Understanding Errors

In Measurements

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A Friendly Pre-Test

- 1) Precision and Accuracy are the same thing T F
- 2) All errors can be avoided T F
- 3) All errors can be eliminated T F
- 4) How many significant figures will an answer
- have if a measured distance is multiplied by Pi?
- 5) How many significant figures is 0.032 ?
- 6) Individual random errors are added together
- to find the total random error of a measurement T F
- 7) If a manufacturer states that your EDM can
- measure to ± (3mm+2ppm) what confidence
- level are they referring to ?
- 8) An instrument centering error refers to
- how well a surveyor can set up over a point T F
- 9) In Surveying, all angle measurements
- are about the same precision T F
- 10) Weighting measurements allows the
- surveyor to put the error where it belongs T F

Understanding Errors In Measurements

(WHAT WE WILL COVER)

- Errors and Mistakes
- Precision and Accuracy
- Sources of Errors in Surveying
- Significant Figures
- Random Error Propagation
- Statistics for Land Surveyors
- Random Errors in Angles and Distance
- Practical Weights of Observations

Errors And Mistakes

Errors And Mistakes

Errors

The difference between the true and measured value of a measurement

The error equals the measured distance minus the true distance

$E = M - T$

They are unavoidable

Errors And Mistakes

Mistakes (Blunder)

A mistake is a blunder caused by carelessness

This type of problem has nothing to do with errors

Systematic And

Random Errors

Systematic And Random Errors

Systematic Errors

Their magnitude and direction can be determined

They are predictable

Systematic errors can be eliminated

This separates them from random errors

Systematic And Random Errors

Random Errors

Are unavoidable

Can be minimized but never eliminated

Have a tendency to cancel but never completely do so.

Can be dealt with by the science of propagation

Precision And Accuracy

Precision And Accuracy

Precision

- *The agreement of readings of the same quantity*
- *The better the precision the smaller the random error*
- *Good precision exposes random error*
- *Crude precision hides random errors*

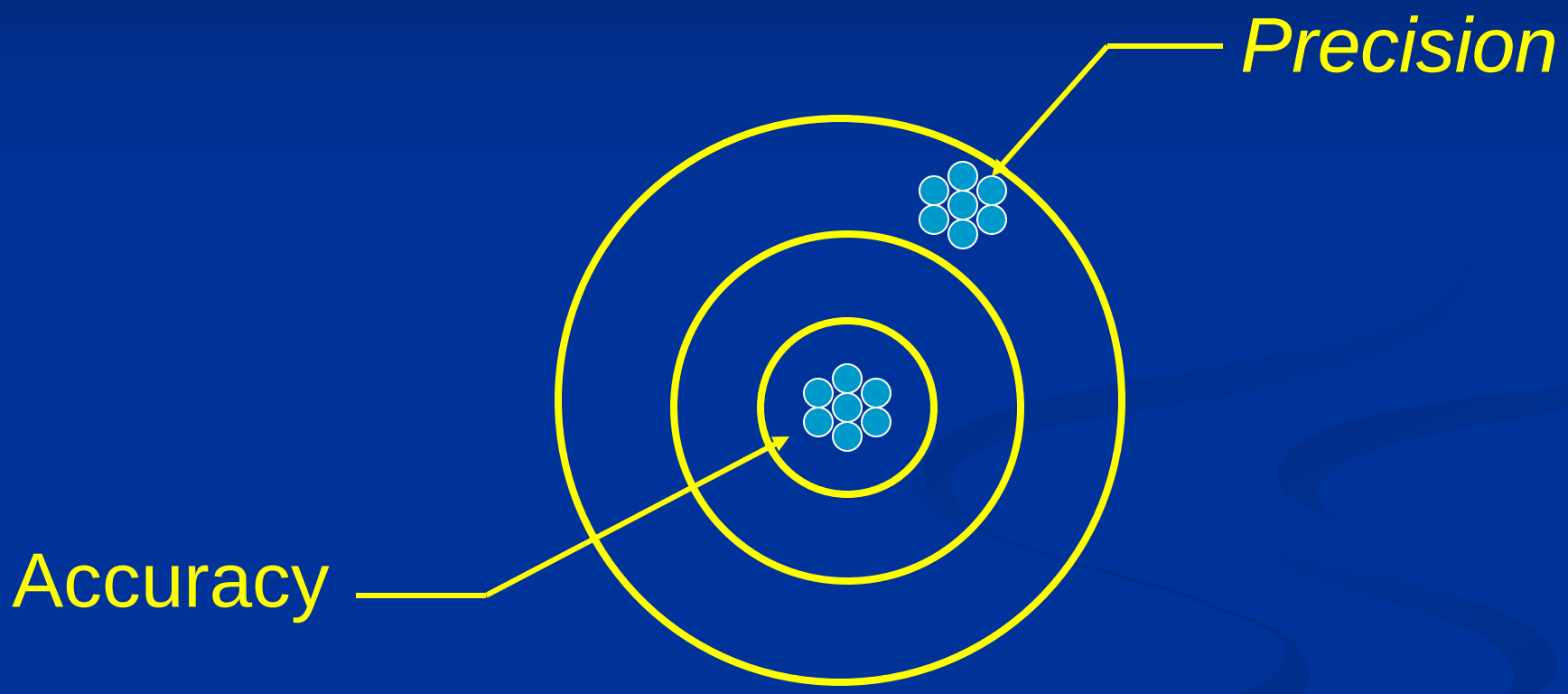
Precision And Accuracy

Accuracy

The agreement of readings with the true value

Accuracy is to systematic errors as precision is to random errors

Precision And Accuracy



Sources Of Errors In Surveying

Sources Of Errors In Surveying

Natural Errors

Caused by nature, wind, temperature, earth curvature, etc.

If the error is subject to known physical laws, it is systematic.

If the error does not follow known physical laws it is probably random

Sources Of Errors In Surveying

Instrumental Errors

Caused by manufacture, wear and tear, or maladjustment of instruments.

This type of error can also be thought of as a blunder

Most instrumental errors are random in nature

Sources Of Errors In Surveying

Personal Errors

Caused by the inability of a person perceive anything exactly

Can be controlled by good training, good motivation, and good technique

Personal errors are random and each person has their own

Significant Figures

Significant Figures

Significant figures is a part of mathematics that deals with the relevancy of digits in a number, and are mainly used in the surveying, scientific, and engineering community.

Significant Figures

Significant figures can be separated into two areas:

1) Significant figures in measurements

2) Significant figures in computations

Significant Figures

Measurements

Relates to the way measurements are made and recorded

No measurement is exact

When measuring, record only the digits that have meaning

Significant Figures

Computations

Concerns itself with round-off error

The surveyor must use established rules of significant figures

Significant Figures

Rules

The following rules apply to both recording data and interpreting recorded data

Significant Figures

Zeroes used merely to indicate the position of a decimal point are not significant

Example:

0.056 has two significant figures

Significant Figures

Rules

Zeroes recorded at the end of measurement are significant

Example:

1.30 has three significant figures

Significant Figures

Example:

Zeroes between non zero digits are significant

Example:

1.04 has three significant figures

Significant Figures

Rules

Numbers ending with one or more zeroes to the left of the decimal should have a special indication

Significant Figures

Example:

17$\overline{5}$,000 has three significant figures

375,000 can have six significant figures

Significant Figures

Rules

When adding or subtracting measured distances the number with the <u>fewest</u> decimal places will dictate the number of significant figures

Significant Figures

Rules

Example: Adding or Subtracting

15.495

10.21

12.2 ⟵ *control, fewest number of decimals*

37.905

The proper answer is 37.9, having three significant figures

Significant Figures

Rules: Multiplication or Division

The product or quotient is determined by the fewest number of significant figures in the values used, if both are measured values

Significant Figures

Example:

5.29 x 0.052 = 0.28 two significant figures

Significant Figures

Rules

Conversion factors do not determine significant figures

Example:

1534.5 in / 12in per ft = 127.88 ft.

Significant Figures

Rules

With large or infinite number conversion factors; use one extra digit

Example:

174.35 x 3.14 = 547.46 ⟵ *incorrect*

174.35 X 3.14159 = 547.74 ⟵ *correct*

Significant Figures

Rules

With intermediate calculations use one extra digit and round off your answer

Example:

Intermediate Calculation

$$\frac{43.56 \times 23.43}{21.02} = \frac{1020.6}{21.02} = 48.55$$

Random Error

Propagation

Random Error Propagation

All measurements have random errors

Random errors have a tendency to cancel

but never completely do so

Random Error Propagation

How random errors accumulate, cancel, decrease or behave through the process of computing the final value is termed "Propagation of Random Errors"

Random Error Propagation

Errors in a sum

Used when all errors are different

It is the square root of the sum of the squares of the errors

$$E = \pm\sqrt{e_1^2 + e_2^2 + e_3^2 + \ldots + e_n^2}$$

Random Error Propagation

Errors in a Series

Used when the same error happens several times

Derived from the formula of errors in a sum

$$E = \pm e\sqrt{n}$$

Random Error Propagation

Errors in a Product

Used in determining the random error of area calculations

Is also the square root of the sum of the squares of the errors

$$E = \pm\sqrt{(Le_w)^2 + (We_L)^2}$$

Statistics For

Surveyors

Statistics For Surveyors

Definitions

Direct Measurements

A measurement made directly between two or more points

Statistics For Surveyors

Definitions

Indirect Measurements

A computed measurement

between points

Statistics For Surveyors

Definitions

Sample Size

The number of observations or measurements in a sample

n = *Sample Size*

Statistics For Surveyors

Mean

The sum of observations of a sample divided by the sample size

$$\overline{X} = \frac{S x_i}{n}$$

$\overline{X}$ =*Mean*

X_i = *The value of the sample*

Theodolite Micrometer Readings
WILD T-2

Observations	Readings, Seconds
1	31.8
2	32.3
3	31.9
4	30.2
5	31.4
6	32.7
7	31.1
8	31.0
9	31.2
10	30.3
11	30.4
12	30.9
13	31.4
14	31.0
15	31.4
16	30.8
17	31.8
18	31.0
19	30.6
20	30.4
21	31.4
22	30.2
23	31.0
24	31.5
25	31.7

Sample Size = 25

Sn = 779.4

Mean = 779.4 / 25 = 31.2

Statistics For Surveyors

Definitions

Median

The middle value of the sample when the data is arranged in ascending or descending order

Statistics For Surveyors

Definitions

Mode

The value which occurs most frequently in a sample

Theodolite Micrometer Readings
WILD T-2

Observations	Readings, Seconds
1	30.2
2	30.2
3	30.3
4	30.4
5	30.4
6	30.6
7	30.8
8	30.9
9	31.0
10	31.0
11	31.0
12	31.0
13	31.1
14	31.2
15	31.4
16	31.4
17	31.4
18	31.4
19	31.5
20	31.7
21	31.8
22	31.8
23	31.9
24	32.3
25	32.7

Sum =	779.4
Mean =	31.2
Median =	31.1
Mode =	31.0 and 31.4
Range =	2.5
n =	25

Mode

Median

Mode

Statistics For Surveyors

Definitions

Residual

The difference between an individual value in a sample and the mean of the sample

$$V_i = X_i - \overline{X}$$

V_i = *Residual*

Statistics For Surveyors

Definitions

Standard Deviation

68% probability of an occurrence

$$s = \pm \sqrt{\frac{Sv_i^2}{n-1}}$$

s = Standard Deviation

Calculation of Standard Deviation

WILD T-2

Observations	Readings, Seconds	Mean	V	V^2
1	31.8	31.2	0.6	0.36
2	32.3	31.2	1.1	1.21
3	31.9	31.2	0.7	0.49
4	30.2	31.2	-1.0	1.00
5	31.4	31.2	0.2	0.04
6	32.7	31.2	1.5	2.25
7	31.1	31.2	-0.1	0.01
8	31.0	31.2	-0.2	0.04
9	31.2	31.2	0.0	0.00
10	30.3	31.2	-0.9	0.81
11	30.4	31.2	-0.8	0.64
12	30.9	31.2	-0.3	0.09
13	31.4	31.2	0.2	0.04
14	31.0	31.2	-0.2	0.04
15	31.4	31.2	0.2	0.04
16	30.8	31.2	-0.4	0.16
17	31.8	31.2	0.6	0.36
18	31.0	31.2	-0.2	0.04
19	30.6	31.2	-0.6	0.36
20	30.4	31.2	-0.8	0.64
21	31.4	31.2	0.2	0.04
22	30.2	31.2	-1.0	1.00
23	31.0	31.2	-0.2	0.04
24	31.5	31.2	0.3	0.09
25	31.7	31.2	0.5	0.25
			$\Sigma V^2 =$	10.04

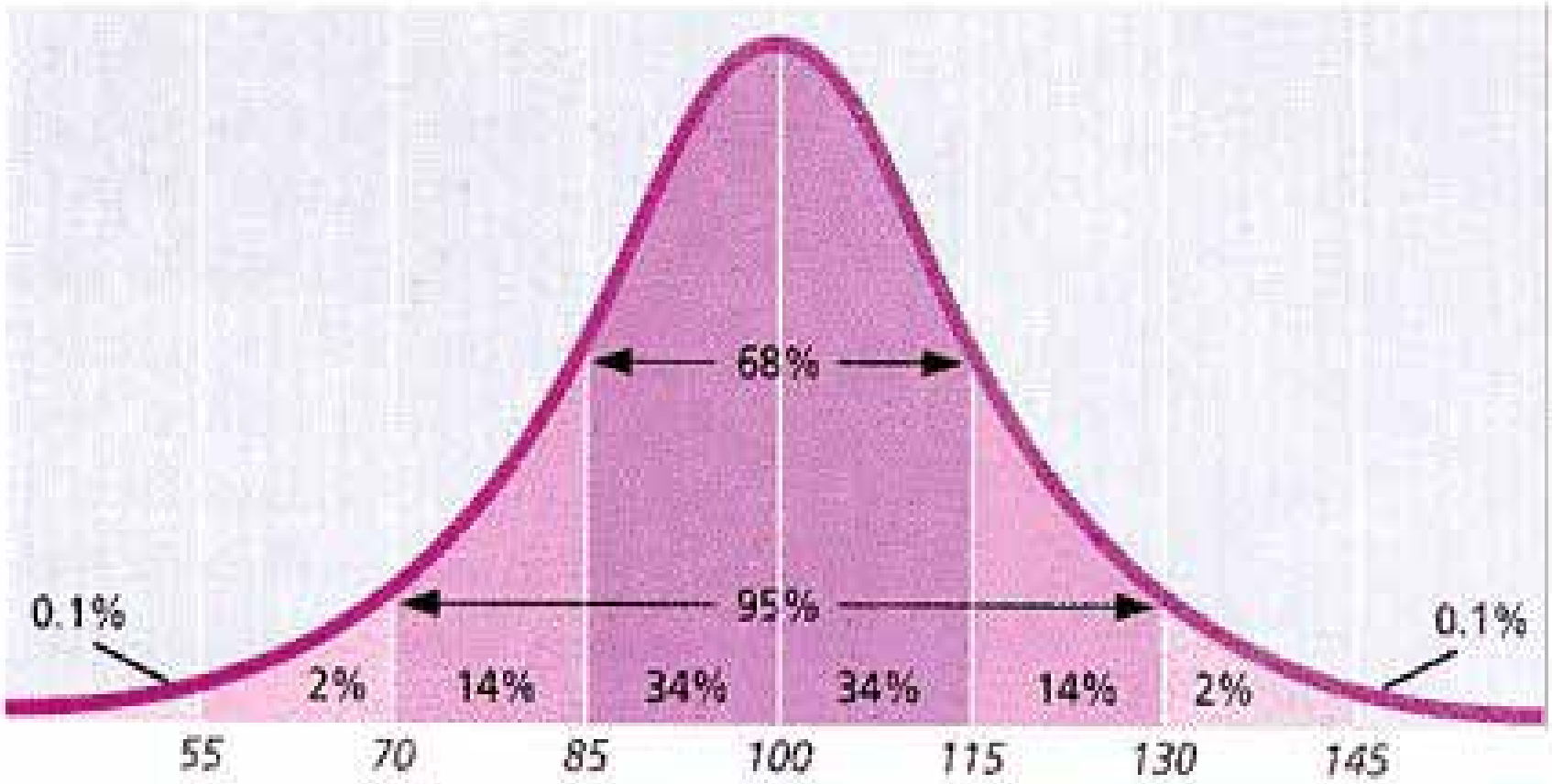
$$\sigma = \pm\sqrt{\frac{\Sigma v^2}{n-1}} = \pm\sqrt{\frac{10.04}{24}} = \pm\sqrt{0.418} = \pm 0.65$$

Statistics For Surveyors

Levels Of Certainty

NAME OF ERROR	SYMBOL	VALUE	% CERTAINTY
PROBABLE	E_{50}	0.6745s	50
STANDARD DEVIATION	s	1s	68.3
90% ERROR	E_{90}	1.6447s	90
TWO SIGMA	E_{95}	2s	95
99% ERROR	E_{99}	2.5s	99
THREE SIGMA	$E_{99.7}$	3s	99.7

Bell Curve



Statistics For Surveyors

Definitions

Standard Error of the Mean

The interval of uncertainty around the true value.

$$S_x = \pm \frac{s}{\sqrt{n}}$$

Statistics For Surveyors

Definitions

Standard Error of the Mean

$$s_{\bar{x}} = \pm \frac{s}{\sqrt{n}} = \pm \frac{0.65}{\sqrt{25}} = \pm 0.13$$

Pre-analysis

Formulas

Pre-analysis Formulas

Reading Error *Directional Theodolite*

$$s_{a_r} = \pm \frac{s_r \sqrt{2}}{\sqrt{n}}$$

s_{ar} = *The total reading error*

s_r = *The individual reading error*

n = *The number of angles turned*

Pre-analysis Formulas

Reading Error *Repetition Theodolite*

$$s_{a_r} = \pm \frac{s_r \sqrt{2}}{n}$$

s_{ar} = *The total reading error*

s_r = *The individual reading error*

n = *The number of angles turned*

Reading Error Example

Directional Theodolite

s_r = *individual reading error* (0.65)

n = *number of angles turned (4)*

$$s_{a_r} = \pm \frac{s_r \sqrt{2}}{\sqrt{n}} \qquad s_{a_r} = \pm \frac{0.65\sqrt{2}}{\sqrt{4}} = 0.46$$

Reading Error Example

Repetition Theodolite

s_r = *individual reading error (0.65)*

n = *number of angles turned (4)*

$$s_{a_r} = \pm \frac{s_r \sqrt{2}}{n} \quad s_{a_r} = \pm \frac{0.65\sqrt{2}}{4} = 0.23$$

Reading Error Example

Topcon IS

Laser class for distance measurement	:	Class 1(IEC Publication 825)
	:	Class I(FDA/BHR 21 CFR 1040)
Atmospheric Correction Range	:	–999.9 ppm to +999.9 ppm, in 0.1 ppm increments
Prism Constant Correction Range	:	–99.9 mm to +99.9 mm, in 0.1 mm increments
Coefficient Factor	:	Meter / Feet
		International feet 1meter = 3.2808398501 ft.
		US SURVEY feet 1meter = 3.2808333333 ft.
Electronic Angle Measurement		
Method	:	Absolute reading
Detecting system :		
Horizontal	:	2 sides
Vertical	:	2 sides
Minimum reading		
IS 01	:	1"/0.5" (0.5mgon/0.1mgon, 5mmil/2mmil) reading
IS 03	:	5"/1" (1mgon/0.2mgon, 20mmil/ 5mmil) reading
Accuracy(Standard deviation based on DIN 18723)		
IS 01	:	1"(0.3mgon)
IS 03	:	3"(1.0mgon)
Diameter of circle	:	71 mm
Tilt Correction		
Type	:	Automatic vertical and Horizontal index
Method	:	Liquid type
Compensating Range	:	±6'
Correction unit	:	1"(0.1mgon)
Computer unit		
Microprocessor	:	Intel PXA255

Pre-analysis Formulas

Pointing Error

E_{pb} = *Error in pointing to the backsight*

E_{pf} = *Error in pointing to the foresight*

d_c = *Estimate of how closely the observer can center the cross-hairs on the target*

D = The distance to the backsight or the foresight

Pre-analysis Formulas

Pointing Error

$$\frac{d_c}{D} = \text{Angle in radians}$$

$$\frac{d_c}{D}(206{,}265) = \text{Angle in Seconds}$$

Pre-analysis Formulas

Pointing Error

$$E_{pb} = \pm \frac{d_b}{D_b}(206{,}265) =$$ *Pointing Error, Backsite*

$$E_{pf} = \pm \frac{d_f}{D_f}(206{,}265) =$$ *Pointing Error, Foresite*

Pointing Error Example

Pointing Error

$$E_{p_b} = \pm \frac{d_b}{D_b}(206265)$$

$d_b = 0.01'$; $D_b = 350.25$

$$E_{p_b} = \pm \frac{0.01}{350.25}(206{,}265) = 5.89''$$

Pointing Error Example

Pointing Error

$$E_{p_f} = \pm \frac{d_f}{D_f}(206{,}265)$$

d_f = 0.01' ; D_f = 425.36

$$E_{p_f} = \pm \frac{0.01}{425.36}(206{,}265) = 4.85''$$

Pre-analysis Formulas

Pointing Error

Error in one angle turned

$$E_p = \pm\sqrt{E_{pb}^{\ 2} + E_{pf}^{\ 2}}$$

Pointing Error Example

Pointing Error

Error in one angle turned

$$E_p = \pm\sqrt{E^2{}_{p_b} + E^2{}_{p_f}}$$

$$E_p = \pm\sqrt{5.89^2 + 4.85^2} = 7.63''$$

Pointing Error Example

Pointing Error

Total error in multiple sets turned

$$s_{ap} = \pm \frac{E_p \sqrt{2}}{\sqrt{n}}$$

Total Pointing Error

$$s_{a_p} = \pm \frac{7.63\sqrt{2}}{\sqrt{4}} = 5.40''$$

Pre-analysis Formulas

Instrument centering error

$$s_{ai} = \pm \frac{d_c D_3}{D_f D_b \sqrt{2}} (206{,}265) = \text{Angle In Seconds}$$

d_c= *Estimate of how well you can set up over a point*

D_b= *Distance to backsight*

D_f= *Distance to foresight*

D_3= *Distance from the backsight to the foresight*

Instrument Centering Error

Example:

$$s_{a_i} = \pm \frac{d_c D_3}{D_f D_b \sqrt{2}} (206{,}265)$$

$d_c = 0.005'$ $D_f = 425.36'$

$D_b = 350.25'$ $D_3 = 372.11'$

$$s_{a_i} = \pm \frac{(0.005')(372.11')}{(425.36')(350.25')\sqrt{2}} (206{,}265) = 1.82''$$

Pre-analysis Formulas

Target Centering Error

$d_b + d_f$ = *How well you can set up a target over a point*

D_b = *Distance to the backsight*

D_f = *Distance to the foresight*

E_{tb} & E_{tf} = *Angular error to the backsight and foresight in seconds*

s_{at} = *Total angular error*

Pre-analysis Formulas

Target Centering Error

$$E_{tb} = \pm \frac{d_b}{D_b}(206{,}265)$$

$$E_{tf} = \pm \frac{d_f}{D_f}(206{,}265)$$

Pre-analysis Formulas

Target Centering Error

$$s_{at} = \pm\sqrt{E_{tb}^{2} + E_{tf}^{2}}$$

Target Centering Error Example

$$E_{t_b} = \frac{d_b}{D_b}(206{,}265)$$

$$d_b = 0.005'$$

$$D_b = 350.25$$

$$E_{t_b} = \frac{0.005'}{350.25'}(206{,}265) = 2.94''$$

Target Centering Error Example

$$E_{t_f} = \frac{d_f}{D_f}(206{,}265)$$

$$d_f = 0.005'$$

$$D_f = 425.36'$$

$$E_{t_f} = \frac{0.005'}{425.36'}(206{,}265) = 2.42''$$

Target Centering Error Example

$$s_{a_t} = \pm\sqrt{E^2{}_{t_b} + E^2{}_{t_f}}$$

$$E_{t_b} = 2.94''$$

$$E_{t_f} = 2.42''$$

$$s_{at} = \pm\sqrt{2.94^2 + 2.42^2} = 3.81''$$

Pre-analysis Formulas

Bubble Centering Error

$$s_{ab} = \pm \frac{\sqrt{(f_d m \tan g_b)^2 + (f_d m \tan g_f)^2}}{n}$$

g= *Vertical angle to backsight and foresight (not zenith angles)*

m= *Bubble sensitivity of the spirit level in seconds*

Pre-analysis Formula

Bubble Centering Error

$$s_{ab} = \pm \frac{\sqrt{(f_d \, m\mathrm{Tan}g_b)^2 + (f_d \, m\mathrm{Tan}g_f)^2}}{n}$$

f_d= Estimate of how closely the instrument can be leveled during a set of angles in fractions of divisions of the spirit level

n = Number of angles turned

Bubble Centering Error Example

$$s_{ab} = \pm \frac{\sqrt{(f_d m \tan g_b)^2 + (f_d m \tan g_f)^2}}{n}$$

$f_d = 0.5$ $m = 10''$ $g_b = 25°30'45''$

$g_f = 32°15'09''$ $n = 4$

Bubble Centering Error Example

$$s_{a_b} = \pm \frac{\sqrt{(0.5 \cdot 10 \cdot Tan 25^0 30' 45'')^2 + (0.5 \cdot 10 \cdot Tan 32^0 15' 09'')^2}}{4} = 0.99''$$

Total Random Error

$$s_a = \pm \sqrt{s_r^2 + s_p^2 + s_i^2 + s_t^2 + s_b^2}$$

s_r = Reading Error

s_p = Pointing Error

s_i = Instrument Centering Error

s_t = Target Centering Error

s_b = Bubble Centering Error

Total Random Error

$$s_a = \pm\sqrt{0.46^2 + 5.40^2 + 1.82^2 + 3.81^2 + 0.99^2} = 6.93''$$

Reading Error $_{directional}$	= 0.46”
Pointing Error	= 5.40”
Instrument Centering Error	= 1.82”
Target Centering Error	= 3.81”
Bubble Centering Error	= 0.99”
Total Angular Error	= 6.93”

Pre-analysis Formulas

EDM Error

$$s_{EDM} = \pm\sqrt{E_m^2 + E_t^2 + E_i^2}$$

E_m= (Standard manufacturer error) (distance)

E_t= Target centering error in feet

E_i= Instrument centering error in feet

Pre-analysis Formulas

EDM Error

$$s_{EDM} = \pm\sqrt{0.01^2 + 0.005^2 + 0.005^2} = 0.01'$$

$E_m = 0.01 \quad \pm [\ 3mm + (3ppm)(425.36')]$

$E_t = 0.005'$ *Target Centering*

$E_i = 0.005'$ *Instrument Centering*

Pre-analysis Formulas

18 SPECIFICATIONS

Measurement accuracy/Least Count in Measurement/Measurement Time

- Prism mode

Measurement mode		Measurement accuracy *1)	Least Count in Measurement	Measurement Time
Fine	0.2mm mode	± (2mm +2ppm × D) m.s.e.	0.2mm (0.001ft)	Approx. 3 sec. (Initial 4 sec.)
	1mm mode		1mm (0.005ft)	Approx. 1.2 sec. (Initial 3 sec.)
Coarse	1mm mode	± (7mm +2ppm × D) m.s.e.	1mm (0.005ft)	Approx. 0.5 sec. (Initial 2.5 sec.)
	10mm mode	± (10mm +2ppm × D) m.s.e.	10mm (0.02ft)	Approx. 0.3 sec. (Initial 2.5 sec.)

D:Measuring distance

- Non-prism mode (Diffusing Surface) D:Measuring distance

Measurement mode		Measurement accuracy	Least Count in Measurement	Measurement Time *2)
Fine	0.2mm mode	± (5mm) m.s.e.	0.2mm (0.001ft)	Approx. 3 sec. (Initial 4 sec.)
	1mm mode		1mm (0.005ft)	Approx. 1.2 sec. (Initial 3 sec.)
Coarse	1mm mode	± (10mm) m.s.e.	1mm (0.005ft)	Approx. 0.5 sec. (Initial 2.5 sec.)
	10mm mode		10mm (0.02ft)	Approx. 0.3 sec. (Initial 2.5 sec.)

- Non-prism long mode *3) *4) (Diffusing Surface) D:Measuring distance

Measurement mode		Measurement accuracy	Least Count in Measurement	Measurement Time
Fine	1mm mode	± (10mm +10ppm × D) m.s.e.	1mm (0.005ft)	Approx. 1.5~6 sec. (Initial 6~8 sec.)
Coarse	5mm mode	± (20mm +10ppm × D) m.s.e.	5mm (0.02ft)	Approx. 1~3 sec. (Initial 6~8 sec.)
	10mm mode	± (100mm) m.s.e.	10mm (0.02ft)	Approx. 0.4 sec. (Initial 4~7 sec.)

*1)More than 2m
*2)The initial time will be different by a condition.
*3)Measurement distance: No more than 500m, When Kodak gray card (white surface) is used.
*4)However, when the measurement distance is more than 500 m, or when the reflectance of the measured surface is low, measurement time will become longer.

In Summary

Random errors are part of every measurement taken by a surveyor.

In order to control random errors a surveyor must first understand them.

In Summary

Once the surveyor understands random errors they can place them where they belong.

This is critical because some measurements are better than others.

Weights Of Observations

General

Some measurements are better than others. This is common knowledge in the surveying profession.

General

Measurements made in good conditions, using good equipment, with proper survey procedures will produce good results.

General

Measurements made in adverse conditions, using poor equipment, and bad surveying procedures will produce bad results.

General

As a rule, surveyors use good equipment, with good procedures, but can work in poor conditions

General

Because of this, the quality of measurements can vary from setup to setup in the same job.

General

Weighting measurements allows the surveyor to distribute errors of the measurements where the error should go.

General

If one angle in a survey is turned under good conditions and another angle, in the same survey, is turned under bad conditions, weighting measurements allows for putting more of the error in the bad angle than in the good angle.

General

According to statistical theory, the weight of a measurement is inversely proportional to the variance.

General

The higher the precision of the measurement, the smaller the variance.

General

The smaller the variance, the larger the weight.

OR

The better the measurement, the larger the weight.

The Variance

What is the variance?

Simply put, the variance is the square of the standard deviation.

The Variance

The standard deviation of a set of measurements can be determined by statistical analysis.

The Variance

This can get complicated in a hurry, and many practicing surveyors tend not to use weights

The Variance

If weights are not applied to the surveyors measurements, all the measurements are treated the same. <u>This is false</u> !

Weights Of Observations

Weighting measurements does not need to be this complicated

Surveyor can assign weights to their measurements

Weights Of Observations

The worse the measurement, the smaller the weight.

The more precise the measurement, the larger the weight.

Example One

A distance between two points were measured four times.

The first distance was found to be 396.57 feet and was measured with a cloth tape

Example One

The second and third distances were found to be 396.61 and 396.62 feet, and were measured with a steel calibrated tape

Example One

The fourth distance was found to be 396.64 feet and was measured with an EDM.

Example One

The party chief assigned a weight of one (1) to the first measurement, a weight of two (2) the second and third measurement, and a weight of four (4) to the final measurement.

These values were not based on statistical theory, but based on field judgment.

Low precision, large variance, low weight

High precision, small variance, large weight

Example One

The formula to calculate the weighted mean of the distance is.

$$\boxed{\frac{SWM}{SW} = \overline{M_W}}$$

SWM = *The sum of the measurements times their weights*

$SW =$ *The sum of the weights*

$\overline{M_W} =$ *The weighted mean distance*

Example One

Using the weighted mean formula in our example we have.

$$\frac{396.57(1)+396.61(2)+396.62(2)+396.64(4)}{1+2+2+4}=396.62$$

While the above example shows how to weight measurements, it is not very practical as most distance measurements are made with EDM's, and the need to weight measurements are rare.

Example Two

A five sided traverse was run with the following results

Station	Angle	Weight
A	76°46’35”	W = 1
B	87°15’20”	W = 2
C	122°10’45”	W = 2
D	165°58’25”	W = 3
E	87°48’50”	W = 4
Total	359°59’55”	12
Error	00°00’05”	

Example Two

Historically, one second would be put into each angle and the error would be eliminated.

Example Two

If this is done, than all of the angles are treated the same, that is, all of the angles are given the same weight.

Example Two

In this case it is the party chief that determines the weights of the angles from the conditions in the field.

Example Two

The party chief assigns the weights of the angles as follows.

Angle “A” is the worst angle

Angles “B” and “C” are better than “a” but still not real good.

Angle “D” was better than the others but not the best.

Angle “E” was the best angle in the traverse

Example Two

The weight of angle “A” = 1,

The weights of angles“B” and “C” = 2

The weight of angle “D” = 3

The weight of angle “E” = 4

.

Example Two

Angle adjustments are made inversely proportional to their weights. The larger the weight of the angle, the smaller the adjustment

Example Two

The table illustrates how weights are used to distribute errors

Station	Measured	Weight	Correction	Numerical Correction	Rounded Correction	Adjusted Angles
A	76°46’35”	1	12X	1.94”	2”	76°46’37”
B	87°15’20”	2	6X	0.97”	1”	87°15’21”
C	122°10’45”	2	6X	0.97”	1”	122°10’46”
D	165°58’25”	3	4X	0.65”	1”	165°58’26”
E	87°48’50”	4	3X	0.47”	0”	87°48’50”
Sum	539°59’55”	12	31X	5.00”	5”	540°00’00”
			31X=5”	X=0.16”		

Example Two

To find the correction factor , divide the individual weights into the sum of the weights.

To find the value of “x”, place the sum of the correction factors equal to the error and solve for “x”

To find the numerical correction, multiply the individual correction factor times the value of “x”

Example Two

As seen in the chart, the worst angle received the largest correction (2”), and the best angle had no correction at all.

This is more realistic with what the party chief observed in the field when the angles were turned

How Weights Can Be Determined

A surveyor can make their own system. One example will be to divide the angles into four categories, as follows.

How Weights Can Be Determined

Category 1 might be one where the setup is on soft ground and the surveyor is having a hard time keeping the instrument level, and their backsite or foresite (or both) is short.

This could receive a weight of one (1)

How Weights Can Be Determined

<u>Category 2:</u> the second example might be where the surveyor is on firm ground but still has a shore backsite and is having a hard time seeing his foresite. This type of angle could receive a weight of two (2)

How Weights Can Be Determined

<u>Category 3:</u> the third example might be where the surveyor is on firm ground, with good sites both front and back, but the conditions are not very good. It could be foggy or there might be a lot of heat waves. This type of angle could receive a weight of three (3)

How Weights Can Be Determined

<u>Category 4:</u> the last example is the best angle. The surveyor is on firm ground with good sites, turning an angle with strong strength of figure. The weather is high overcast skies and about 65°f This type of angle could receive a weight of four (4)

Conclusion

*Many programs, such as star*net, allow you to weight your measurements very easily and with very little practice the surveyor can use weights and put the error where it belongs.*

Conclusion

Using weights helps take control of measurements and helps distribute errors in a more realistic manner that can result in a better, more accurate survey.