Least Squares Adjustment

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THE PRIME DIRECTIVE

- Please silence your communicators.
Objectives

- A brief review of geodesy and datums
- Designing a control network for accuracy
- Configuring STAR*NET for optimal results
- STAR*NET commands, data entry, and data management
- Reviewing the STAR*NET results
- Understanding STAR*NET errors
What is Least Squares?

**Definition** - a model for the solution of an overdetermined system of equations based on the principle of least squares of observation residuals. It is used extensively in the disciplines of surveying, geodesy, and photogrammetry—the field of geomatics, collectively.
Why do we need to adjust our survey data?
Least Squares Adjustment
You Are Seeking Truth, Not Moving Points

- The points are fixed on the ground.
- A geodetic control adjustment does not move the position of the points on the ground.
- A geodetic control adjustment does provide positional answers that should increasingly reflect truth with each set of new data.
Weak Network Geometry – Minimal Ties
Strong Network Geometry – Redundant Ties
Redundancy is Critical to Successful Survey Control
COMAR 09.13.06.03.G. Accuracy Standards. (1) The maximum allowable relative positional precision for boundary surveys shall be 0.07 feet (or 2 centimeters) plus 50 parts per million, based on the direct distance between the two corners being tested.

What control adjustment methods result in a relative positional precision?
2. Datums and Adjustments

A. Datums: Unless specifically directed to use a different datum, all work for the MDOT SHA Plats and Surveys Division is to be completed under the following datums.

Horizontal - NAD 83/93
Vertical – NAVD 88
Geoid Model – 128

B. Adjustments: Least squares adjustment software (SurfNet, SurvNet, etc.) shall be used. The project settings, equipment tolerances and files required should follow the guidelines below.

i. Project settings: The following pages contain screen shots of SurvNet Project Options settings tabs that identify information that should be included in listings report. If other adjustment software is used, similar parameters should be set. Any deviation from these settings should be reported and approved before project delivery.

ii. Equipment tolerances: Tolerance settings within the software should reflect the equipment manufactures specifications for horizontal and vertical angle accuracies. The correct distance constant and PPM values should also be used. Reasonable centering errors should also be applied in accordance with manufactures specifications.

iii. Files required with project submission: Any RWS and DAT files both unedited and edited shall be supplied. The listing file and a network plot showing the project should also be included. If GPS data or leveling data is included with the project, all unedited and edited files should also be included.
Coordinates
HOW DO WE GET PLANAR COORDINATES ON AN ELLIPSOIDAL PLANET?
Published in 1772 by Johann Heinrich Lambert.

The projection minimizes scaling distortions with true scale lying along the two parallels. Scale decreases between the parallels and increases outside the parallels.
## Maryland Coordinate System

### Table 2: Comparison of the technical aspects of the legal definitions of the 1939 and the 1987 Maryland Coordinate Systems.

<table>
<thead>
<tr>
<th>Aspect</th>
<th>1939 Coordinate System</th>
<th>1987 Coordinate System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map Projection</td>
<td>Lambert conformal projection of the Clarke spheroid of 1866</td>
<td>Lambert conic conformal projection of the geodetic reference system of 1980</td>
</tr>
<tr>
<td>North American Datum</td>
<td>NAD27</td>
<td>NAD83</td>
</tr>
<tr>
<td>Latitude of Origin (at the 77th meridian)</td>
<td>37°50' North latitude</td>
<td>37°40' North latitude</td>
</tr>
<tr>
<td>Central Meridian</td>
<td>77°00' West longitude</td>
<td>77°00' West longitude</td>
</tr>
<tr>
<td>Standard Parallel 1</td>
<td>38°18' North latitude</td>
<td>38°18' North latitude</td>
</tr>
<tr>
<td>Standard Parallel 2</td>
<td>39°27' North latitude</td>
<td>39°27' North latitude</td>
</tr>
<tr>
<td>False Easting (at the 77th meridian)</td>
<td>800,000 feet</td>
<td>400,000 meters</td>
</tr>
<tr>
<td>False Northing (at the latitude of origin)</td>
<td>0 feet</td>
<td>0 meters</td>
</tr>
<tr>
<td>Latitude/Longitude at artificial origin (0,0)</td>
<td>37°48'00.06790'' N/79°46'07.35361'' W</td>
<td>37°34'36.14264'' N/81°31'45.07877'' W</td>
</tr>
</tbody>
</table>
Maryland Coordinate System

- Maryland Code, Real Property, §14–401 thru 407
- NAD83 is legislatively defined.
- Must conform to the coordinates per NGS.
- System is based on meters.
- Defines the U.S. survey foot for conversion.
Realizations of NAD 1983

- NAD83 (1986) – initial release of 1983 tied to GRS80 and WGS84
- NAD83(1991) – localized HARN adjustment incorporating GPS observation, first 3D adjustment
- NAD83(CORS96) – national adjustment utilizing only CORS data
- NAD83(NSRS2007) epoch 2002.0 – national adjustment with GPS data only, fixed to CORS, first velocity-based system
- US National Spatial Reference System NAD 83(2011) epoch 2010.00 – velocity based geodetic system with CORS updates
The Future Maryland Coordinate System

- Based on NATRF2022 & NAPGD2022
- Maryland Code, Real Property, needs revision.
- Will rely on NSRS per NGS.
- Will use a single central parallel.
- Will use international feet for conversion.
- Will require an epoch and geoid reference.
National Geodetic Vertical Datum of 1927

- Based on Mean Sea Level as observed at 26 tide gauges in the U.S. and 5 in Canada.
- 66,315 miles of leveling. Assumed mean sea level was consistent around the globe.
North American Vertical Datum of 1988

- Continental leveling fixed to a single origin point in Pointe-au-Pere, Rimouski, Quebec, Canada. Mean sea level based on Great Lakes tidal study.

- Incorporated over 388,000 miles of leveling and 505,000 permanently monumented benchmarks.
NAVD88 VERSUS NGVD29

- Distortion throughout the United States based on a false assumption.
- Errors listed in centimeters.
- $30.48\text{cm} = 1.00 \text{USft}$
- $100\text{cm} = 3.28 \text{USft}$
GEOID18

- An equipotential surface of the Earth’s gravity field which best fits global mean sea level.
- In Maryland the typical geoid height is -33.0 meters ± (-108.27 USft ±)
NAVD88 from GEOID18

- GPS/GNSS-derived elevations are only an approximation of NAVD88.
- NAVD88 can only be established through differential leveling from established NGS benchmarks.
- NAGPD2022 will be an equipotential GNSS-based model only.
Planning for Success
What are the project considerations?

- Horizontal Datum
- Vertical Datum
- Accuracy of Locations
- Deliverables
- Availability of control
- Accessibility of control
- Equipment
Horizontal and vertical datums should be established from known control.

Whenever possible, GNSS locations should be repeated with different satellites and should always begin and end on at least two NGS control points.

Whenever possible, total station observations should form a loop with at least two known control points.

If total station observations do not form a loop, at least two known control points should be used at each end of a linear traverse.

Whenever possible, level runs should be a circuit and should include two known benchmarks.
Preparing Star*Net

CONFIGURING THE SETTINGS TO ENSURE OPTIMAL RESULTS
Opening/Starting a Project

- It is recommended to place Star*Net input and output into its own folder on the disk or network, such as /starnet
- Before adding data always check the project options.
Options - Adjustment

- Make sure you understand the data you are adjusting and choose the Adjustment Type and Coordinate System accordingly.
Options - General

- Default values generally used.
- Middle settings will affect the way data files are read.
Options - Instrument

- Instrument errors should be set based on a review of manufacturer specifications.
- Centering errors are an approximation from years of field experience. If these are left at zero the network will be over-constrained.
- Leveling may be set as an error per distance or as a general error per number of turns between points.
Options – Listing File

- Highly recommend to always include a copy of the input data so the listing file can be a stand-alone product.
- Showing coordinate changes from entered provisionals is a great method to tell how well your adjustment is matching a known datum – particularly in a minimally constrained network.
- Sorting by standard residual helps you to identify errors more quickly.
Options – Other Files

- The PTS file should be created for importing into CAD/COGO/GIS.

- The GND file is optional, but recommended. In areas of high grid-to-ground distortion the GND is mandatory.
It is recommended to always let Star*Net determine a computed average scale factor. This average factor will be listed in the GND file.

It is recommended that when trying to match ground data to grid data that a central station be held to given coordinates if available, or adjusted coordinates if no known points are centrally located.

WARNING!!! Always be sure to fully understand the impact of the grid-to-ground factor before using these settings.
COMAR and the 2011 ALTA Standards both establish a standard positional tolerance of 0.07 USft + 50ppm. It is recommended to leave this option on for all adjustments.

Any redundant measurements to sideshots should be treated as multi-observation network points.
Options - GPS

- Instrument errors should be set based on a review of manufacturer specifications.
- Setting shown here are for the Leica GS12 using the Leica SmartNet RTN.
- ECEF = Earth Centered Earth Fixed
Technical specifications are vital to good adjustments!

These are the specifications for the Leica GS12.

Instrument Specification Sheets
Calculations assume the Leica GS12 and the Leica SmartNet RTN

From SmartNet: “Assuming the standard GPS RTK protocols and best practice methods are employed for maximum precision i.e. good satellite coverage, good geometry of precisions, low multipath environments etc, SmartNet typically achieves an RTK RMS accuracy of 1-2 cm plan and 2-3 cm height, in areas of SmartNet network correction coverage.”

2 observed points = (2cm network error + 0.8cm instrument error + 0.15cm centering error) * 2 points = 5.90cm or 0.193 USft of potential normal error

0.193 – 0.07 = 0.123 ÷ 50ppm = 0.123 ÷ 0.00005 = 2,460 USft minimal distance between RTN control points
GNSS – Setting Standard Errors

Adjustment | General | Instrument | Listing File | Other Files | Special | GPS | Modeling |
---|---|---|---|---|---|---|---|
Apply Default Std Errs to Vectors with no Supplied Weighing (Meters):<br>Std Err: 0.00800000<br>At Vert Std Err: 0.01500000<br><br>Factor Supplied Std Errs by:<br>Factor: 2.0000<br>Alternate Vert: 3.0000<br><br>Apply Centering to Std Errs:<br>Centering: 0.00150000<br>Alternate Vert: 0.00000000 (Meters)

Accuracy (rms)<sup>1</sup>

<table>
<thead>
<tr>
<th>DGPS/RTCM</th>
<th>Typically 25 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single baseline (&lt; 30 km)</td>
<td>Horizontal: 8 mm + 1 ppm&lt;br&gt;Vertical: 15 mm + 1 ppm</td>
</tr>
<tr>
<td>Network RTK</td>
<td>Horizontal: 8 mm + 0.5 ppm&lt;br&gt;Vertical: 15 mm + 0.5 ppm</td>
</tr>
<tr>
<td>Post processing (phase)</td>
<td>Horizontal: 3 mm + 0.1 ppm&lt;br&gt;Vertical: 5 mm + 0.4 ppm</td>
</tr>
<tr>
<td>Static with long observations</td>
<td>Horizontal: 3 mm + 0.5 ppm&lt;br&gt;Vertical: 5 mm + 0.5 ppm</td>
</tr>
<tr>
<td>Post processing (phase)</td>
<td>Horizontal: 8 mm + 0.5 ppm&lt;br&gt;Vertical: 15 mm + 0.5 ppm</td>
</tr>
</tbody>
</table>

On-The-Fly Initialization

<table>
<thead>
<tr>
<th>Reliability&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Better than 99.99% using Leica SmartCheck technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time for initialization</td>
<td>Typically 4 sec&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>RTK baseline range</td>
<td>up to 70 km</td>
</tr>
</tbody>
</table>

Data Recording

| Recording rate | Up to 20 Hz |

User Interface
Options - Modeling

- These files we created from the NGS CONUS files.
- It is recommended to create geoid files that cover your region of operation.
- It is helpful to format the same geoid file to work with your GNSS data collection system so that all input is equal.
Using Star*Net

DATA MANAGEMENT, COMMANDS, AND DATA ENTRY
Data Input Files

- Data files have a .dat extension.
- Data may be all contained in one file.
- Larger projects might consist of many data files.
- The index number corresponds to the file number in output files.
- There is no significance to the order of the input files.
- Star*Net is a simultaneous least-squares solution.
Metadata in the .DAT Files

- Anything following a # symbol in a line is ignored by Star*Net
- # designates comments
- Do not be afraid to place many comments in the .DAT file.
- Always include the project and working directory for each and every .DAT file.
- It is a good idea to include information regarding the datum.
Recommended Sequence of Data

- Known Control
- GNSS/GPS
- Total Station Observations for Traverse
- Level Runs
- Observations for Locations Other Than Traverse
C code for known coordinates:

```
C   [STATION]   [NORTH]   [EAST]   [ELEVATION]  [HELD?]  [DESCRIPTION]
C   JV0578   582,058.61   1,430,949.91   30.41   !!!   'CM   #NGS 857 4680 TIDAL BASIC
```

P code for known latitude and longitude:

```
P   [STATION]   [LATITUDE]   [LONGITUDE]   [ELEVATION]  [HELD?]  [DESCRIPTION]
P   JV0578   39-15-50.88809   076-34-51.83402   30.41   !!!   'CM   #NGS 857 4680 TIDAL BASIC
```

H code added for Ellipsoid Height, ex: CH or PH
Known Elevations

- E code for known elevations:
  - E [STATION] [ELEVATION] [HELD?] [DESCRIPTION]
  - E JV0578 30.41 ! ‘CM #NGS 857 4680 TIDAL BASIC

- H code added for Ellipsoid Height, ex: EH
GPS/GNSS Import

- GNSS data will never be hand entered, but will always be the result of a translation.

- Be sure to review the G1 line of the resulting DAT file for common points and misnamed points.

- **NOTE:** Pay attention to imported coordinates within the resulting DAT file.
Total Station Observations for Traverse

- **M code for measurements:**
  - M [AT-FROM-TO] [ANGLE] [DIST] [ZENITH] [HI/HT] [DESCRIPTION]
  - M TR2-TR1-TR3 65-30-15.25 250.75 89-45-30 5.25/5.10 ‘IP

- **DV code for distance and vertical measurements:**
  - DV [AT-TO] [DISTANCE] [ZENITH] [HI/HT] [DESCRIPTION]
  - DV TR2-TR3 250.75 89-45-30 5.25/5.10 ‘IP

- .3R code will reduce a 3D measurement to a 2D observation; eliminate HI/HT
Level Runs

- Typically hand-entered data, therefore the most common source of error.
- Error weighting based on distance or number of turns
- L code for differential level observations

L  [AT-TO]  [ELEV DIFF]  [DIST or TURNS]  [DESCRIPTION]
L  JV0578-TR1  -4.25  2  ‘TR
Other Total Station Observations

- SS code for sideshots:
  - SS [AT-FROM-TO] [ANGLE] [DIST] [ZENITH] [HI/HT] [DESCRIPTION]
  - SS TR2-TR1-5001 65-30-15.25 250.75 89-45-30 5.25/5.10 ‘IP

- SS targets can only have one measurement line. If there is more than one measurement of any type, change the SS to an M.

- T codes stand for Traverse. This can provide a traverse closure report, but makes troubleshooting more difficult. In the Positional Tolerance age, a traverse closure is unnecessary and largely meaningless. Avoid using the T code unless absolutely required.
Reviewing Star*Net

DECIPHERING THE LISTING FILE
Adjustment Statistical Summary

- The Error Factor ranges should be between 0.5 and 1.5
- The larger Error Factor is almost always an indicator as to where the data may have a blunder or be of poor quality.
- Large errors may also indicate unrealistically small standard errors. Be sure your settings are realistic.
- See “Troubleshooting” until the Error Factors are acceptable.

<table>
<thead>
<tr>
<th>Observation</th>
<th>Count</th>
<th>Error Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angles</td>
<td>122</td>
<td>0.574</td>
</tr>
<tr>
<td>Distances</td>
<td>451</td>
<td>0.475</td>
</tr>
<tr>
<td>Zeniths</td>
<td>234</td>
<td>0.932</td>
</tr>
<tr>
<td>Level Data</td>
<td>50</td>
<td>0.547</td>
</tr>
<tr>
<td>GPS Deltas</td>
<td>480</td>
<td>1.387</td>
</tr>
<tr>
<td>Total</td>
<td>1337</td>
<td>0.980</td>
</tr>
</tbody>
</table>

Chi-Square Test at 5.00% Level Passed
Lower/Upper Bounds (0.952/1.048)

Performing Error Propagation ...
Writing Output Files ...

Network Processing Completed
Elapsed Time = 00:00:04
Chi-Square Test

- Essentially a test to determine if the resulting residuals are due to random errors.
- If the test fails, the errors are likely systematic errors, blunders, or incorrect standard errors.
- Exceeding the upper bound indicates excessive residuals and/or may be the result of too small of standard errors. THIS MUST ALWAYS BE FIXED!
- Exceeding the lower bounds should be evaluated, but is not a cause for concern.

<table>
<thead>
<tr>
<th></th>
<th>Level Data</th>
<th>GPS Deltas</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50</td>
<td>480</td>
<td>1337</td>
</tr>
<tr>
<td>Chi-Square</td>
<td>0.547</td>
<td>1.387</td>
<td>0.980</td>
</tr>
<tr>
<td>Test at 5.00%</td>
<td>Level Passed</td>
<td>Lower/Upper Bounds (0.952/1.048)</td>
<td></td>
</tr>
</tbody>
</table>

Performing Error Propagation ...
Writing Output Files ...

Network Processing Completed
After satisfied with Error Factor in the Adjusted Statistical Summary, move to the end of the Listing File to review the Positional Tolerance.

Stations that fail the Positional Tolerance test will have an asterisk next to them.

Evaluate if these stations have redundancy and if the error is acceptable.

Keep in mind that the positional tolerance should be met for ALTA surveys and boundary surveys.

### Positional Tolerance Check (Ft/US)
**Allowable Tolerance = 0.0700 + 50 PPM**
**Tolerance Check Confidence Region = 95%**
**Listing Failures Only**

<table>
<thead>
<tr>
<th>Stations</th>
<th>From</th>
<th>To</th>
<th>Horizontal Distance</th>
<th>Semi-Major-Axis Actual</th>
<th>Allowed</th>
<th>Actual/Allowed</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>JU124</td>
<td>RKK722</td>
<td>519.9300</td>
<td>0.1104</td>
<td>0.0860</td>
<td>1.1498 *</td>
</tr>
<tr>
<td>RKK310</td>
<td>RKK723</td>
<td>RKK724</td>
<td>528.3911</td>
<td>0.1062</td>
<td>0.0864</td>
<td>1.2228 *</td>
</tr>
<tr>
<td>RKK724</td>
<td>RKK725</td>
<td>RKK731</td>
<td>612.0461</td>
<td>0.1283</td>
<td>0.1056</td>
<td>1.2751 *</td>
</tr>
<tr>
<td>RKK724</td>
<td>RKK725</td>
<td>RKK731</td>
<td>665.9312</td>
<td>0.2157</td>
<td>0.1033</td>
<td>2.0885 *</td>
</tr>
<tr>
<td>RKK724</td>
<td>RKK725</td>
<td>RKK731</td>
<td>388.7888</td>
<td>0.1308</td>
<td>0.0884</td>
<td>1.4621 *</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>280.3845</td>
<td>0.0981</td>
<td>0.0840</td>
<td>1.1681 *</td>
</tr>
</tbody>
</table>

Connections Checked = 232
Number of Failures = 7
Coordinate Standard Deviations

- Shows the amount of coordinate uncertainty at 67% confidence (one-sigma)
- Fixed stations will be shown with zero deviation.
- High deviations indicate areas that may have errors, weak observations, or may require greater redundancy.

<table>
<thead>
<tr>
<th>Station</th>
<th>N</th>
<th>E</th>
<th>Elev</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>0.035296</td>
<td>0.045217</td>
<td>0.051784</td>
</tr>
<tr>
<td>451</td>
<td>0.050656</td>
<td>0.042724</td>
<td>0.053124</td>
</tr>
<tr>
<td>452</td>
<td>0.055766</td>
<td>0.054876</td>
<td>0.053353</td>
</tr>
<tr>
<td>453</td>
<td>0.043255</td>
<td>0.057649</td>
<td>0.053237</td>
</tr>
<tr>
<td>5502</td>
<td>0.082016</td>
<td>0.053666</td>
<td>0.274546</td>
</tr>
<tr>
<td>13077_RKK1</td>
<td>0.033419</td>
<td>0.030857</td>
<td>0.022132</td>
</tr>
<tr>
<td>13077_RKK10</td>
<td>0.048956</td>
<td>0.045716</td>
<td>0.030147</td>
</tr>
<tr>
<td>13077_RKK11</td>
<td>0.051935</td>
<td>0.043604</td>
<td>0.031423</td>
</tr>
<tr>
<td>13077_RKK12</td>
<td>0.047680</td>
<td>0.046466</td>
<td>0.032234</td>
</tr>
<tr>
<td>13077_RKK13</td>
<td>0.044467</td>
<td>0.044197</td>
<td>0.031911</td>
</tr>
<tr>
<td>13077_RKK14</td>
<td>0.042132</td>
<td>0.042870</td>
<td>0.030196</td>
</tr>
<tr>
<td>13077_RKK15</td>
<td>0.037946</td>
<td>0.040370</td>
<td>0.027945</td>
</tr>
<tr>
<td>13077_RKK16</td>
<td>0.036194</td>
<td>0.035562</td>
<td>0.024401</td>
</tr>
<tr>
<td>13077_RKK17</td>
<td>0.036878</td>
<td>0.034097</td>
<td>0.023371</td>
</tr>
<tr>
<td>13077_RKK18</td>
<td>0.039932</td>
<td>0.037306</td>
<td>0.024217</td>
</tr>
<tr>
<td>13077_RKK19</td>
<td>0.040555</td>
<td>0.037149</td>
<td>0.023269</td>
</tr>
<tr>
<td>13077_RKK2</td>
<td>0.034631</td>
<td>0.036306</td>
<td>0.018370</td>
</tr>
<tr>
<td>13077_RKK3</td>
<td>0.039917</td>
<td>0.036848</td>
<td>0.019960</td>
</tr>
<tr>
<td>13077_RKK4</td>
<td>0.042917</td>
<td>0.037034</td>
<td>0.020536</td>
</tr>
</tbody>
</table>
Station Coordinate Error Ellipses

- Similar to the coordinate standard deviations, but with the additional information indicating the direction of the potential error.
- The confidence level may be set, but 95% confidence (two-sigma) is typical.
- If the adjustment fails the Chi-Square test, the deviations are multiplied by the Total Error Factor.

<table>
<thead>
<tr>
<th>Station</th>
<th>Semi-Major Axis</th>
<th>Semi-Minor Axis</th>
<th>Azimuth of Major Axis</th>
<th>Elev</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>0.1153632</td>
<td>0.092475</td>
<td>109-13</td>
<td>0.101495</td>
</tr>
<tr>
<td>451</td>
<td>0.1388277</td>
<td>0.083893</td>
<td>145-38</td>
<td>0.104122</td>
</tr>
<tr>
<td>452</td>
<td>0.1662011</td>
<td>0.089701</td>
<td>135-49</td>
<td>0.104569</td>
</tr>
<tr>
<td>453</td>
<td>0.1526497</td>
<td>0.088432</td>
<td>117-56</td>
<td>0.104343</td>
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Troubleshooting Star*Net

COMMON ERRORS, COMMON SOLUTIONS
Fast Troubleshooting

- Be sure sorting by Std Residual was set in the listing files options.
- Review which data type had the highest Error Factor.
- Navigate to the Adjusted Observations and Residuals for target data type.
- Examine the highest errors against the input data for blunders or inconsistent data.
- Rerun adjustment after each fix and target the next highest error.

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Hand Entered Data

- Often errors are a result of mis-entered information.
- Be sure to carefully review input data that is causing large errors against the original notes.
- If the notes match, see if there is sufficient data to make sure there was not an error in the hand-written notes.
Point Names/Numbers

- Star*Net allows for alpha-numeric naming/numbering.
- Make sure all unique points have unique names.
- Make sure all redundant points use identical names.
- Be sure to always thoroughly review the network plot for points sharing a common position.
Temporary Placeholders

- Sometimes errors occur because there is not enough data for Star*Net to accurately determine where a point should be.

- In these instances, create a temporary coordinate close to the points location, but leave all elements open for adjustment.

- Be sure to clearly denote the file with comments that these points are only to assist with Star*Net processing.

Output

MicroSurvey STAR*NET-PRO Error Log

ERROR Station Incorrectly Connected to Network: JU1474
ERROR Station Incorrectly Connected to Network: JU1470
ERROR Station Incorrectly Connected to Network: JU1473
WARNING Network Has No Fixed XY Stations
WARNING Network Has No Fixed Z Stations
Processing Terminated Due to Errors.
Sideshots with Redundant Data

- If a point believed to be a sideshot has more than one dataset, it is no longer a sideshot.
- Alter the SS code to an M code.
.DATA ON/OFF

- Inline command for ignoring data.
- Best used when multiple lines are to be ignored.
- Recommend using comments (#) to help make .data off commands standout in the .dat file.
Problems with Zenith Angles

- Review errors to see if a bad HI/HT is responsible.
- If HI/HT appears to be good or is unknown, the angle and distance measurements can still be used.
- Set 3D Reduce mode with the .3R inline command.
- Comment out the HI/HT
- Be sure to set .3D after the line in question.
Notations for Bad Data

- Some data simply is bad or incorrect.
- Use # at the beginning of lines to be ignored, but do not delete the data.
- Add additional comment lines to explain why the data is being ignored, i.e.:
  - # Bad/unknown rod height.
  - # Mismnamed point. Actual point unknown.
  - # High residual errors.
Final Notes

PARTING THOUGHTS
Direct Measurements

- Direct measurements between two points are preferable to indirect measurements.
- It is encouraged to use boundary evidence with a defined point for survey control.
- Using boundary evidence has two primary benefits:
  - It provides direct measurements on the evidence when evaluating the positional tolerance.
  - It reduces the monuments in the ground that might cause confusion for future surveyors.
The purpose of using Star*Net is to get close to the truth through the elimination/proper distribution of sources of error.

More data should mean a closer answer to truth.

Remember: Truth will never actually be known.

Minor variations, 0.03′±, are not a matter of concern.

Large variations should be discussed and their cause and merit fully understood before becoming set on the idea of ignoring new input.

An inconvenient truth is never an excuse for poor procedures!
Conclusion

REMEMBER THAT STAR*NET HAS A VERY EXTENSIVE REFERENCE MANUAL.