

MEETING ALTA/ACSM SURVEY REQUIREMENTS FOR ERROR CERTIFICATION

Prof. Bill Hazelton
UAA Geomatics

ALTA/ACSM STANDARD

3A. 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 (two standard deviations). Relative Positional Precision is estimated by the results of a correctly weighted least squares adjustment of the survey.

KEY ISSUES

- **Least Squares Adjustment, correctly weighted**
- **Semi-major axis of error ellipses between points**
- **95% Confidence Interval (2 sigma)**
- **Relative precision vs absolute precision**
- **Random errors only**

CONTROLLING ERRORS

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, and (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).

KEY ISSUES

- **Relative Positional Precision is the only error source of the four over which the surveyor has control**
- **The other error sources need to be ‘projected’ (not estimated) using evidence and non-statistical methods**
- **We will focus on the Relative Positional Precision in this discussion**

PRECISION VS ACCURACY

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.

KEY ISSUES

- **The key difference between precision and accuracy**
- **Relative Positional Precision is all about precision, not accuracy**
- **The other error sources give information about accuracy**

TECHNOLOGY

IV. For any measurement technology or procedure used on an ALTA/ACSM 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.

KEY ISSUES

- **Trained personnel**
- **Calibration**
- **Systematic error correction**
- **Geometric contribution to error must be tracked, as well as measurement contribution to error (least squares adjustment helps here)**

ALLOWABLE PRECISION

The maximum allowable Relative Positional Precision for an ALTA/ACSM 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 Paragraph 6.B.ix below

KEY ISSUES

- **Direct connections between corners:**
 - **Which are the worst corners on a job?**
 - **Does this mean all corners with respect to all others?**
- **Error beyond that allowed must be reported and explained**

‘ABSOLUTE’ PRECISION

- **‘Absolute’ precision is usually considered to be the precision of a point with respect to some datum, e.g., NAD 83**
- **This really means the precision with respect to the center of the Earth**
- **This will include all measurements and their errors to get to you from the datum point (this may be large)**

‘ABSOLUTE’ PRECISION

- **In a small survey, all the points in the survey will have about the same ‘absolute’ precision**
- **This is because they are all about the same distance from the datum and connected in about the same way**
- **‘Absolute’ precision can approach meters for older jobs (imagine the traverse back to Meade’s Ranch)**

‘ABSOLUTE’ PRECISION

- **As will be appreciated, ‘absolute’ precision is of little use for a local survey, even though it may be available**
- **Two nearby surveys of comparable quality may have radically different ‘absolute’ precisions, owing to different connections to the datum, which were not done by the surveyors doing the actual jobs**
- **So we use ‘Relative’ Precision instead for small surveys**

‘RELATIVE’ PRECISION

- **Note that ‘Relative’ Precision is NOT Local Accuracy, which requires more complex calculations**
- **Relative Positional Precision is how repeatably pairs of points are positioned with respect to each other within a single survey**
- **This can be determined using positional error ellipses in an unconstrained adjustment, as one approach**

UN/CONSTRAINED

- If we adjust a set of survey data using the absolute minimum number of constraints that allow a solution, we have a ‘minimally constrained’ adjustment, loosely termed ‘unconstrained’
- The minimum constraints for a 2-D network are one fixed point and one fixed azimuth
- If any other data are held fixed, e.g., control points, this is a constrained adjustment

UNCONSTRAINED

- If we fix a single point in a survey network, so its adjusted precision equals zero, the error ellipses of the other points show the relative precision with respect to the fixed point
- This allows a quick and simple estimate of the relative position of all points with respect to just one
- What about relative precision with respect to other points?

UNCONSTRAINED

- The adjustment needs to be re-run with another point held fixed, and the process repeated
- A search through the various error ellipse parameters produced by the adjustment will show the largest relative error between pairs of points
- However, this is tedious for a large adjustment, but fairly simple for a small one

UNCONSTRAINED

- **An unconstrained (minimally constrained) adjustment usually gives the smallest possible corrections to measurements**
- **This is because the measurements ‘fall’ into an arrangement that depends only on themselves**
- **This allows you to find errors and other problems much more easily**

CONSTRAINED

- **As soon as you start to add additional control points, the 'shape' of the network starts to get distorted**
- **The size of the adjustments to the measurements necessarily will increase**
- **A good fit to control means minimal change from the unconstrained adjustment**
- **Large corrections can mean problems fitting control**

READING THE ADJUSTMENT

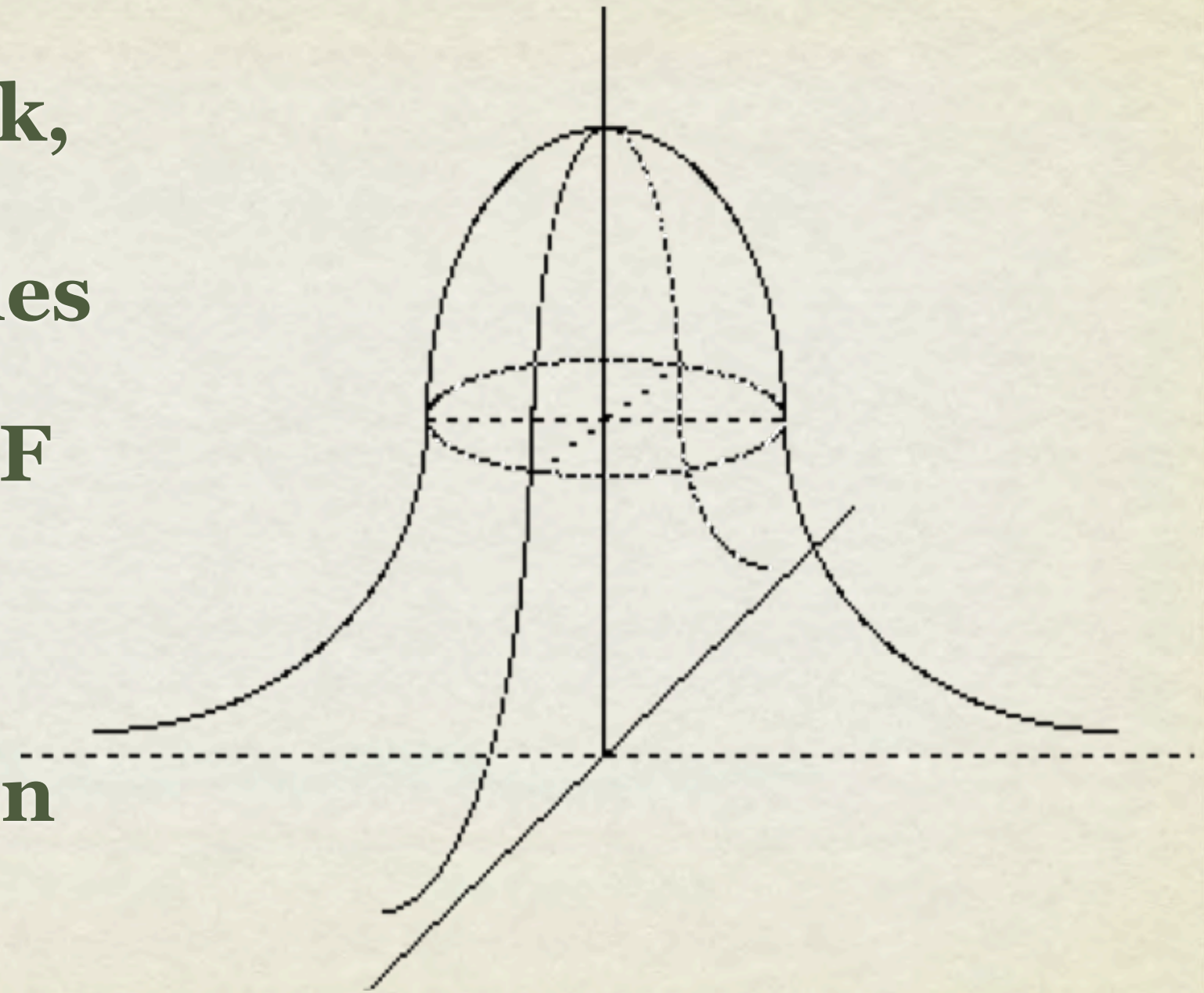
- Example output:

2D LEAST SQUARES ERROR ANALYSIS			

Semi-Axes are at 95% Confidence Level			
Point#	Semi-Major Axis	Semi-Minor Axis	Axis Azimuth
3	0.010295	0.005760	36-00-18.1
5	0.011959	0.005944	4-11-01.9
4	0.012488	0.006779	11-54-58.6
8	0.006740	0.003963	104-45-31.0
7	0.013419	0.010318	6-49-22.1
10	0.006532	0.003810	64-34-22.5

ERROR ELLIPSES

- For any point in the 2-D network, the two co-ordinates are correlated joint random variables
- The two variables have joint PDF which looks like this
- We can find a region in space around the point that has a given probability of finding the point



ERROR ELLIPSES

- **The error ellipse covers an area in which the point has a 39% probability (approx.) of being found**
- **The error ellipse gives the precision of one standard deviation in the direction of the major and minor axes**
- **You need to scale up the error ellipse axis lengths to cover the area that gives a 95% probability**

ELLIPSE SCALING

- Most adjustments will scale the error ellipses to 95% (required by ALTA/ACSM), but check that the scaling uses the correct values, as per the table:

Confidence Region	39%	86%	90%	95%
Scale Factor	1.0	2.0	2.4	3.0

- Because this is 2-D (not 1-D) you must increase the axis lengths 3 times, not the 2 times (2 sigma) given in the ALTA/ACSM requirements (that is for 1-D)

ERROR ELLIPSES

- To find other relative positional precisions, run the adjustment again with a different fixed point
- If your adjustment software calculates co-ordinates for you, run it with the particular fixed point shifted each time and observe the results (keep the same azimuth fixed)
- Note that the actual co-ordinates used have no impact on the error ellipse dimensions

ERROR ELLIPSES

- To reduce the time spent doing this, only use the extreme edge points as fixed points, as the farther apart points are, the larger the relative positional precision between them
- Similarly, the relative positional precision between points should be much the same from either direction, i.e., with either point held fixed

DIRECT CALCULATION

- It is possible to calculate the relative precision in azimuth and distance between points in the network directly from the variance-covariance matrix of the adjusted unknowns (the co-ordinates)
- Very few adjustment packages show you this data
- You can get it if you write your own software

DIRECT CALCULATION

- To compute directly from the variance-covariance matrix, you need to develop a new set of observation equations that relate the desired distances and azimuths (a new A matrix)
- Take the variance co-variance matrix of the adjusted co-ordinates (V_x) and calculate the error parameters for azimuths and distances (in V_p):

$$V_p = A V_x A^T$$

DIRECT CALCULATION

- The V_p matrix will then hold all the parameters for derived azimuth and distance precision between all the points that were included in the observation equations
- These parameters are the axes of the relative error ellipses between pairs of points
- They will need to be scaled to 95%

MORE CONSIDERATIONS

- **Traditional measurements are simple to run through an adjustment (well, simple enough!)**
- **GPS data by themselves are fairly simple to adjust**
- **Mixing the two types means having a very good handle on the errors in the GPS observations compared to the terrestrial observations**
- **This is not always obvious**

GPS ERRORS

- **GPS errors do not propagate linearly with distance**
- **The propagate very slowly with increased distance**
- **Multi-path error is usually the largest error source and is can be very hard to predict**
- **GPS surveys need a lot of redundant measurements to track possible multi-path errors and to determine the overall error in a survey**

GPS ERRORS

- **Measure critical points more than once at different times (separate by 2 hours, if possible)**
- **Measure a selection of lines more than once**
- **Design the GPS network so that removing one or two sides does not destroy the network**
- **Look for larger-than-normal/expected measurement corrections in the least squares adjustment of the survey network**

GPS ERRORS

- **Careful work with the network will allow a good estimate of GPS errors, which will then provide a defensible estimate of relative positional errors**
- **These can be reported as part of the ALTA/ACSM certification**
- **‘Defensible’ means that the error estimate would stand up to expert scrutiny in a court of law**

POINTS TO REMEMBER

- **GPS needs redundancy, often much more than traditional survey networks**
- **Think network, not traverse**
- **Least squares must be understood to work properly**
- **Precision claims should be defensible**
- **Take care not to fool yourself about data quality**

THANK YOU