the confidence level
- Doubling the certainty level will double the standard error
- To decrease the standard error, increase the accuracy or redundancy

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Definitions & Concepts of Statistical Terms Continued:

- Statistics for real world measurements:
 - All contributions to the total error must be considered.
 - Mathematically errors accumulate in the following format.

$$\sigma_T = \pm \sqrt{\sigma_{x1}^2 + \sigma_{x2}^2 \cdots \sigma_{xn}^2}$$

σ_T = Total Standard Error

σ_x = Standard Error for each error source

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Star*Net Unadjusted Input Observations

Summary of Unadjusted Input Observations

Number of Measured Angle Observations (DMS) = 5

At	From	To	Angle	StdErr	t-T
302	301	303	182-02-24.50	9.10	0.01
302	301	1001	82-24-04.00	8.51	-0.00
302	302	304	347-59-39.25	4.24	0.00
304	303	305	83-02-34.25	10.97	-0.00
302	302	306	103-41-50.00	25.67	0.00

Number of Measured Distance Observations (FeetUS) = 5

From	To	Distance	StdErr	HI	HT	Comb	Type
302	303	384.2394	0.0091	5.730	5.320	0.9999556	S
302	1001	254.0649	0.0090	5.730	5.000	0.9999554	S
303	304	407.5322	0.0092	5.320	5.560	0.9999556	S
304	305	140.2624	0.0088	5.560	5.900	0.9999554	S
303	306	58.7463	0.0088	5.480	5.000	0.9999554	S

Number of Zenith Observations (DMS) = 5

From	To	Zenith	StdErr	HI	HT
302	303	91-30-57.25	9.09	5.730	5.320
302	1001	90-08-48.75	12.52	5.730	5.000
303	304	88-34-52.75	8.73	5.320	5.560
304	305	90-36-06.75	21.39	5.560	5.900
303	306	93-00-38.00	49.86	5.480	5.000

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Definitions & Concepts of Statistical Terms Continued:

- Example EDM error sources simplified
 - Instrument centering 0.005 ft
 - Target centering 0.005 ft
 - EDM system constant 0.016 ft (0.005mm)
 - EDM scale error 5ppm
 - EDM temp & press error 6ppm

$$\sigma = \pm\sqrt{0.005^2 + 0.005^2 + 0.016^2} = \pm 0.017\text{ft}$$

$$\sigma = \pm\sqrt{5^2 + 6^2} \text{ ppm} = \pm 7.8\text{ppm}$$

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Definitions & Concepts of Statistical Terms Continued:

- The Standardized Residual:
 - The residual divided by the standard deviation

Observation	Residual	Std Error	Std Residual
1000.46 ft	.05 ft	.02 ft	2.50
100°12'23"	8"	12"	.66

- The standardized residual is more sensitive to blunders than a residual, since it takes into consideration the geometry of the survey

Definitions & Concepts of Statistical Terms Continued:

- Standardized residuals that exceed 3 should be considered for rejection.

Star*Net Adjusted Observations Results

Adjusted Observations and Residuals
=====

Adjusted Coordinate Observations (FeetUS)
(Stations with Partially Fixed Coordinate Components)

Station	Component	Adj Coordinate	Residual	StdErr	StdRes	File:Line
304	Elev	162.0998	-0.0936	1.19		
	E	1355489.3610	-0.0390	0.0500	0.8	
	N	524404.8372	-0.0307			
1001	N	524583.4989	0.0628	1.21		
	E	1355204.3408	0.0423	0.0500	0.8	
	Elev	162.0609	0.0343			

Adjusted Measured Angle Observations (DMS)

At	From	To	Angle	Residual	StdErr	StdRes	File:Line
302	301	1001	82-24-01.32	-0-00-02.68	8.51	0.3	1:34
303	302	304	347-59-38.93	-0-00-00.32	4.24	0.1	1:36
302	301	303	182-02-23.82	-0-00-00.68	9.10	0.1	1:32
303	302	306	103-41-50.00	0-00-00.00	25.87	0.0	1:40
304	303	305	83-02-34.25	-0-00-00.00	10.97	0.0	1:38

Adjusted Measured Distance Observations (FeetUS)

From	To	Distance	Residual	StdErr	StdRes	File:Line
302	303	384.2409	0.0015	0.0091	0.2	1:32
303	304	407.5308	-0.0014	0.0092	0.2	1:36
302	1001	254.0652	0.0003	0.0090	0.0	1:34
304	305	140.2624	-0.0000	0.0088	0.0	1:38
303	306	58.7463	-0.0000	0.0088	0.0	1:40

Adjusted Zenith Observations (DMS)

From	To	Zenith	Residual	StdErr	StdRes	File:Line
303	304	88-34-48.77	-0-00-03.98	8.73	0.5	1:36
302	303	91-30-53.17	-0-00-04.08	9.09	0.4	1:32
302	1001	90-08-50.59	0-00-01.84	12.52	0.1	1:34
304	305	90-36-06.75	-0-00-00.00	21.39	0.0	1:38
303	306	93-00-38.00	-0-00-00.00	49.86	0.0	1:40

Standardized Residual

Residuals

Definitions & Concepts of Statistical Terms Continued:

- Degrees of freedom or:
 - Number of Redundant Observations
 - Redundancy of a Network
 - Practically:
 - A measure of the over determination or redundancy of a survey network.
 - Mathematically:
 - The difference between the given number of observations, and the minimum required to uniquely determine the survey network.

Total Error Factor:

- Also known as:
- Reference Factor
or Variance of unit weight $\hat{\sigma}_o$

The relationship between the observation errors and the predicted error.

- When they are the same the $\hat{\sigma}_o = 1$
- When the observation errors are less $\hat{\sigma}_o < 1$
- When the observation errors are more $\hat{\sigma}_o > 1$

Chi Square Test:

Tests the total error factor to see if it is significantly greater than 1.0 or less than 1.0

Star*Net Statistical Summary

Adjustment Statistical Summary
 =====

Iterations = 2
 Number of Stations = 7
 Number of Observations = 21
 Number of Unknowns = 15
 Number of Redundant Obs = 6

Observation	Count	Sum Squares of StdRes	Error Factor
Coordinates	6	6.036	1.876
Angles	5	0.111	0.278
Distances	5	0.054	0.194
Zeniths	5	0.430	0.549
Total	21	6.631	1.051

The Chi-Square Test at 5.00% Level Passed
 Lower/Upper Bounds (0.454/1.552)

Least Squares (Mathematically):

Is an adjustment where the sum of the weighted squares of the residuals is at a minimum.

Advantages to Least Squares:

Minimizes the differences between any possible adjustment and the observations.

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Redundancy, the Key to Not Doing Work Over:

- With enough redundancy in a survey network
 - The observations with the errors will be the ones adjusted.
 - Observations with blunders can be deleted without adverse impact on the network.

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Knowledge of Error Sources:

- EDM
- Angles
- Accessories
- Natural
- GPS Vectors
- Leveling

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EDM Error Sources:

- | | |
|--------------------------|-----------------------|
| • Nominal accuracy | ±0.016 ft (5mm+5 ppm) |
| • Instrument Centering | ±0.005 ft |
| • Reflector Centering | ±0.005 ft |
| • Temperature & Pressure | ±5 ppm |
| • Instrument Constant | ±0.006 (2mm) |
| • Reflector Constant | ±0.006 (2mm) |

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Potential Sources of Angle Error:

- Pointing $\pm 3.0" (DIN) \times \sqrt{2} = 4.2$
- Reading 1" – 6" Normal
- Collimation 1" – 30" Normal +
- Parallax 2" – 3" Normal +
- Inclination 1" – 3" Normal +
- Centering Instrument & Targets ????
- Environmental 1" – 3" Normal +
- Tripod Stability 1" – 3" Normal +

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Centering Error Examples

- | | |
|--------------------------|---------------------------|
| • Example #1 | • Example #2 |
| $\theta=45^\circ$ | $\theta=180^\circ$ |
| $D_1=300\text{ft}$ | $D_1=600\text{ft}$ |
| $D_2=300\text{ft}$ | $D_2=600\text{ft}$ |
| $\sigma_t=0.01\text{ft}$ | $\sigma_t=0.005\text{ft}$ |
| $\sigma_c=0.01\text{ft}$ | $\sigma_c=0.005\text{ft}$ |

$$\sigma_T = \pm \sqrt{\sigma_{x1}^2 + \sigma_{x2}^2 + \dots + \sigma_{xn}^2}$$

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Centering Error Examples

- Example #1

$\theta=45^\circ$ $\sigma_{\theta_t} = 9.7''$
 $D_1=300\text{ft}$ $\sigma_{\theta_c} = 5.3''$
 $D_2=300\text{ft}$
 $\sigma_t=0.01\text{ft}$ $\sigma_T = 11.1''$
 $\sigma_c=0.01\text{ft}$

- Example #2

$\theta=180^\circ$ $\sigma_{\theta_t} = 4.9''$
 $D_1=600\text{ft}$ $\sigma_{\theta_c} = 4.9''$
 $D_2=600\text{ft}$
 $\sigma_t=0.005\text{ft}$ $\sigma_T = 6.9''$
 $\sigma_c=0.005\text{ft}$

$$\sigma_T = \pm \sqrt{\sigma_{x1}^2 + \sigma_{x2}^2 + \dots + \sigma_{xn}^2}$$

Note 1" = .005'/1000' or 1ft/41 miles

Centering Error Examples

- Example #1

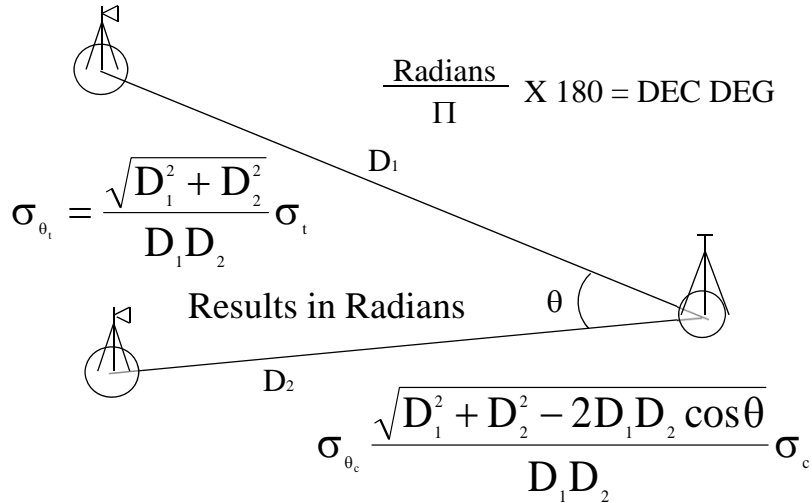
$\theta=45^\circ$
 $D_1=300\text{ft}$
 $D_2=300\text{ft}$
 $\sigma_t=0.01\text{ft}$
 $\sigma_c=0.01\text{ft}$

- Example #2

$\theta=180^\circ$
 $D_1=600\text{ft}$
 $D_2=600\text{ft}$
 $\sigma_t=0.005\text{ft}$
 $\sigma_c=0.005\text{ft}$

$$\sigma_T = \pm \sqrt{\sigma_{x1}^2 + \sigma_{x2}^2 + \dots + \sigma_{xn}^2}$$

Centering Errors:



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Error Propagation Due To Centering Errors for Instrument and Targets

Accuracy of Measuring Each Angle of a Traverse					
Horz Angle	$\theta =$	180	Deg		
Back Dist	$D_1 =$	600.000	Ft		
Fwd Dist	$D_2 =$	600.000	Ft		
Target Centering Error	$\sigma_t =$	0.010	Ft	$\sigma_{\theta_t} =$	4.9 "
Inst Centering Error	$\sigma_c =$	0.010	Ft	$\sigma_{\theta_c} =$	6.9 "
Number Positons	$n =$	2			
Pointing Accuracy	$\sigma_p =$	2.0	Sec		
Reading Accuracy	$\sigma_r =$	2.0	Sec		
Instrument Error				$\sigma_{\sigma_p} =$	1.4 "
Pointing Error				$\sigma_{\sigma_r} =$	1.4 "
	Dist	5280	Ft	$\sigma_T =$	8.7 "
		206265			
	σ_T	=	1 /	23,832	=Precision
	Trav Dist				
	Precision	=	0.22 Ft		Trav Error in Feet

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Accessories Error Sources:

- Tribrachs
- Tripods
- Thermometer
- Barometer

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Error Estimation Input for Star*Net

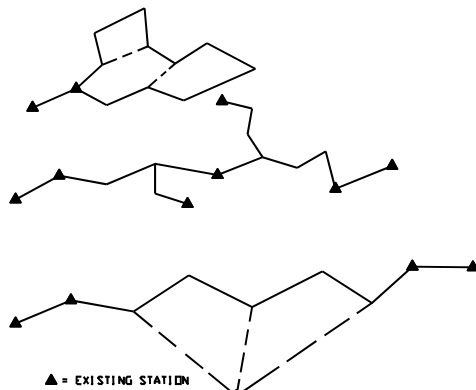
The screenshot shows the 'Project Options' dialog box with the 'Instrument' tab selected. The 'Conventional' section includes fields for Distance Constant (0.005000 FeetUS), Distance PPM (2.000), Angle (2.000000 Seconds), Direction (3.000000 Seconds), Azimuth / Bearing (4.000000 Seconds), Zenith (5.000000 Seconds), Elev Diff Constant (0.050000 FeetUS), and Elev Diff PPM (25.000). The 'Leveling' section has 'Sections as' with radio buttons for Length and Tums (selected), and an 'Elev Diff' field (0.005000 FeetUS/Tum). The 'Centering Errors' section includes Horiz Instrument (0.005000 FeetUS), Horiz Target (0.005000 FeetUS), and Vertical (0.010000 FeetUS).

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Network Design:

Add redundancy where possible and practical.



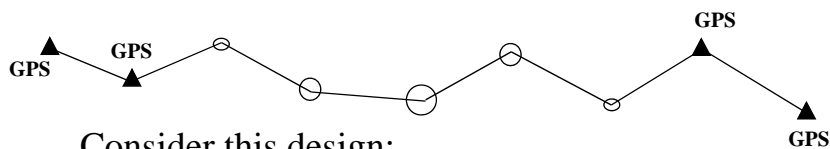
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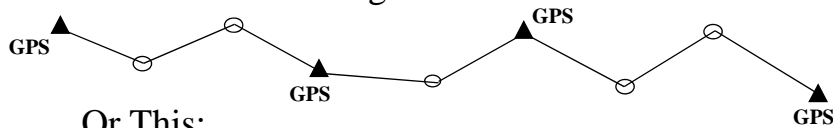
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Network Design for Efficiency & Accuracy

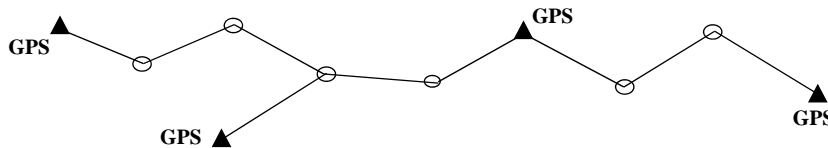
Instead of this design with its associated errors:



Consider this design:



Or This:



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Two Techniques for Not Finding Problems With Survey Measurements

- #1 Use Procedures That:
 - Show the accuracy of your instruments
 - Show the accuracy of your measurements
 - Use redundancy added to a network to divulge errors and increase confidence.
 - Use adjustment techniques that show the accuracy of individual measurements and individual results.

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Two Techniques for Not Finding Problems With Survey Measurements

- #2 Use Procedures
 - Where these things are not done so you never see a problem.
- WHICH WAY DO YOU WANT TO GO INTO COURT!

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Relative Positional Tolerances?

“Relative Positional Precision” means the length of the semi-major axis, expressed in feet or meters, of the error ellipse representing the uncertainty due to random errors in measurements in the location of the monument, or witness, marking any corner of the surveyed property relative to the monument, or witness, marking any other corner of the surveyed property at the 95 percent confidence level. Relative Positional Precision is estimated by the results of a correctly weighted “*minimally constrained*” least squares adjustment of the survey.

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Data Input Format for Star*Net

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Basic Format for 3D Data Entry:

Items enclosed in square brackets [], are optional.

- **Special codes:**

- & Defaults to the value defined in Instrument options.
- ! Observation is FIXED.
- * Observation is FREE.

- **Coordinates:**

C Station North East Elev [std. errors]

Examples

C A26C 264874.34 4576845.53 348.43 ! ! !

Or

C 19253 ? ? 385.74 * * !

Basic Format for 3D Data Entry (Continued):

- **Traverse begins:**

TB BS station name

Example

TB 19345

TB BS bearing (or azimuth)

Examples

TB N43-56-42W

TB 324-37-44

Basic Format for 3D Data Entry

(Continued):

Items enclosed in square brackets [], are optional.

- Traverse data:
 - T At Angle Dist Zenith [std. errors]
 - (Measurements from the previous T Line Station to the next T Line Station)
- Example
- T A62D 178-45-10 1353.83 90-12-56
- Distance & Vertical Distance to Another Station:
 - DV From-To Slope dist Zenith [std. errors] HI/HT
 - Example
 - DV 19345-19346 984.364 89-56-49 5.65/5.32

Basic Format for 3D Data Entry

(Continued):

Items enclosed in square brackets [], are optional.

- Traverse ends:
 - TE End station name
 - Example
 - TE A62F
 - TE End station Close angle Close station [std. error]
 - Example
 - TE A62F 174-38-56 A62G
 - TE End station Close angle Closing bearing [std. error]
 - Example
 - TE A62F 174-38-56 S54-36-52W

Basic Format for Other 3D Data Type Entry (Continued):

Items enclosed in square brackets [], are optional.

Zenith Angles (3D only):

V from-to DD-MM-SS [std. error]

Bearing or Azimuth:

B from-to Bearing [std. error]

B from-to Azimuth [std. error]

Horizontal angles:

A at-from-to Angle [std. error]

Basic Format for Other 3D Data Type Entry (Continued):

Items enclosed in square brackets [], are optional.

Distances 3D:

from-to Slope distance [std. error] HI/HT

Measurements:

M at-from-to Angle Distance Zenith [std. error]

Measurement option:

M at-to-to ? Distance Zenith HI/HT

Measurement From One Setup Should Be Entered As One Measurement

Example of how not to enter angle and distance data

D 49-22	726.3148 'DISK	D 1103-49	244.4096 'DISK
M 22-49-1103	196-31-26.00 244.4104	M 49-1103-919	198-11-12.50 264.1402
D 49-22	726.3156 'DISK	D 1103-49	244.4104 'DISK
M 22-49-1103	196-31-22.00 244.4102	M 49-1103-919	198-10-56.50 264.1398
D 49-22	726.3164 'DISK	D 1103-49	244.4099 'DISK
M 22-49-1103	196-31-22.00 244.4104	M 49-1103-919	198-11-02.50 264.1405
D 49-22	726.3161 'DISK	D 1103-49	244.4106 'DISK
M 22-49-1103	196-31-21.50 244.4102	M 49-1103-919	198-10-58.50 264.1402
D 49-22	726.3154 'DISK	D 1103-49	244.4099 'DISK
M 22-49-1103	196-31-23.00 244.4106	M 49-1103-919	198-11-02.00 264.1407
D 49-22	726.3148 'DISK	D 1103-49	244.4109 'DISK
M 22-49-1103	196-31-27.00 244.4104	M 49-1103-919	198-11-01.50 264.1410
D 49-22	726.3154 'DISK	D 1103-49	244.4101 'DISK
M 22-49-1103	196-31-22.00 244.4109	M 49-1103-919	198-11-00.00 264.1408
D 49-22	726.3162 'DISK	D 1103-49	244.4101 'DISK
M 22-49-1103	196-31-23.00 244.4106	M 49-1103-919	198-11-04.00 264.1408
		D 919-1103	264.1406

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Measurement From One Setup Should Be Entered As One Measurement

Example of how not to enter distance data

Coordinate values from GPS Adjustment

C 301	524278.7057	1355298.9976	172.5062 !!!
C 302	524467.2040	1355430.2133	161.9831 !!!
C 303	524774.5550	1355660.5683	152.2176 * * *
C 304	524404.8679	1355489.4000	162.1934 .05 .05 .06
C 305	524361.8244	1355622.8797	160.2301 * * *
C 1001	524583.4361	1355204.2985	162.0266 .05 .05 .06
M 302:301:303	182-02-24.50	384.2394	91-30-57.25 5.730/5.320 'TRAV
M 302:301:1001	82-24-04.00	254.0649	90-08-48.75 5.730/5.000 'TRAV
M 303:302:304	347-59-39.25	407.5322	88-34-52.75 5.320/5.560 'TRAV
M 304:303:305	83-02-34.25	140.2624	90-36-06.75 5.560/5.900 'TRAV
M 303:302:306	103-41-50.00	58.7463	93-00-38.00 5.480/5.000 'TRAV

.PTOLERANCE /EVERY

Example of how to compute positional tolerances

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Star*Net Adjustment Lab

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Setup StarNet Parameters for Class Project

- Under Options/Project/Adjustment set:
 - 3D
 - US Feet
 - Grid
 - NAD83
 - 1900 MD
 - Average Geoid Height: -33.000 (Meters)

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Setup Instrument Adjustment Errors for Class Project

- Under Options/Project/Instrument set:
 - Distance Constant: 0.005
 - Distance PPM: 2.000
 - Angle: 3.5
 - Zenith: 15
 - Horiz Instrument: 0.005
 - Horiz Target: 0.005
 - Vertical: 0.010

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Sample StarNet Data File

```

C 19962 526394.367 1266548.609 481.426 ! ! !
C 19963 527366.301 1265750.290 505.576 ! ! !
C A90E 528635.003 1265883.165 508.892 ! ! *
C A90H 530816.855 1268337.586 465.164 ! ! !

TB 19962
DV 19962-19963 1258.070 88-55-04 5.69/5.31
DV 19963-19962 1258.072 91-05-26 5.33/5.67
T 19963 154-20-17 652.523 90-18-01 5.33/5.18
DV A90D-19963 652.527 89-42-18 5.17/5.31
T A90D 281-09-32 1229.740 89-40-35 5.17/5.56
DV A90E-A90D 1229.736 90-19-54 5.59/5.16
T A90E 203-01-20 1464.825 91-57-14 5.57/5.70
DV A90F-A90E 1464.823 88-03-38 5.71/5.55
T A90F 153-40-06 1109.217 90-20-20 5.71/5.44
DV A90G-A90F 1109.220 89-40-08 5.45/5.69
T A90G 197-24-04 778.029 89-04-29 5.45/5.50
DV A90H-A90G 778.031 90-56-02 5.52/5.43
TE A90H
    
```

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Data Entry For Project: PT33-028

C	19533	516947.596	1325887.115	458.154	!	!	!
C	19701	516845.656	1326377.926	459.837	!	!	!
C	19887	515997.322	1327212.805	418.303	!	!	!
C	19886	517202.288	1327893.496	409.326	!	!	!
C	F07H	?	?	446.100	*	*	!
C	F07J	?	?	463.500	*	*	!

TB	19533						
DV	19701-19533		501.311	90-05-55	5.45/5.76		
T	19701	88-40-34	320.298	88-29-34	5.45/5.97		
DV	F07G-19701		320.262	91-17-21	5.37/6.02		
T	F07G	207-14-38	401.564	92-54-27	5.37/6.09		
DV	F07H-F07G		401.623	86-55-31	5.50/5.97		
T	F07H	262-59-06	408.339	87-30-06	5.50/5.93		
DV	F07J-F07H		408.287	92-19-50	5.33/6.09		
T	F07J	140-37-46	1111.589	92-34-32	5.33/5.94		
DV	F07K-F07J		1111.641	87-21-40	5.36/5.93		
T	F07K	323-40-14	333.812	90-28-53	5.36/6.15		
DV	19886-F07K		333.815	89-18-33	5.56/5.94		
T	19886	164-30-42	1384.282	89-36-23	5.56/6.09		
TE	19887						

Trouble Shooting Adjustments That Don't Run

- Under Output/Errors Inspect error file
- Check for incorrect station names
 - (F07G is not the same as FO7G)

Trouble Shooting Adjustments That Run

- Use minimum constraints to isolate incorrect control or blunders
- Swap constraints to isolate incorrect control or blunders
- Eliminate blunders
- Set incorrect control to “Free” so that it will take on adjustment
- If necessary refine instrument errors
- Adjust weighting until adjustment passes chi-square test.

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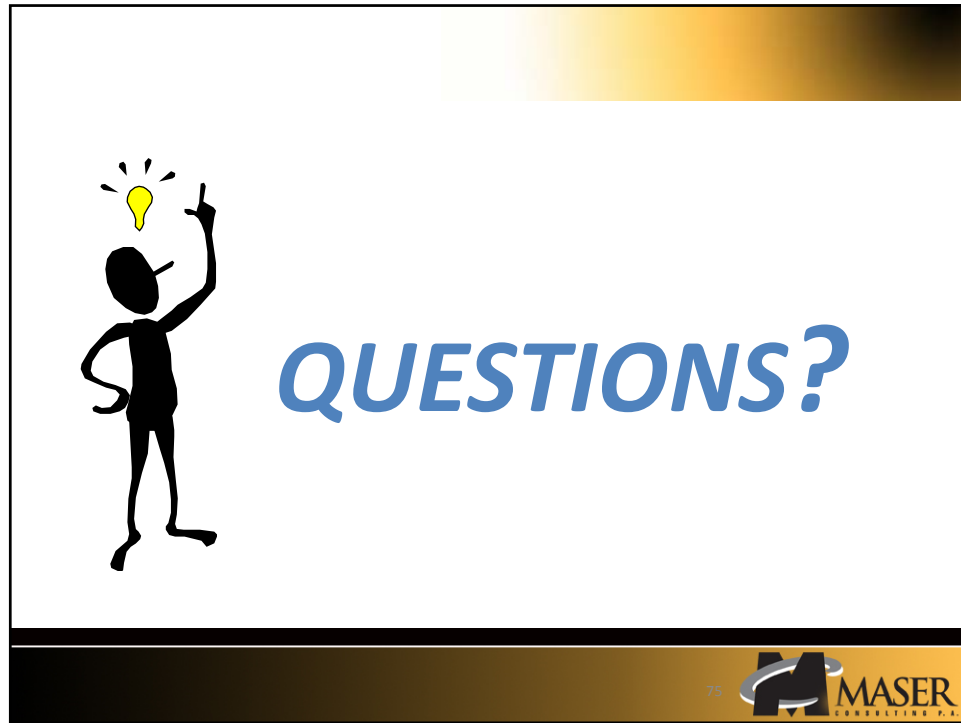


Adjustment Results and Their Evaluation:

- Residuals
- Standardized Residuals
- Error Factor
- Chi Square Test Results
- Unadjusted Results
- Precision
- Error Ellipses
- Network Design
- Positional Tolerances

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**MINIMUM STANDARD DETAIL REQUIREMENTS FOR
ALTA/NSPS LAND TITLE SURVEYS**
(Effective February 23, 2016)

NOTE - Attention is directed to the fact that the National Society of Professional Surveyors, Inc. (NSPS) is the legal successor organization to the American Congress on Surveying and Mapping (ACSM) and that these 2016 Minimum Standard Detail Requirements for ALTA/NSPS Land Title Surveys are the next version of the former Minimum Standard Detail Requirements for ALTA/ACSM Land Title Surveys.

1. Purpose - Members of the American Land Title Association® (ALTA®) have specific needs, unique to title insurance matters, when asked to insure title to land without exception as to the many matters which might be discoverable from survey and inspection, and which are not evidenced by the public records.

For a survey of real property, and the plat, map or record of such survey, to be acceptable to a title insurance company for the purpose of insuring title to said real property free and clear of survey matters (except those matters disclosed by the survey and indicated on the plat or map), certain specific and pertinent information must be presented for the distinct and clear understanding between the insured, the client (if different from the insured), the title insurance company (insurer), the lender, and the surveyor professionally responsible for the survey.

In order to meet such needs, clients, insurers, insureds, and lenders are entitled to rely on surveyors to conduct surveys and prepare associated plats or maps that are of a professional quality and appropriately uniform, complete, and accurate. To that end, and in the interests of the general public, the surveying profession, title insurers, and abstractors, the ALTA and the NSPS jointly promulgate the within details and criteria setting forth a minimum standard of performance for ALTA/NSPS Land Title Surveys. A complete 2016 ALTA/NSPS Land Title Survey includes:

- (i) the on-site fieldwork required pursuant to Section 5,
- (ii) the preparation of a plat or map pursuant to Section 6 showing the results of the fieldwork and its relationship to documents provided to or obtained by the surveyor pursuant to Section 4,
- (iii) any information from Table A items requested by the client, and
- (iv) the certification outlined in Section 7.

2. Request for Survey - The client shall request the survey, or arrange for the survey to be requested, and shall provide a written authorization to proceed from the person or entity responsible for paying for the survey. Unless specifically authorized in writing by the insurer, the insurer shall not be responsible for any costs associated with the preparation of the survey. The request shall specify that an "**ALTA/NSPS LAND TITLE SURVEY**" is required and which of the optional items listed in Table A, if any, are to be incorporated. Certain properties or interests in real properties may present issues outside those normally encountered on an ALTA/NSPS Land Title Survey (e.g., marinas, campgrounds, trailer parks; easements, leases, other non-fee simple interests). The scope of work related to surveys of such properties or interests in real properties should be discussed with the client, lender, and insurer; and agreed upon in writing prior to commencing work on the survey. The client may need to secure permission for the surveyor to enter upon the property to be surveyed, adjoining properties, or offsite easements.

3. **Surveying Standards and Standards of Care**

- A. Effective Date** - The 2016 Minimum Standard Detail Requirements for ALTA/NSPS Land Title Surveys are effective February 23, 2016. As of that date, all previous versions of the Minimum Standard Detail Requirements for ALTA/ACSM Land Title Surveys are superseded by these standards.
- B. Other Requirements and Standards of Practice** - Many states and some local jurisdictions have adopted statutes, administrative rules, and/or ordinances that set out standards regulating the practice of surveying within their jurisdictions. In addition to the standards set forth herein, surveyors shall also conduct their surveys in accordance with applicable jurisdictional survey requirements and standards of practice. Where conflicts between the standards set forth herein and any such jurisdictional requirements and standards of practice occur, the more stringent shall apply.
- C. The Normal Standard of Care** - Surveyors should recognize that there may be unwritten local, state, and/or regional standards of care defined by the practice of the “prudent surveyor” in those locales.
- D. Boundary Resolution** - The boundary lines and corners of any property being surveyed as part of an ALTA/NSPS Land Title Survey shall be established and/or retraced in accordance with appropriate boundary law principles governed by the set of facts and evidence found in the course of performing the research and fieldwork.
- E. Measurement Standards** - The following measurement standards address Relative Positional Precision for the monuments or witnesses marking the corners of the surveyed property.
- i. “Relative Positional Precision” means the length of the semi-major axis, expressed in feet or meters, of the error ellipse representing the uncertainty due to random errors in measurements in the location of the monument, or witness, marking any corner of the surveyed property relative to the monument, or witness, marking any other corner of the surveyed property at the 95 percent confidence level. Relative Positional Precision is estimated by the results of a correctly weighted least squares adjustment of the survey.
 - ii. Any boundary lines and corners established or retraced may have uncertainties in location resulting from (1) the availability, condition, history and integrity of reference or controlling monuments, (2) ambiguities in the record descriptions or plats of the surveyed property or its adjoiners, (3) occupation or possession lines as they may differ from the written title lines, or (4) Relative Positional Precision. Of these four sources of uncertainty, only Relative Positional Precision is controllable, although, due to the inherent errors in any measurement, it cannot be eliminated. The magnitude of the first three uncertainties can be projected based on evidence; Relative Positional Precision is estimated using statistical means (see Section 3.E.i. above and Section 3.E.v. below).
 - iii. The first three of these sources of uncertainty must be weighed as part of the evidence in the determination of where, in the surveyor’s opinion, the boundary lines and corners of the surveyed property should be located (see Section 3.D. above). Relative Positional Precision is a measure of how precisely the surveyor is able to monument and report those positions; it is not a substitute for the application of proper boundary law principles. A boundary corner or line may have a small Relative Positional Precision because the survey measurements were precise, yet still be in the wrong position (*i.e.*, inaccurate) if it was established or retraced using faulty or improper application of boundary law principles.
 - iv. For any measurement technology or procedure used on an ALTA/NSPS Land Title Survey, the surveyor shall (1) use appropriately trained personnel, (2) compensate for systematic errors, including those associated with instrument calibration, and (3) use appropriate error propagation and measurement design theory (selecting the proper instruments, geometric layouts, and field and computational procedures) to control random errors such that the

maximum allowable Relative Positional Precision outlined in Section 3.E.v. below is not exceeded.

- v. The maximum allowable Relative Positional Precision for an ALTA/NSPS Land Title Survey is 2 cm (0.07 feet) plus 50 parts per million (based on the direct distance between the two corners being tested). It is recognized that in certain circumstances, the size or configuration of the surveyed property, or the relief, vegetation, or improvements on the surveyed property, will result in survey measurements for which the maximum allowable Relative Positional Precision may be exceeded. If the maximum allowable Relative Positional Precision is exceeded, the surveyor shall note the reason as explained in Section 6.B.x. below.

4. Records Research - It is recognized that for the performance of an ALTA/NSPS Land Title Survey, the surveyor will be provided with appropriate and, when possible, legible data which can be relied upon in the preparation of the survey. The request for an ALTA/NSPS Land Title Survey shall set forth the current record description of the property to be surveyed or, in the case of an original survey prepared for purposes of locating and describing real property that has not been previously separately described in documents conveying an interest in the real property, the current record description of the parent parcel that contains the property to be surveyed.

In order to complete an ALTA/NSPS Land Title Survey, the surveyor must be provided with complete copies of the most recent title commitment or, if a title commitment is not available, other title evidence satisfactory to the title insurer. In addition, the surveyor must be provided with the following:

- (i) The following records established under state statutes for the purpose of imparting constructive notice of matters relating to real property (public records):
 - (a) The current record descriptions of any adjoiners to the property to be surveyed, except where such adjoiners are lots in platted, recorded subdivisions;
 - (b) Any recorded easements benefitting the property;
 - (c) Any recorded easements, servitudes, or covenants burdening the property;
- (ii) Any unrecorded documents affecting the property being surveyed and containing information to which the survey shall make reference, if desired by the client.

Except, however, if the documents outlined above in (i) and (ii) of this section are not provided to the surveyor or if non-public or quasi-public documents are required to complete the survey, the surveyor shall be required to conduct only that research which is required pursuant to the statutory or administrative requirements of the jurisdiction where the property being surveyed is located and that research (if any) which is negotiated and outlined in the terms of the contract between the surveyor and the client.

5. Fieldwork - The survey shall be performed on the ground (except as otherwise negotiated pursuant to Table A, Item 15 below, if selected by the client). The fieldwork shall include the following, located to what is, in the surveyor's professional opinion, the appropriate degree of precision based on (a) the planned use of the property, if reported in writing to the surveyor by the client, lender, or insurer, or (b) the existing use, if the planned use is not so reported:

A. Monuments

- i. The location, size, character, and type of any monuments found during the fieldwork.
- ii. The location, size, character, and type of any monuments set during the fieldwork, if item 1 of Table A was selected or if otherwise required by applicable jurisdictional requirements and/or standards of practice.
- iii. The location, description, and character of any lines that control the boundaries of the

surveyed property.

B. Rights of Way and Access

- i. The distance from the appropriate corner or corners of the surveyed property to the nearest right of way line, if the surveyed property does not abut a right of way.
- ii. The name of any street, highway, or other public or private way abutting the surveyed property, together with the width of the travelled way and the location of each edge of the travelled way including on divided streets and highways. If the documents provided to or obtained by the surveyor pursuant to Section 4 indicate no access from the surveyed property to the abutting street or highway, the width and location of the travelled way need not be located.
- iii. Visible evidence of physical access (e.g., curb cuts, driveways) to any abutting streets, highways, or other public or private ways.
- iv. The location and character of vehicular, pedestrian, or other forms of access by other than the apparent occupants of the surveyed property to or across the surveyed property observed in the process of conducting the fieldwork (e.g., driveways, alleys, private roads, railroads, railroad sidings and spurs, sidewalks, footpaths).
- v. Without expressing a legal opinion as to ownership or nature, the location and extent of any potentially encroaching driveways, alleys, and other ways of access from adjoining properties onto the surveyed property observed in the process of conducting the fieldwork.
- vi. Where documentation of the location of any street, road, or highway right of way abutting, on, or crossing the surveyed property was not disclosed in documents provided to or obtained by the surveyor, or was not otherwise available from the controlling jurisdiction (see Section 6.C.iv. below), the evidence and location of parcel corners on the same side of the street as the surveyed property recovered in the process of conducting the fieldwork which may indicate the location of such right of way lines (e.g., lines of occupation, survey monuments).
- vii. Evidence of access to and from waters adjoining the surveyed property observed in the process of conducting the fieldwork (e.g., paths, boat slips, launches, piers, docks).

C. Lines of Possession and Improvements along the Boundaries

- i. The character and location of evidence of possession or occupation along the perimeter of the surveyed property, both by the occupants of the surveyed property and by adjoining, observed in the process of conducting the fieldwork.
- ii. Unless physical access is restricted, the character and location of all walls, buildings, fences, and other improvements within five feet of each side of the boundary lines, observed in the process of conducting the fieldwork. Trees, bushes, shrubs, and other natural vegetation need not be located other than as specified in the contract, unless they are deemed by the surveyor to be evidence of possession pursuant to Section 5.C.i.
- iii. Without expressing a legal opinion as to the ownership or nature of the potential encroachment, the evidence, location and extent of potentially encroaching structural appurtenances and projections observed in the process of conducting the fieldwork (e.g., fire escapes, bay windows, windows and doors that open out, flue pipes, stoops, eaves, cornices, areaways, steps, trim) by or onto adjoining property, or onto rights of way, easements, or setback lines disclosed in documents provided to or obtained by the surveyor.

D. Buildings

The location of buildings on the surveyed property observed in the process of conducting the fieldwork.

E. Easements and Servitudes

- i. Evidence of any easements or servitudes burdening the surveyed property as disclosed in the documents provided to or obtained by the surveyor pursuant to Section 4 and observed in the process of conducting the fieldwork.

- ii. Evidence of easements, servitudes, or other uses by other than the apparent occupants of the surveyed property not disclosed in the documents provided to or obtained by the surveyor pursuant to Section 4, but observed in the process of conducting the fieldwork if they appear to affect the surveyed property (e.g., roads; drives, sidewalks, paths and other ways of access; utility service lines; water courses; ditches; drains; telephone, fiber optic lines, or electric lines; or water, sewer, oil or gas pipelines on or across the surveyed property and on adjoining properties).
- iii. Surface indications of underground easements or servitudes on or across the surveyed property observed in the process of conducting the fieldwork (e.g., utility cuts, vent pipes, filler pipes).
- iv. Evidence on or above the surface of the surveyed property observed in the process of conducting the fieldwork, which evidence may indicate utilities located on, over or beneath the surveyed property. Examples of such evidence include pipeline markers, manholes, valves, meters, transformers, pedestals, clean-outs, utility poles, overhead lines and guy wires.

F. Cemeteries

As accurately as the evidence permits, the perimeter of cemeteries and burial grounds, and the location of isolated gravesites not within a cemetery or burial ground, (i) disclosed in the documents provided to or obtained by the surveyor, or (ii) observed in the process of conducting the fieldwork.

G. Water Features

- i. The location of springs, ponds, lakes, streams, rivers, canals, ditches, marshes, and swamps on, running through, or outside, but within five feet of the perimeter boundary of, the surveyed property, observed during the process of conducting the fieldwork.
- ii. The location of any water feature forming a boundary of the surveyed property. The attribute(s) of the water feature located (e.g., top of bank, edge of water, high water mark) should be congruent with the boundary as described in the record description or, in the case of an original survey, in the new description (see Section 6.B.vi. below).

6. Plat or Map - A plat or map of an ALTA/NSPS Land Title Survey shall show the following information. Where dimensioning is appropriate, dimensions shall be annotated to what is, in the surveyor's professional opinion, the appropriate degree of precision based on (a) the planned use of the property, if reported in writing to the surveyor by the client, lender, or insurer, or (b) existing use, if the planned use is not so reported.

A. The evidence and locations gathered, and the monuments and lines located during the fieldwork pursuant to Section 5 above, with accompanying notes if deemed necessary by the surveyor or as otherwise required as specified below.

B. Boundary, Descriptions, Dimensions, and Closures

- i. (a) The current record description of the surveyed property, or
(b) In the case of an original survey, the current record description of the parent tract that contains the surveyed property.
- ii. Any new description of the surveyed property that was prepared in conjunction with the survey, including a statement explaining why the new description was prepared. Except in the case of an original survey, preparation of a new description should be avoided unless deemed necessary or appropriate by the surveyor and insurer. Preparation of a new description should also generally be avoided when the record description is a lot or block in a platted, recorded subdivision. Except in the case of an original survey, if a new description is prepared, a note shall be provided stating (a) that the new description describes the same real estate as the record description or, if it does not, (b) how the new description differs from

- the record description.
- iii. The point of beginning, the remote point of beginning or point of commencement (if applicable) and all distances and directions identified in the record description of the surveyed property (and in the new description, if one was prepared). Where a measured or calculated dimension differs from the record by an amount deemed significant by the surveyor, such dimension shall be shown in addition to, and differentiated from, the corresponding record dimension. All dimensions shown on the survey and contained in any new description shall be ground dimensions unless otherwise noted.
 - iv. The directional, distance and curve data necessary to compute a mathematical closure of the surveyed boundary. A note if the record description does not mathematically close. The basis of bearings and, where it differs from the record basis, the difference.
 - v. The remainder of any recorded lot or existing parcel, when the surveyed property is composed of only a portion of such lot or parcel, shall be graphically depicted. Such remainder need not be included as part of the actual survey, except to the extent necessary to locate the lines and corners of the surveyed property, and it need not be fully dimensioned or drawn at the same scale as the surveyed property.
 - vi. When the surveyed property includes a title line defined by a water boundary, a note on the face of the plat or map noting the date the boundary was measured, which attribute(s) of the water feature was/were located, and the caveat that the boundary is subject to change due to natural causes and that it may or may not represent the actual location of the limit of title. When the surveyor is aware of natural or artificial realignments or changes in such boundaries, the extent of those changes and facts shall be shown or explained.
 - vii. The relationship of the boundaries of the surveyed property with its adjoiners (e.g., contiguity, gaps, overlaps), where ascertainable from documents provided to or obtained by the surveyor pursuant to Section 4 and/or from field evidence gathered during the process of conducting the fieldwork. If the surveyed property is composed of multiple parcels, the extent of any gaps or overlaps between those parcels shall be identified. Where gaps or overlaps are identified, the surveyor shall, prior to or upon delivery of the final plat or map, disclose this to the insurer and client.
 - viii. When, in the opinion of the surveyor, the results of the survey differ significantly from the record, or if a fundamental decision related to the boundary resolution is not clearly reflected on the plat or map, the surveyor shall explain this information with notes on the face of the plat or map.
 - ix. The location of all buildings on the surveyed property, located pursuant to Section 5.D., dimensioned perpendicular to those perimeter boundary lines that the surveyor deems appropriate (i.e., where potentially impacted by a setback line) and/or as requested by the client, lender or insurer.
 - x. A note on the face of the plat or map explaining the site conditions that resulted in a Relative Positional Precision that exceeds the maximum allowed pursuant to Section 3.E.v.
 - xi. A note on the face of the plat or map identifying areas, if any, on the boundaries of the surveyed property, to which physical access within five feet was restricted (see Section 5.C.ii.).
 - xii. A note on the face of the plat or map identifying the source of the title commitment or other title evidence provided pursuant to Section 4, and the effective date and the name of the insurer of same.
- C. Easements, Servitudes, Rights of Way, Access, and Documents**
- i. The location, width, and recording information of all plottable rights of way, easements, and servitudes burdening and benefitting the property surveyed, as evidenced by documents provided to or obtained by the surveyor pursuant to Section 4.

- ii. A summary of all rights of way, easements and servitudes burdening the property surveyed and identified in the title evidence provided to or obtained by the surveyor pursuant to Section 4. Such summary shall include the record information of each such right of way, easement or servitude, a statement indicating whether or not it is shown on the plat or map, and a related note if:
 - (a) the location cannot be determined from the record document;
 - (b) there was no observed evidence at the time of the fieldwork;
 - (c) it is a blanket easement;
 - (d) it is not on, or does not touch, the surveyed property;
 - (e) it limits access to an otherwise abutting right of way;
 - (f) the documents are illegible; or
 - (g) the surveyor has information indicating that it may have been released or otherwise terminated.

In cases where the surveyed property is composed of multiple parcels, indicate which of such parcels the various rights of way, easements, and servitudes cross or touch.

- iii. A note if no physical access to a public way was observed in the process of conducting the fieldwork.
- iv. The locations and widths of rights of way abutting or crossing the surveyed property, and the source of such information, (a) where available from the controlling jurisdiction, or (b) where disclosed in documents provided to or obtained by the surveyor pursuant to Section 4.
- v. The identifying titles of all recorded plats, filed maps, right of way maps, or similar documents which the survey represents, wholly or in part, with their recording or filing data.
- vi. For non-platted adjoining land, recording data identifying adjoining tracts according to current public records. For platted adjoining land, the recording data of the subdivision plat.
- vii. Platted setback or building restriction lines which appear on recorded subdivision plats or which were disclosed in documents provided or obtained by the surveyor.

D. Presentation

- i. The plat or map shall be drawn on a sheet of not less than 8 ½ by 11 inches in size at a legible, standard engineering scale, with that scale clearly indicated in words or numbers and with a graphic scale.
- ii. The plat or map shall include:
 - (a) The boundary of the surveyed property drawn in a manner that distinguishes it from other lines on the plat or map.
 - (b) If no buildings were observed on the surveyed property in the process of conducting the fieldwork, a note stating “*No buildings observed.*”
 - (c) A north arrow (with north to the top of the drawing when practicable).
 - (d) A legend of symbols and abbreviations.
 - (e) A vicinity map showing the property in reference to nearby highway(s) or major street intersection(s).
 - (f) Supplementary or detail diagrams when necessary.
 - (g) Notes explaining any modifications to Table A items and the nature of any additional Table A items (e.g., 21(a), 21(b), 21(c)) that were negotiated between the surveyor and client.
 - (h) The surveyor’s project number (if any), and the name, registration or license number, signature, seal, street address, telephone number, company website, and email address (if any) of the surveyor who performed the survey.
 - (i) The date(s) of any revisions made by the surveyor who performed the survey.
 - (j) Sheet numbers where the plat or map is composed of more than one sheet.
 - (k) The caption “ALTA/NSPS Land Title Survey.”

iii. When recordation or filing of a plat or map is required by law, such plat or map shall be produced in recordable form.

7. **Certification** - The plat or map of an ALTA/NSPS Land Title Survey shall bear only the following certification, unaltered, except as may be required pursuant to Section 3.B. above:

To (name of insured, if known), (name of lender, if known), (name of insurer, if known), (names of others as negotiated with the client):

This is to certify that this map or plat and the survey on which it is based were made in accordance with the 2016 Minimum Standard Detail Requirements for ALTA/NSPS Land Title Surveys, jointly established and adopted by ALTA and NSPS, and includes Items _____ of Table A thereof. The fieldwork was completed on _____ [date].

Date of Plat or Map: _____ (Surveyor's signature, printed name and seal with Registration/License Number)

8. **Deliverables** - The surveyor shall furnish copies of the plat or map of survey to the insurer and client and as otherwise negotiated with the client. Hard copies shall be on durable and dimensionally stable material of a quality standard acceptable to the insurer. A digital image of the plat or map may be provided in addition to, or in lieu of, hard copies pursuant to the terms of the contract. When required by law or requested by the client, the plat or map shall be produced in recordable form and recorded or filed in the appropriate office or with the appropriate agency.

TABLE A

OPTIONAL SURVEY RESPONSIBILITIES AND SPECIFICATIONS

NOTE: The twenty (20) items of Table A may be negotiated between the surveyor and client. Any additional items negotiated between the surveyor and client shall be identified as 21(a), 21(b), etc. and explained pursuant to Section 6.D.ii.(g). Notwithstanding Table A Items 5 and 11, if an engineering design survey is desired as part of an ALTA/NSPS Land Title Survey, such services should be negotiated under Table A, Item 21.

If checked, the following optional items are to be included in the ALTA/NSPS LAND TITLE SURVEY, except as otherwise qualified (see note above):

1. _____ *Monuments placed (or a reference monument or witness to the corner) at all major corners of the boundary of the property, unless already marked or referenced by existing monuments or witnesses in close proximity to the corner.*

2. _____ *Address(es) of the surveyed property if disclosed in documents provided to or obtained by the surveyor, or observed while conducting the fieldwork.*

3. _____ *Flood zone classification (with proper annotation based on federal Flood Insurance Rate Maps or the state or local equivalent) depicted by scaled map location and graphic plotting only.*

4. _____ *Gross land area (and other areas if specified by the client).*

5. _____ *Vertical relief with the source of information (e.g., ground survey, aerial map), contour interval, datum, and originating benchmark identified.*

6. _____ *(a) If set forth in a zoning report or letter provided to the surveyor by the client, list the current zoning classification, setback requirements, the height and floor space area restrictions, and parking requirements. Identify the date and source of the report or letter.*
_____ *(b) If the zoning setback requirements are set forth in a zoning report or letter provided to the surveyor by the client, and if those requirements do not require an interpretation by the surveyor, graphically depict the building setback requirements. Identify the date and source of the report or letter.*

7. _____ *(a) Exterior dimensions of all buildings at ground level.*
(b) Square footage of:
_____ *(1) exterior footprint of all buildings at ground level.*
_____ *(2) other areas as specified by the client.*
_____ *(c) Measured height of all buildings above grade at a location specified by the client. If no location is specified, the point of measurement shall be identified.*

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8. _____ *Substantial features observed in the process of conducting the fieldwork (in addition to the improvements and features required pursuant to Section 5 above) (e.g., parking lots, billboards, signs, swimming pools, landscaped areas, substantial areas of refuse).*
9. _____ *Number and type (e.g., disabled, motorcycle, regular and other marked specialized types) of clearly identifiable parking spaces on surface parking areas, lots and in parking structures. Striping of clearly identifiable parking spaces on surface parking areas and lots.*
10. _____ *(a) As designated by the client, a determination of the relationship and location of certain division or party walls with respect to adjoining properties (client to obtain necessary permissions).*
- _____ *(b) As designated by the client, a determination of whether certain walls are plumb (client to obtain necessary permissions).*
11. _____ *Location of utilities existing on or serving the surveyed property as determined by:*
- *observed evidence collected pursuant to Section 5.E.iv.*
 - *evidence from plans requested by the surveyor and obtained from utility companies, or provided by client (with reference as to the sources of information), and*
 - *markings requested by the surveyor pursuant to an 811 utility locate or similar request*
- Representative examples of such utilities include, but are not limited to:*
- *Manholes, catch basins, valve vaults and other surface indications of subterranean uses;*
 - *Wires and cables (including their function, if readily identifiable) crossing the surveyed property, and all poles on or within ten feet of the surveyed property. Without expressing a legal opinion as to the ownership or nature of the potential encroachment, the dimensions of all encroaching utility pole crossmembers or overhangs; and*
 - *Utility company installations on the surveyed property.*
- Note to the client, insurer, and lender - With regard to Table A, item 11, source information from plans and markings will be combined with observed evidence of utilities pursuant to Section 5.E.iv. to develop a view of the underground utilities. However, lacking excavation, the exact location of underground features cannot be accurately, completely, and reliably depicted. In addition, in some jurisdictions, 811 or other similar utility locate requests from surveyors may be ignored or result in an incomplete response, in which case the surveyor shall note on the plat or map how this affected the surveyor's assessment of the location of the utilities. Where additional or more detailed information is required, the client is advised that excavation and/or a private utility locate request may be necessary.*
12. _____ *As specified by the client, Governmental Agency survey-related requirements (e.g., HUD surveys, surveys for leases on Bureau of Land Management managed lands).*

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13. _____ *Names of adjoining owners according to current tax records. If more than one owner, identify the first owner's name listed in the tax records followed by "et al."*
 14. _____ *As specified by the client, distance to the nearest intersecting street.*
 15. _____ *Rectified orthophotography, photogrammetric mapping, remote sensing, airborne/mobile laser scanning and other similar products, tools or technologies as the basis for the showing the location of certain features (excluding boundaries) where ground measurements are not otherwise necessary to locate those features to an appropriate and acceptable accuracy relative to a nearby boundary. The surveyor shall (a) discuss the ramifications of such methodologies (e.g., the potential precision and completeness of the data gathered thereby) with the insurer, lender, and client prior to the performance of the survey, and (b) place a note on the face of the survey explaining the source, date, precision, and other relevant qualifications of any such data.*
 16. _____ *Evidence of recent earth moving work, building construction, or building additions observed in the process of conducting the fieldwork.*
 17. _____ *Proposed changes in street right of way lines, if such information is made available to the surveyor by the controlling jurisdiction. Evidence of recent street or sidewalk construction or repairs observed in the process of conducting the fieldwork.*
 18. _____ *If there has been a field delineation of wetlands conducted by a qualified specialist hired by the client, the surveyor shall locate any delineation markers observed in the process of conducting the fieldwork and show them on the face of the plat or map. If no markers were observed, the surveyor shall so state.*
 19. _____ *Include any plottable offsite (i.e., appurtenant) easements or servitudes disclosed in documents provided to or obtained by the surveyor as a part of the survey pursuant to Sections 5 and 6 (and applicable selected Table A items) (client to obtain necessary permissions).*
 20. _____ *Professional Liability Insurance policy obtained by the surveyor in the minimum amount of \$_____ to be in effect throughout the contract term. Certificate of Insurance to be furnished upon request, but this item shall not be addressed on the face of the plat or map.*
 21. _____ _____

*Adopted by the Board of Governors, American Land Title Association, on October 8, 2015.
American Land Title Association, 1800 M St., N.W., Suite 300S, Washington, D.C. 20036-5828.
www.alta.org*

*Adopted by the Board of Directors, National Society of Professional Surveyors, on October 9, 2015.
National Society of Professional Surveyors, Inc., 5119 Pegasus Court, Suite Q, Frederick, MD 21704.
<http://www.nsp.us.com/>*