MicroSurvey®
STAR*NET

Least Squares Adjustment

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- Education Committee Chair
- Technology Committee Chair
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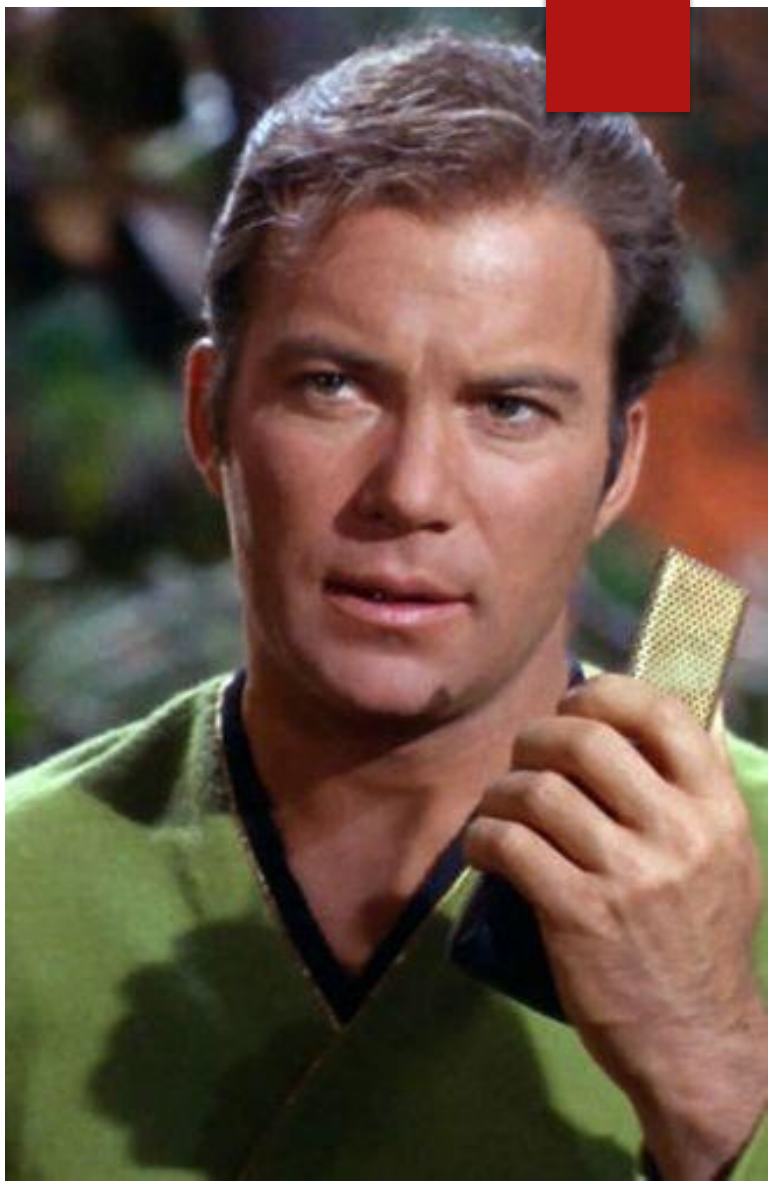
THE PRIME DIRECTIVE

- Please silence your communicators.

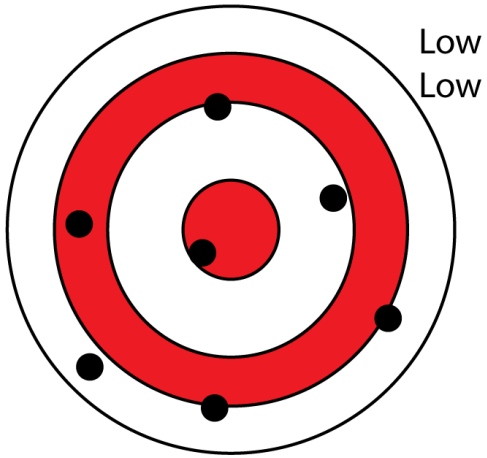


Objectives

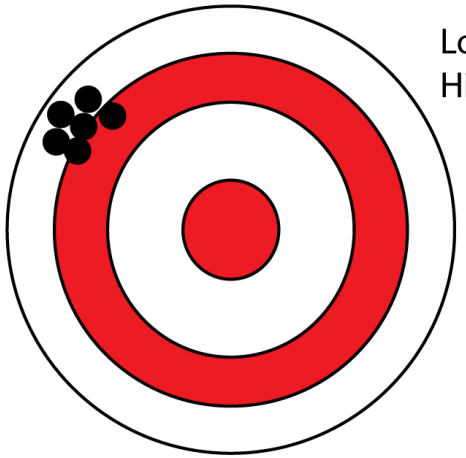
- A brief review of geodesy and datums
- Designing a control network for accuracy
- Configuring STAR*NET for optimal results
- STAR*NET commands, data entry, and data management
- Reviewing the STAR*NET results
- Understanding STAR*NET errors

What is Least Squares?

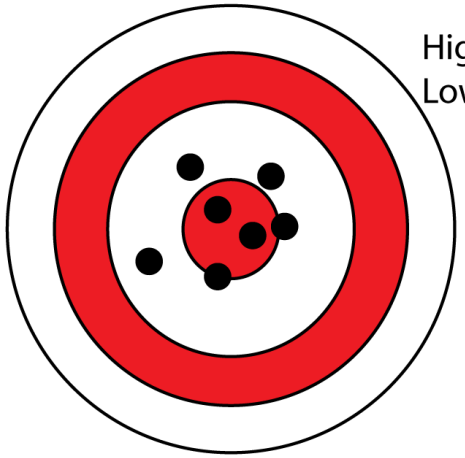
- *Definition* - a model for the solution of an overdetermined system of equations based on the principle of least squares of observation residuals. It is used extensively in the disciplines of surveying, geodesy, and photogrammetry—the field of geomatics, collectively.



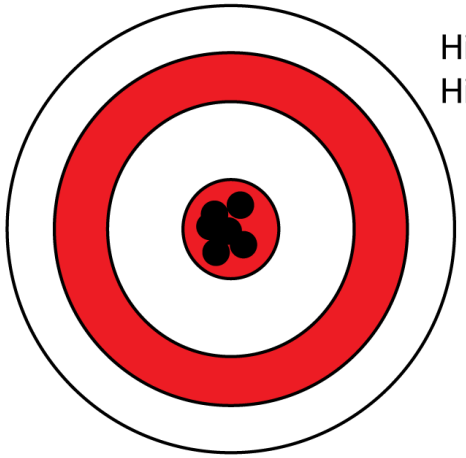
Low accuracy
Low precision



Low accuracy
High precision

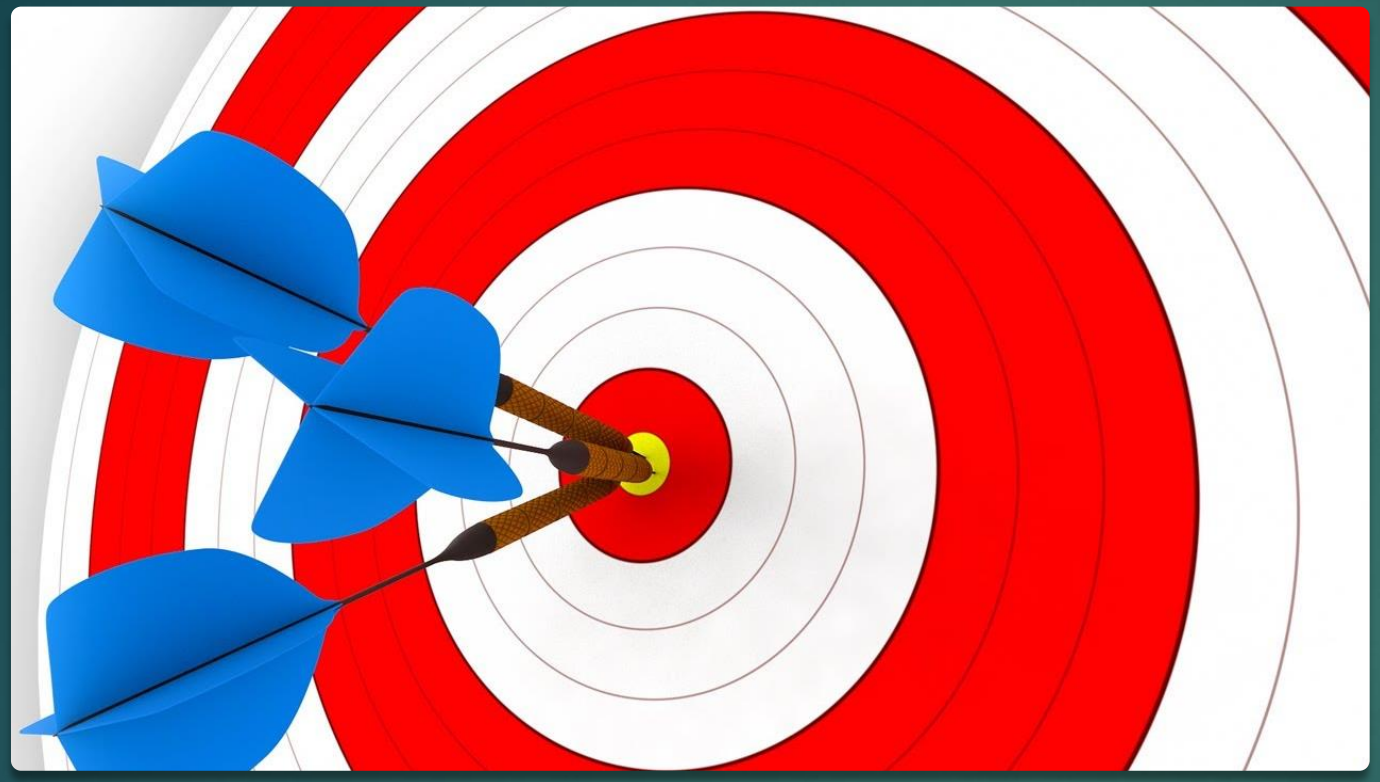


High accuracy
Low precision



High accuracy
High precision

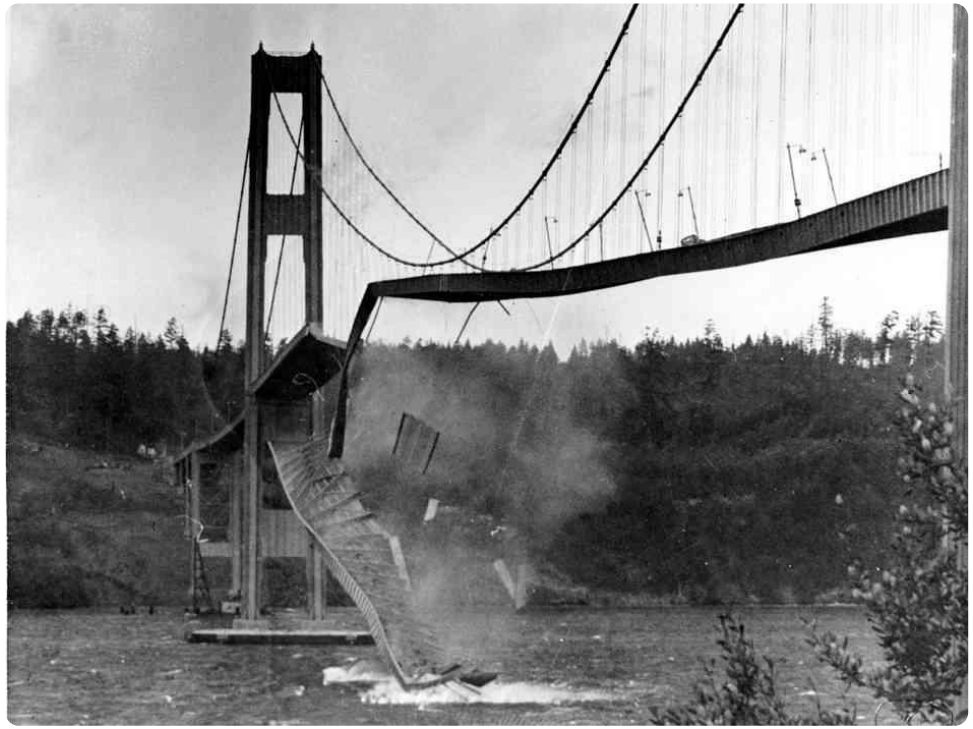
Why do we need to adjust our survey data?

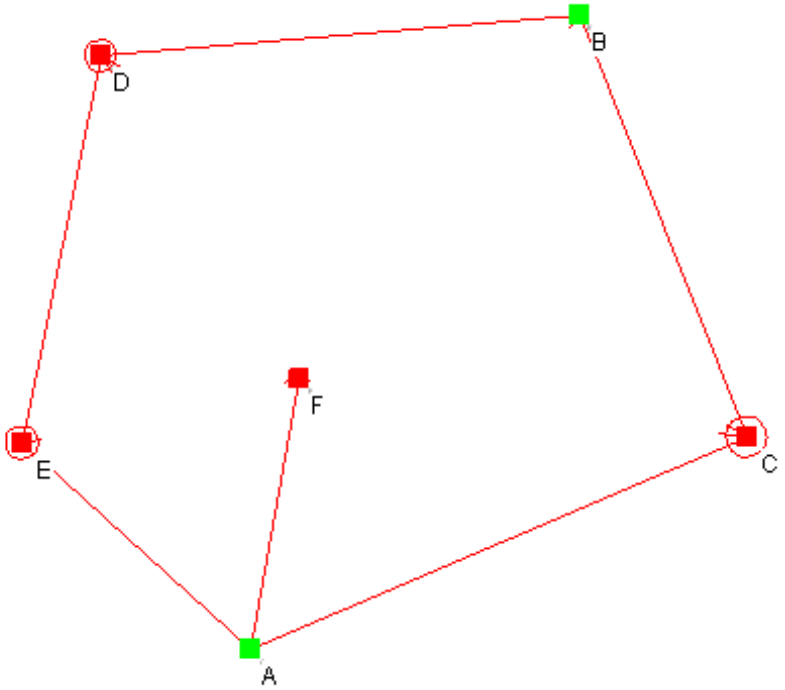


Least Squares Adjustment

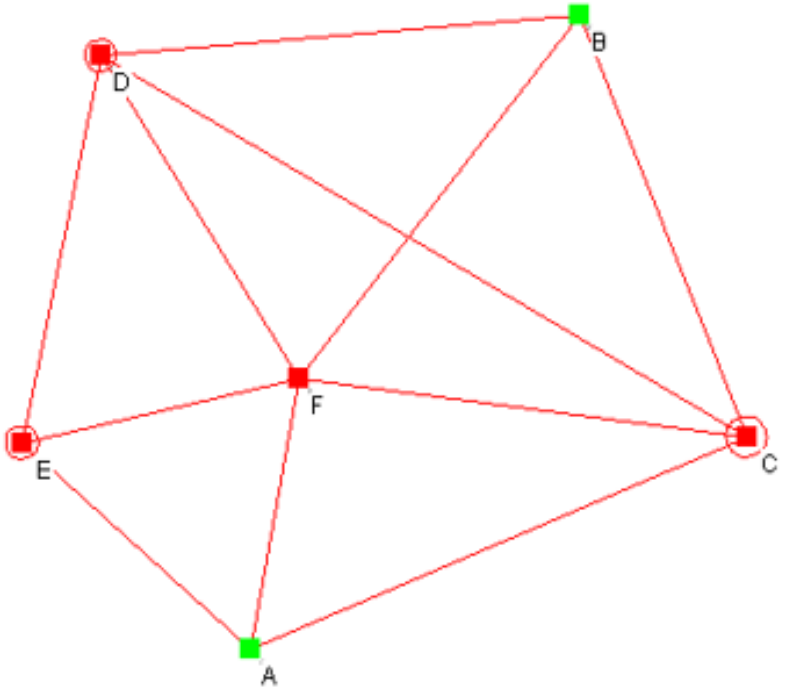
You Are Seeking Truth, Not Moving Points

- 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.

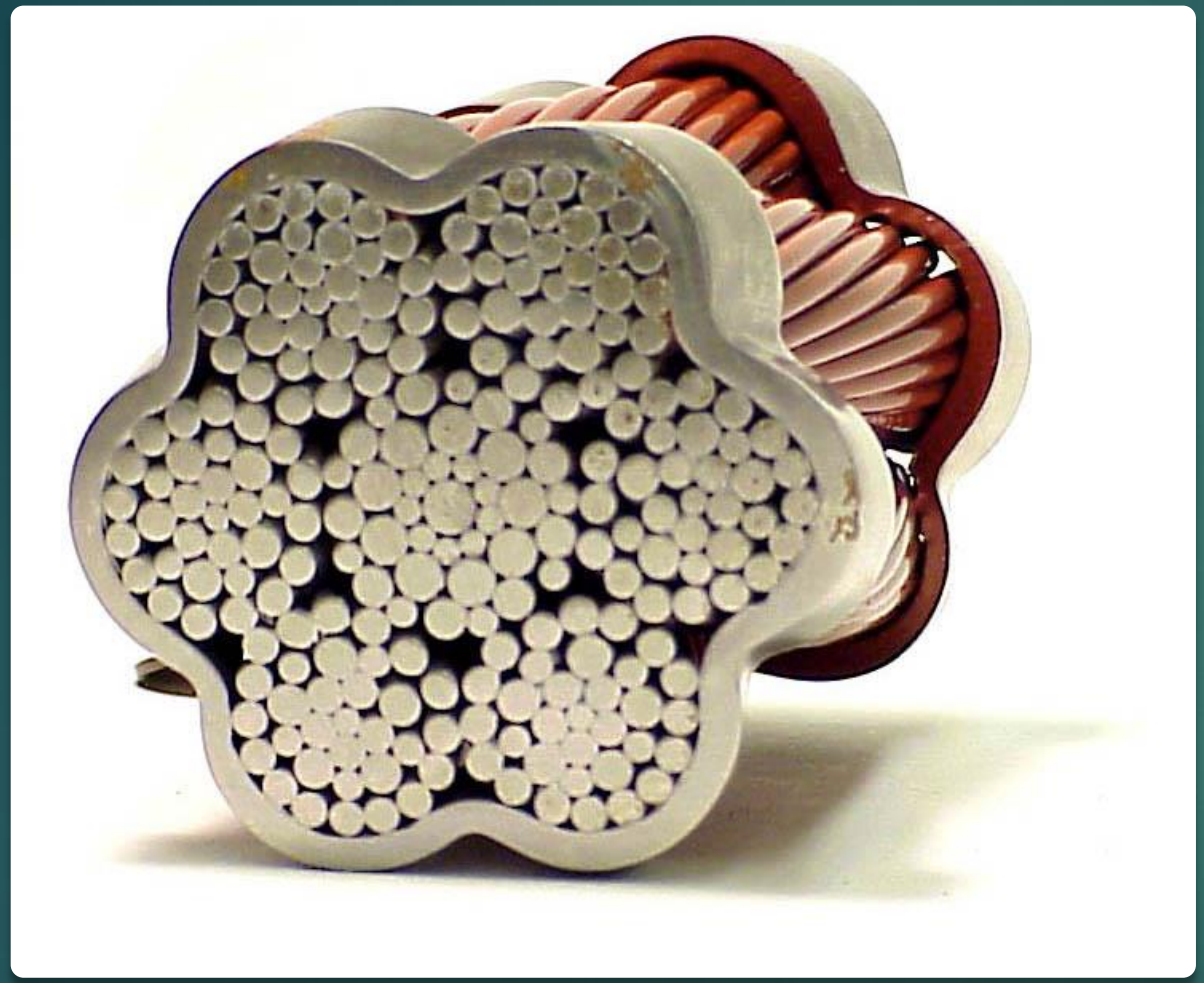




Weak Network Geometry – Minimal Ties



Strong Network Geometry – Redundant Ties



Redundancy is Critical to Successful Survey Control

Wait! Aren't Other Adjustment Methods Good Enough?

- 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?

MDOT SHA Procedures Manual 2018

MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

The Office of Highway Development
Plats and Surveys Division

Field Procedures Manual - 2018
Consultant Version

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.

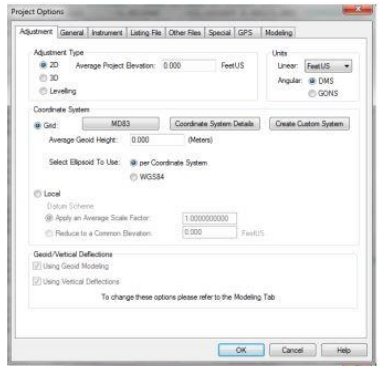
Horizontal - NAD 83/91
Vertical – NAVD 88
Geoid Model – 12B

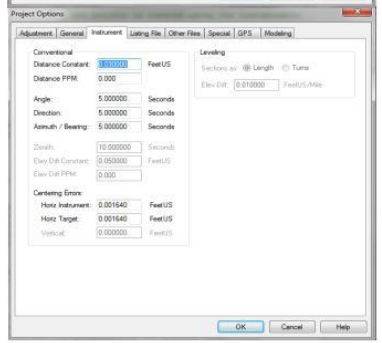
B. Adjustments: Least squares adjustment software (StarNet, SurvNet, etc.) shall be used. The project settings, equipment tolerances and files required should follow the guidelines below.

i. Project settings: The following pages contain screen shots of StarNet 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 RW5 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.



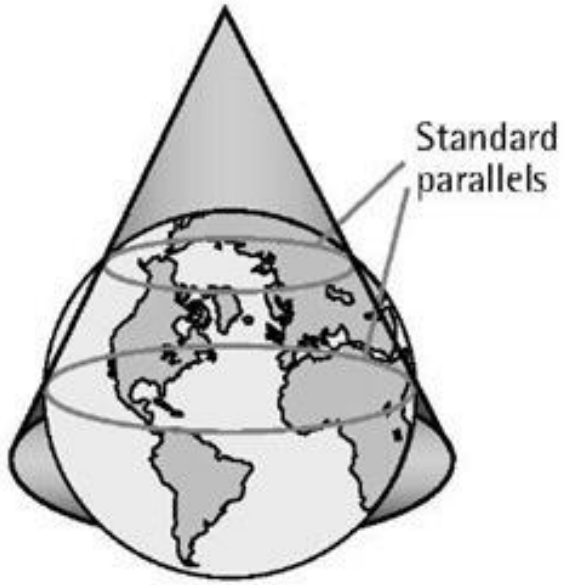


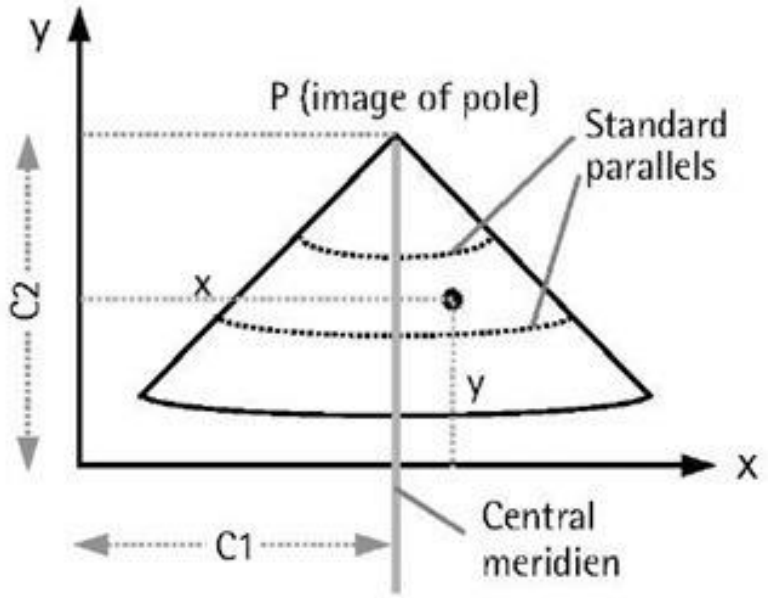
Coordinates

HOW DO WE GET PLANAR COORDINATES ON AN ELLIPSOIDAL PLANET?

Lambert Conformal Projection

- 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.



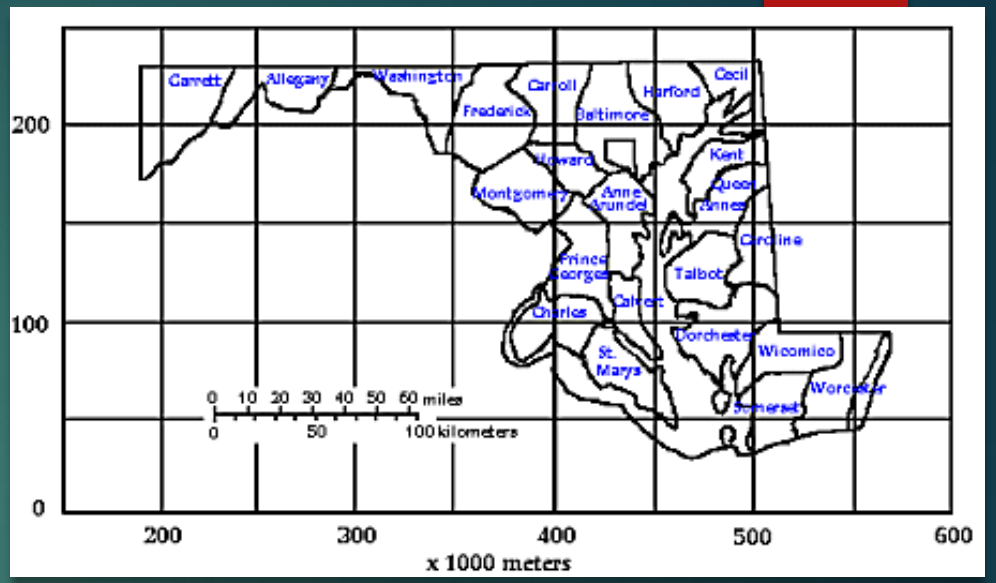


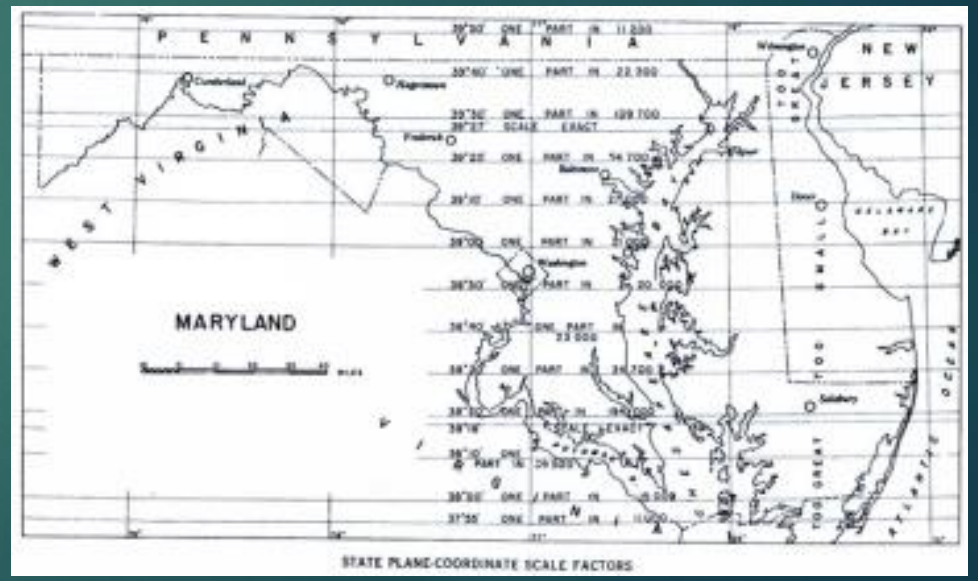
Maryland Coordinate System

Table 2. Comparison of the technical aspects of the legal definitions of the 1939 and the 1987 Maryland Coordinate Systems.		
Aspect	**1939 Coordinate System**	**1987 Coordinate System**
Map Projection	Lambert conformal projection of the Clarke spheroid of 1866	Lambert conic conformal projection of the geodetic reference system of 1980
North American Datum	NAD27	NAD83
Latitude of Origin(at the 77th meridian)	37°50' North latitude	37°40 North latitude
Central Meridian	77°00 West longitude	77°00' West longitude
Standard Parallel 1	38°18 North latitude	38°18' North latitude
Standard Parallel 2	39°27 North latitude	39°27' North latitude
False Easting(at the 77th meridian)	800,000 feet	400,000 meters
False Northing(at the latitude of origin)	0 feet	0 meters
Latitude/Longitude at artificial origin (0,0)	37°48' 00.06798" N/ 79°46' 07.35361" W	37°34' 38.14264" N/ 81°31' 45.07877" W

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.



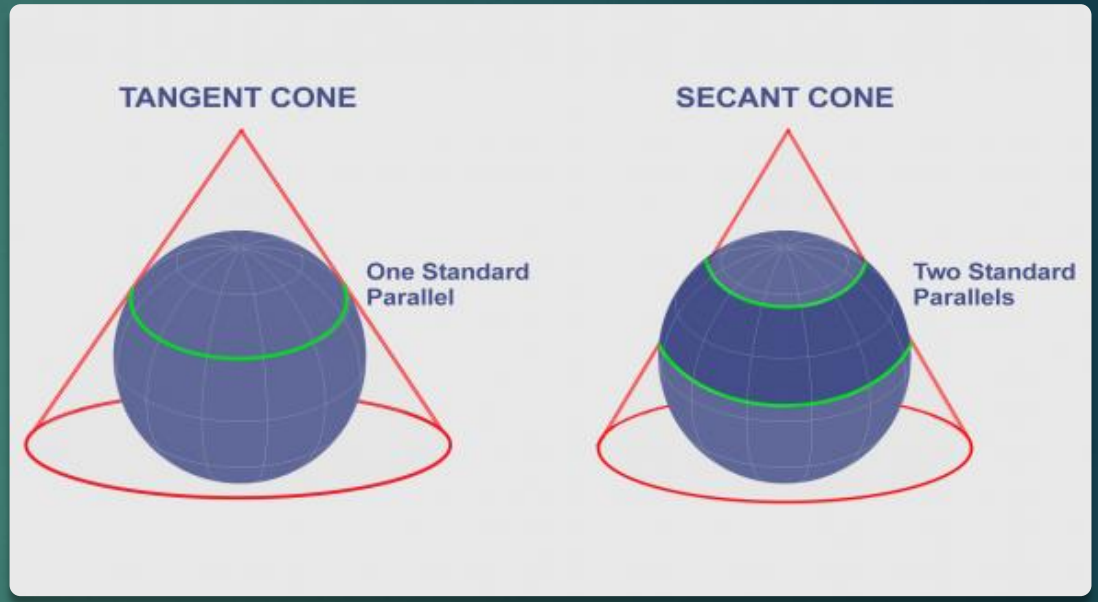


Realizations of NAD 1983

- 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.
- 30.48cm = 1.00 USft
- 100cm = 3.28 USft

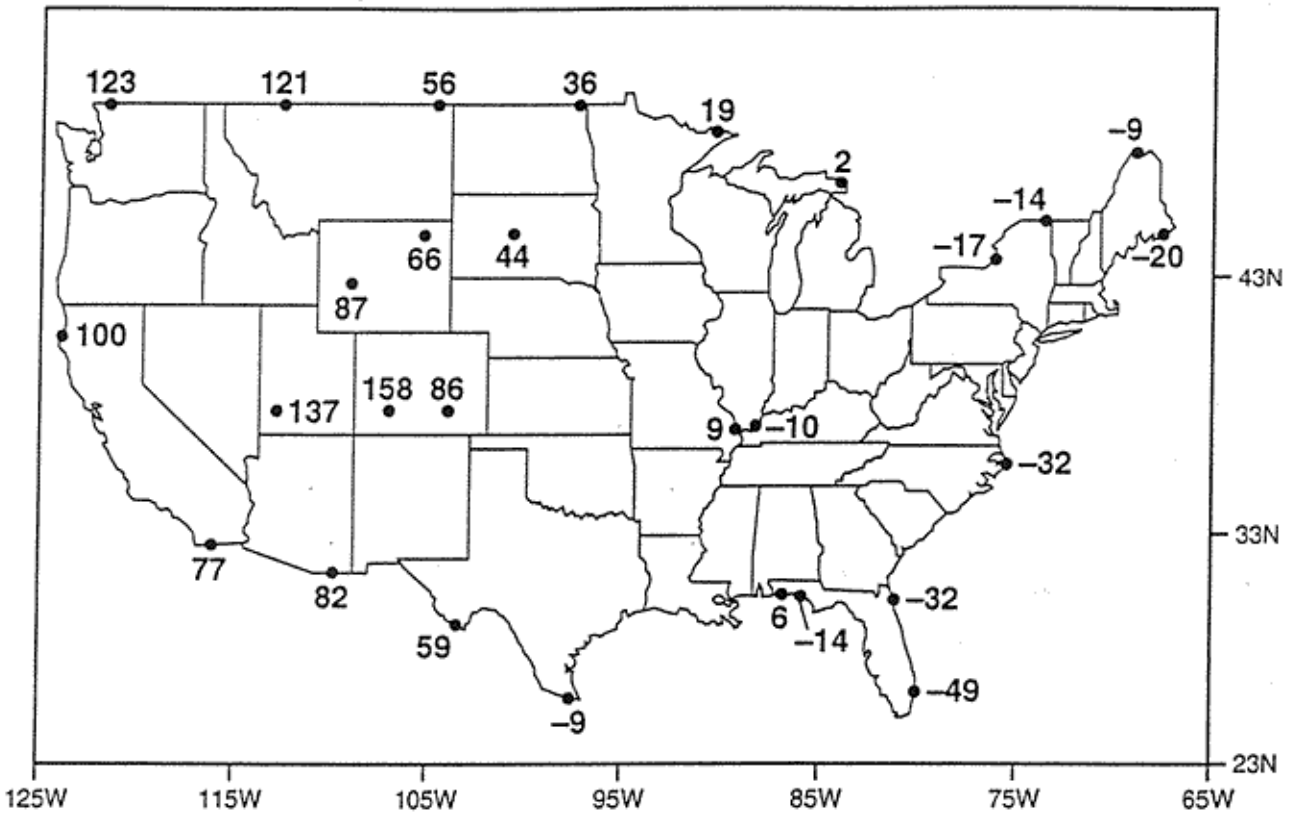
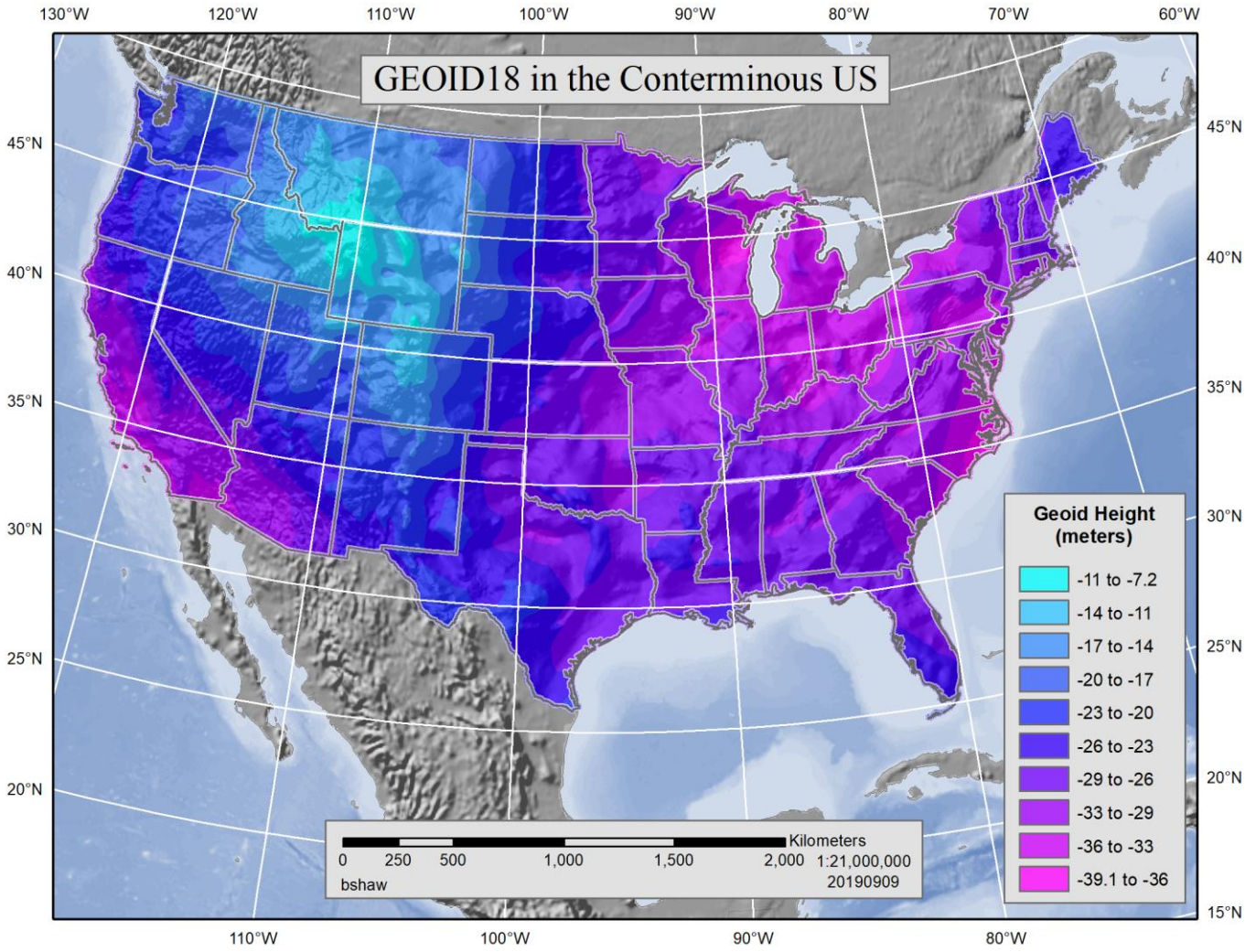


Figure 12. Height differences between NAVD 88 and NGVD 29 in conterminous United States (units = cm).

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

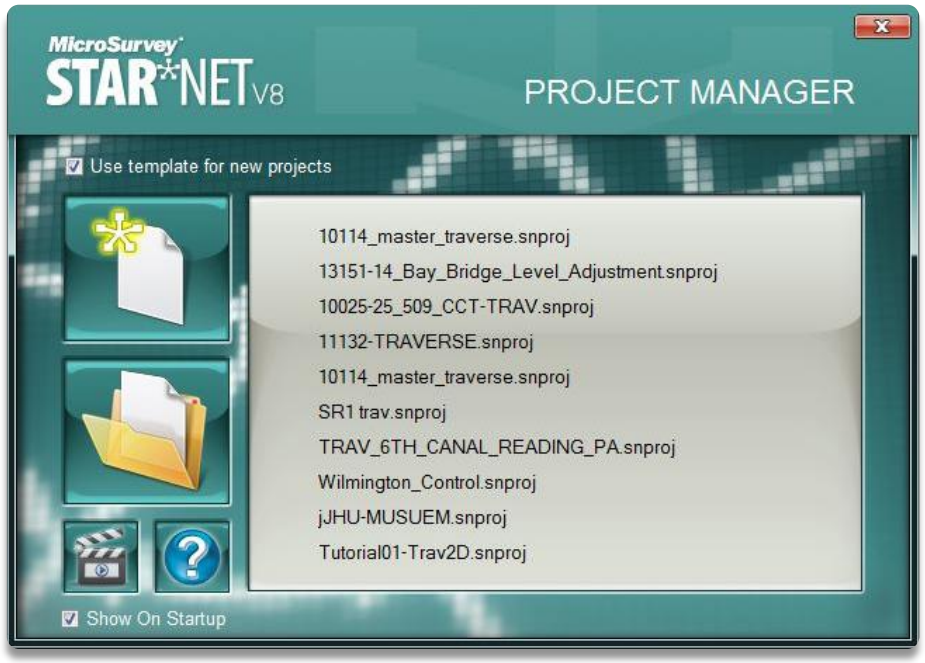
Building a Solid Foundation

- 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

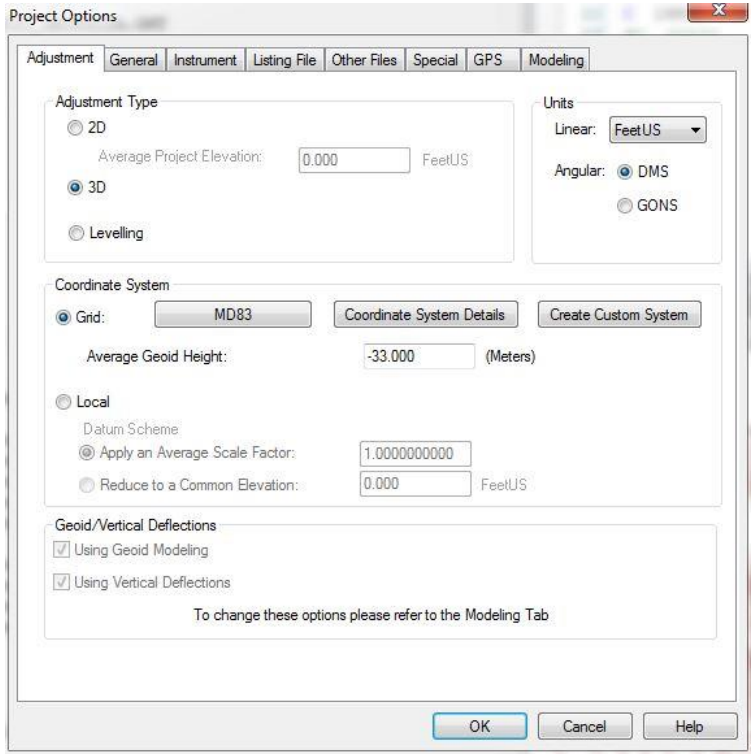
Opening/Starting a Project

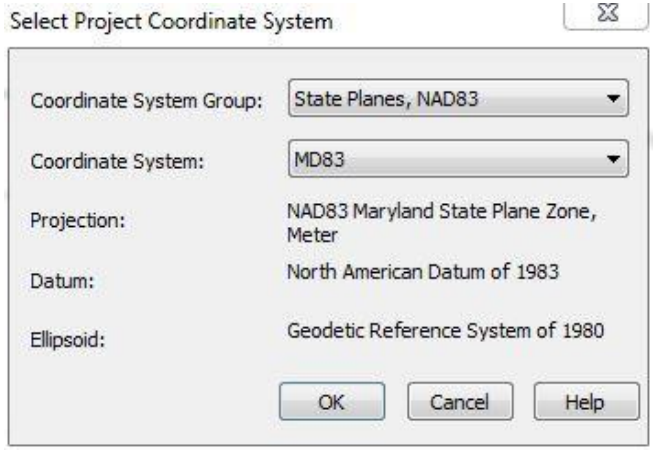


- It is recommended to place Star*Net input and output into its own folder on the disk or network, such as /starnet
- Before adding data always check the project options.

Options - Adjustment

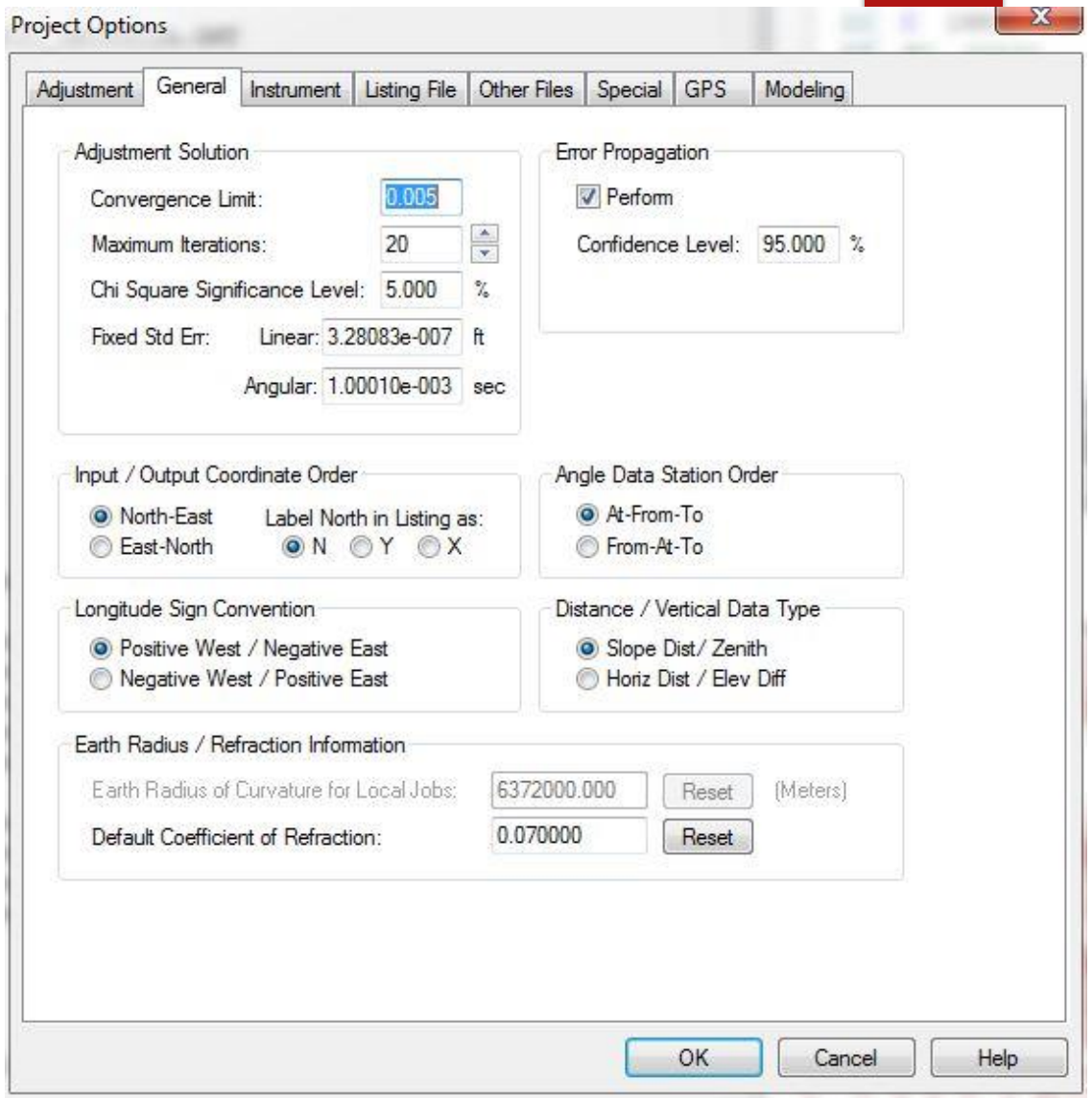
- Make sure you understand the data you are adjusting and choose the Adjustment Type and Coordinate System accordingly.





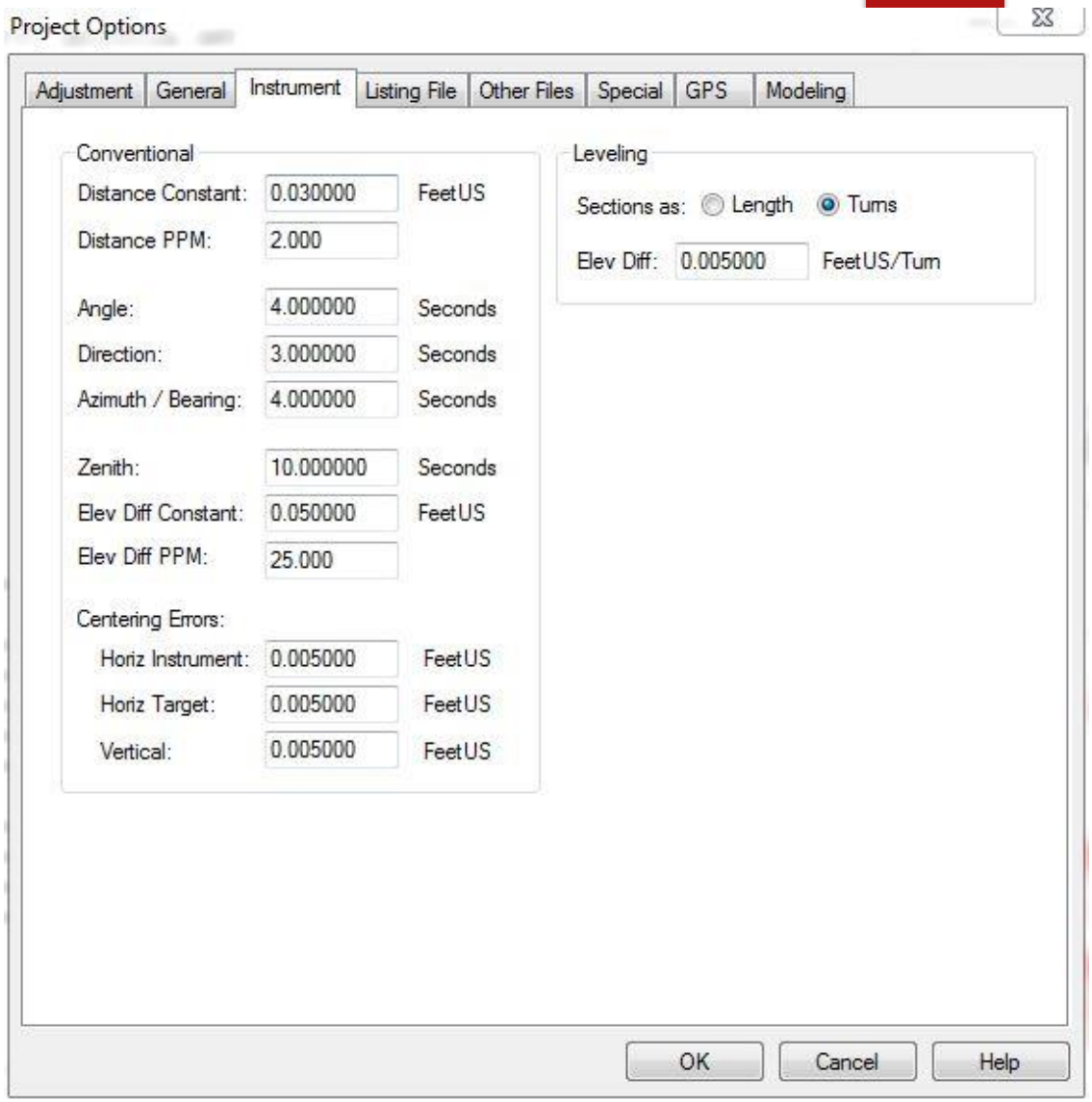
Options - General

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



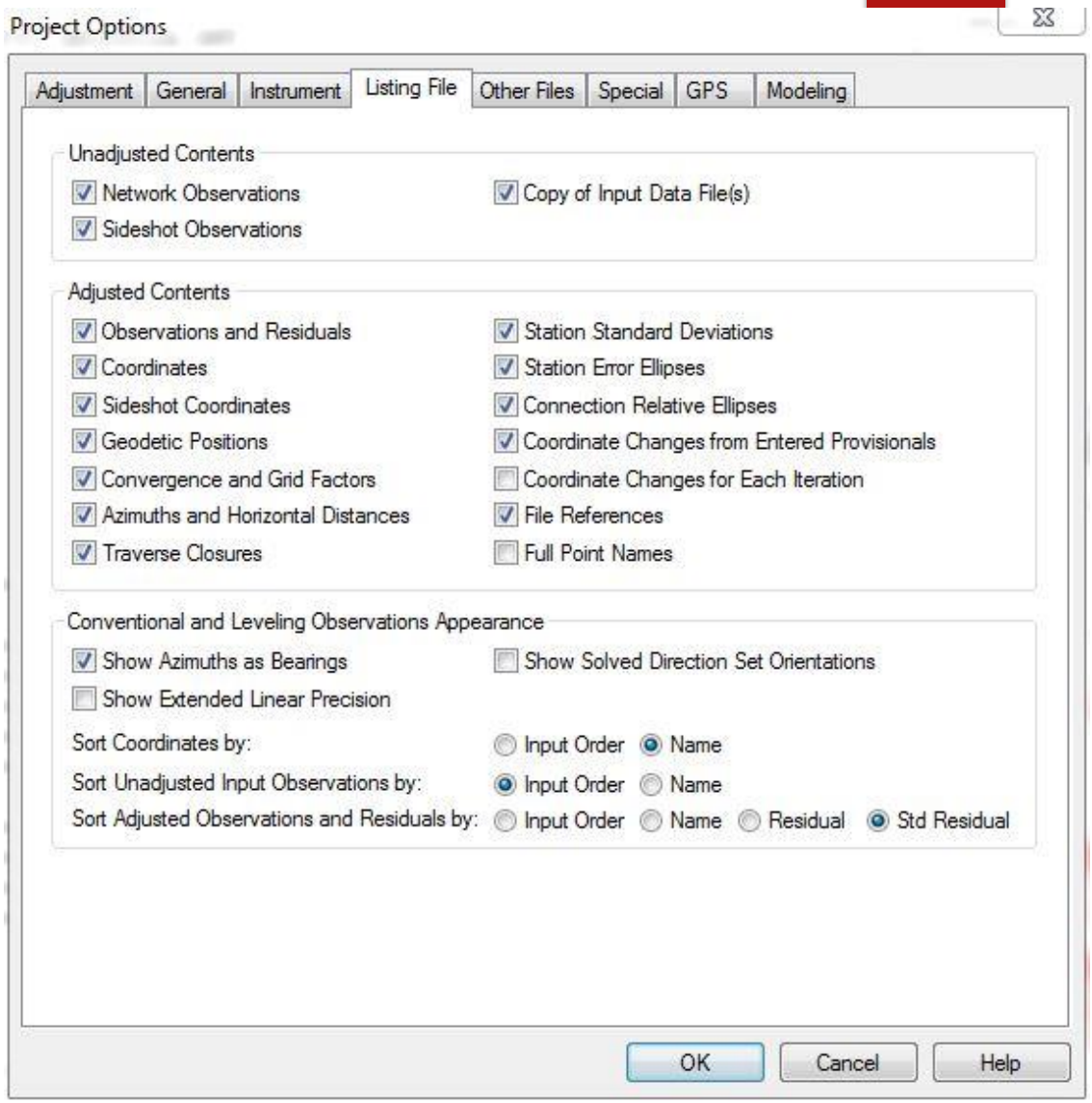
Options - Instrument

- 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.



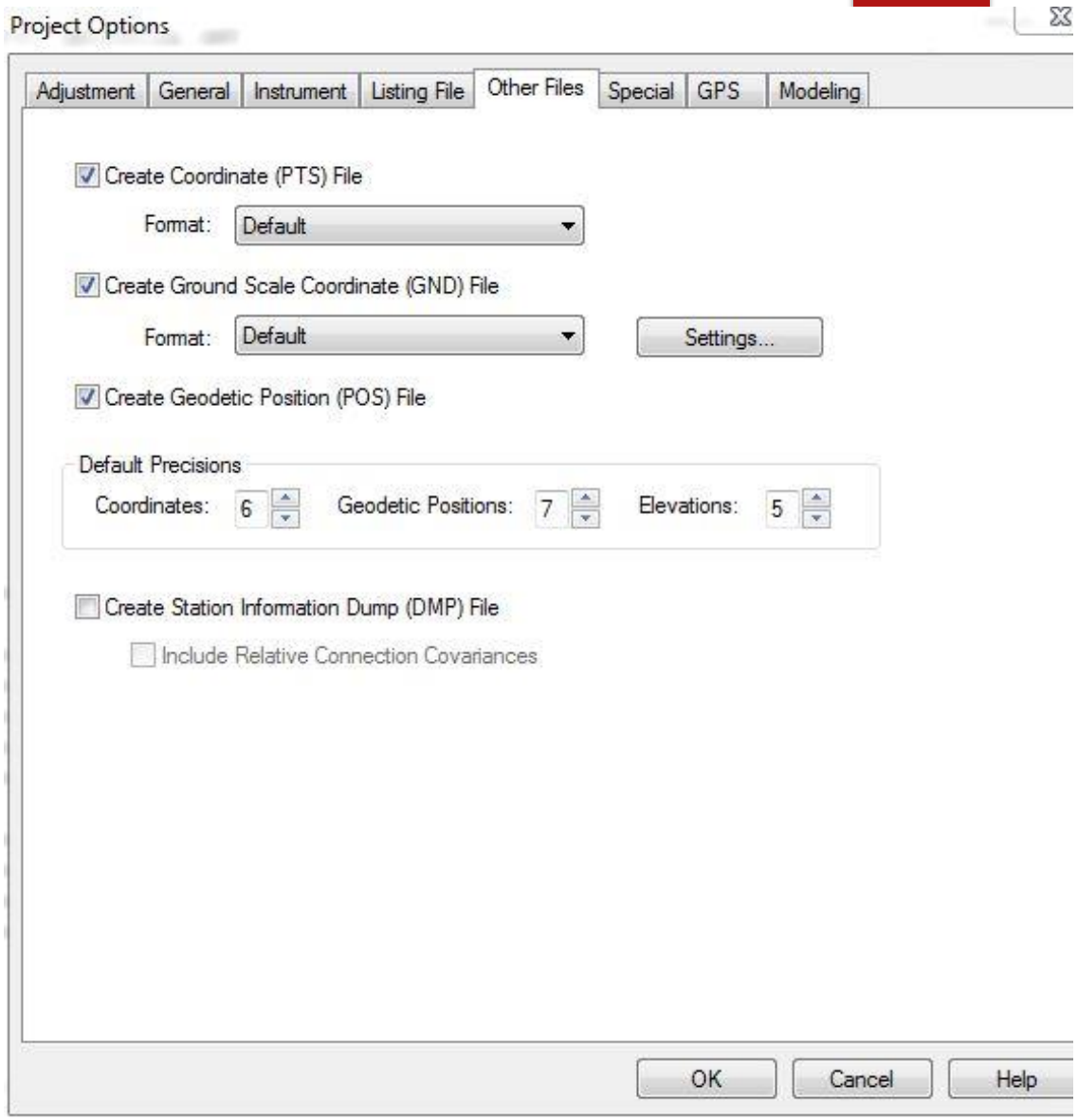
Options – Listing File

- 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.



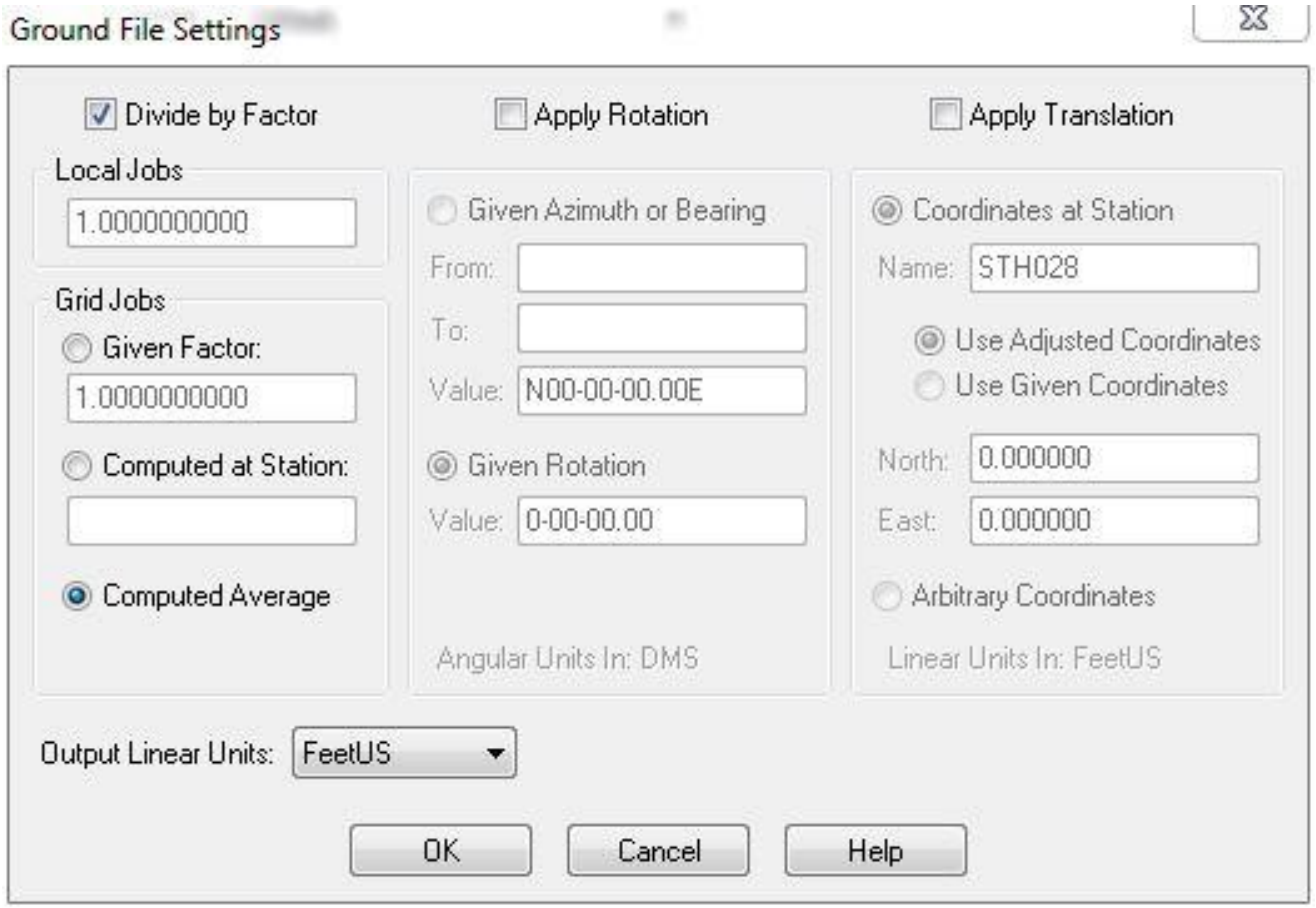
Options – Other Files

- 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.



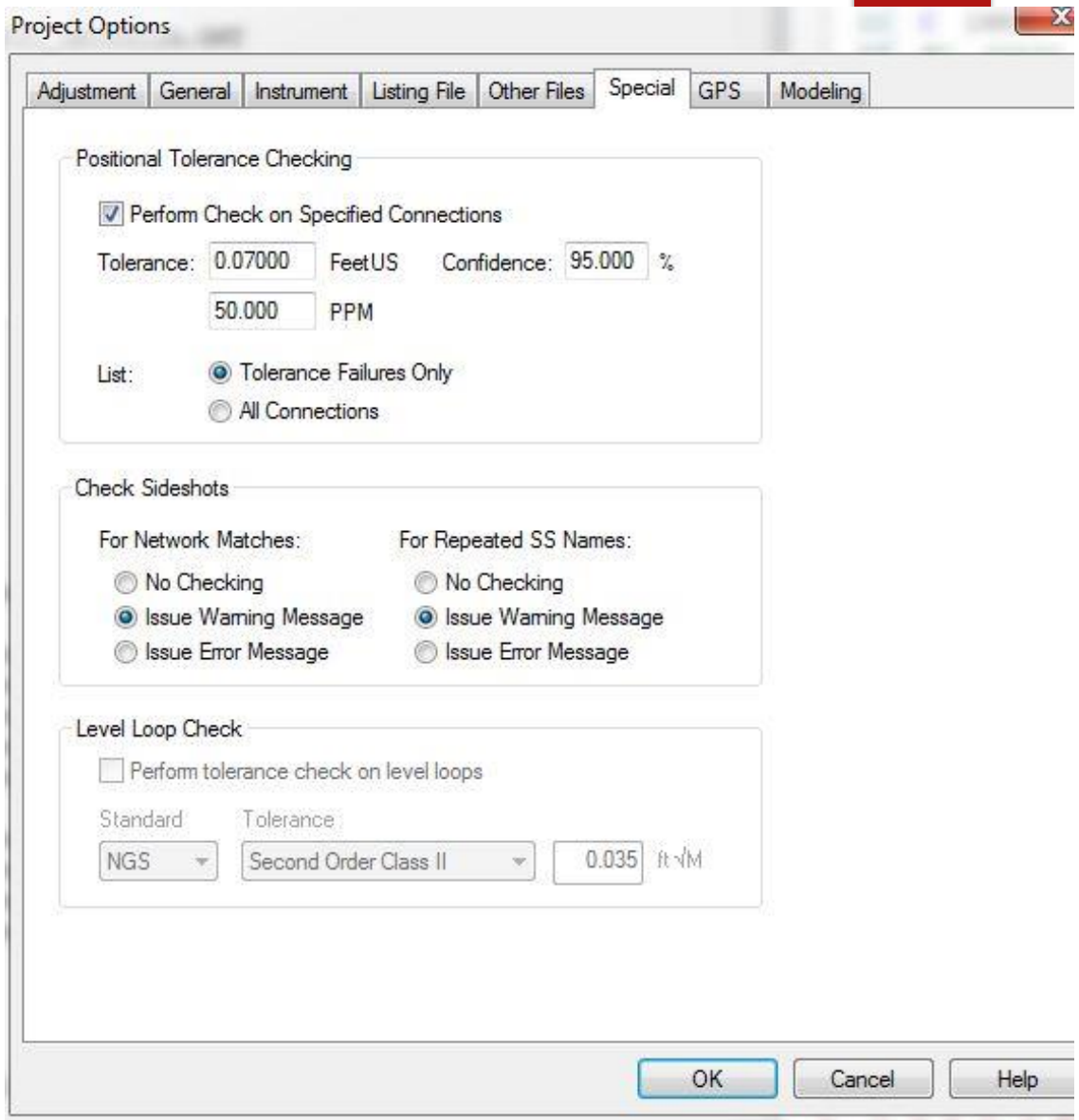
Options – Ground File Settings

- 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.



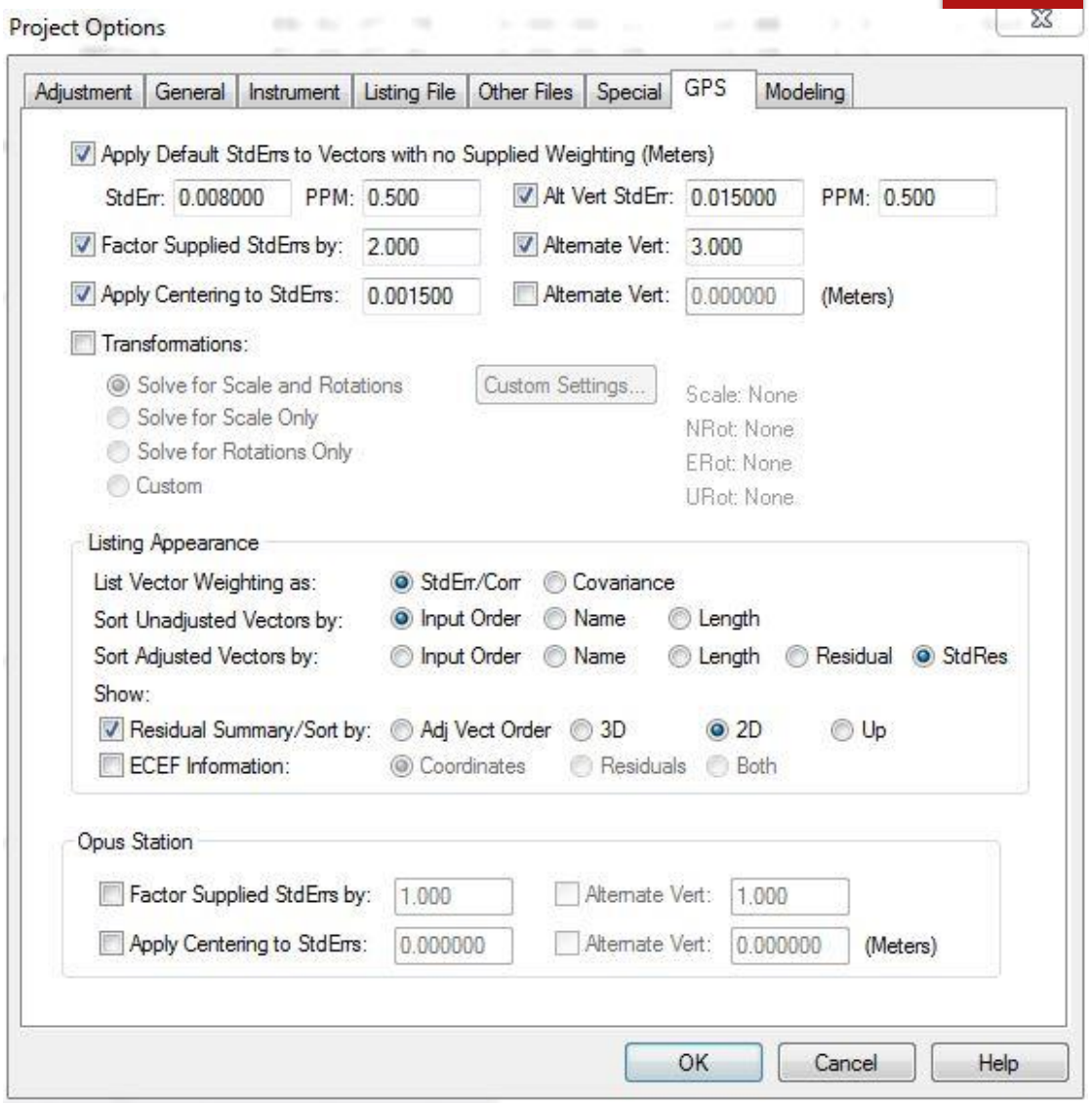
Options - Special

- 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



Instrument Specification Sheets

- Technical specifications are vital to good adjustments!
- These are the specifications for the Leica GS12.

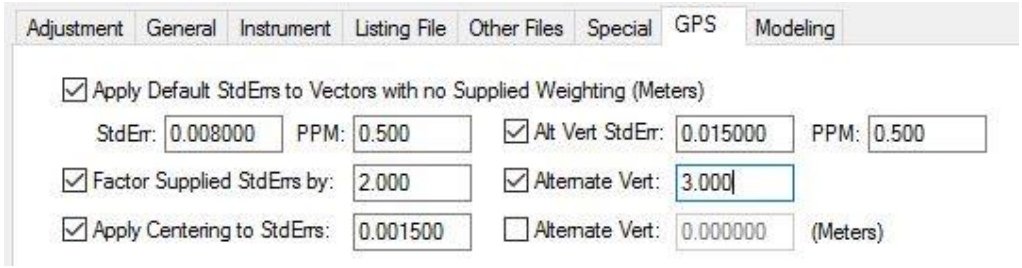
Technical Specifications

GNSS Technology	**Advanced Measurement Engine**	
	Leica patented SmartTrack technology	• Jamming resistant measurements • High precision pulse aperture multipath correlator • Excellent low elevation tracking technology • Very low noise GNSS carrier phase measurements with <0.5 mm precision • Minimum acquisition time
	No. of channels	120 channels
	Max. simultaneous tracked satellites	Up to 60 Satellites simultaneously on two frequencies
	Reacquisition time	<1 sec
	Position latency	Typically 0.02 sec
	GNSS Measurements	
	Satellite signals tracking	GPS: L1, L2, L2C, L5 (C/A, P, C Code) GLONASS: L1, L2 (C/A, P narrow Code); Galileo: E1, E5a, E5b, Alt-BOC; SBAS: WAAS, EGNOS, GAGAN, MSAS
Measurement Performance	**Accuracy (rms)[1]**	
	DGPS/RTCM	Typically 25 cm
	Single baseline (<30 km)	Horizontal: 8 mm + 1 ppm Vertical: 15 mm + 1 ppm
	Network RTK	Horizontal: 8 mm + 0.5 ppm Vertical: 15 mm + 0.5 ppm
	Post processing (phase) Static with long observations	Horizontal: 3 mm + 0.1 ppm Vertical: 3.5 mm + 0.4 ppm
	Post processing (phase) Rapid static mode	Horizontal: 3 mm + 0.5 ppm Vertical: 5 mm + 0.5 ppm
	On-The-Fly Initialization	
	Reliability[1]	Better than 99,99% using Leica SmartCheck technology
	Time for initialization	Typically 4 sec[2]
	RTK baseline range	up to 70 km
	Data Recording	
	Recording rate	Up to 20 Hz
Hardware	**User Interface**	

Sidenote: Distance between RTN GNSS Points

- 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



Accuracy (rms)[1]	
DGPS/RTCM	Typically 25 cm
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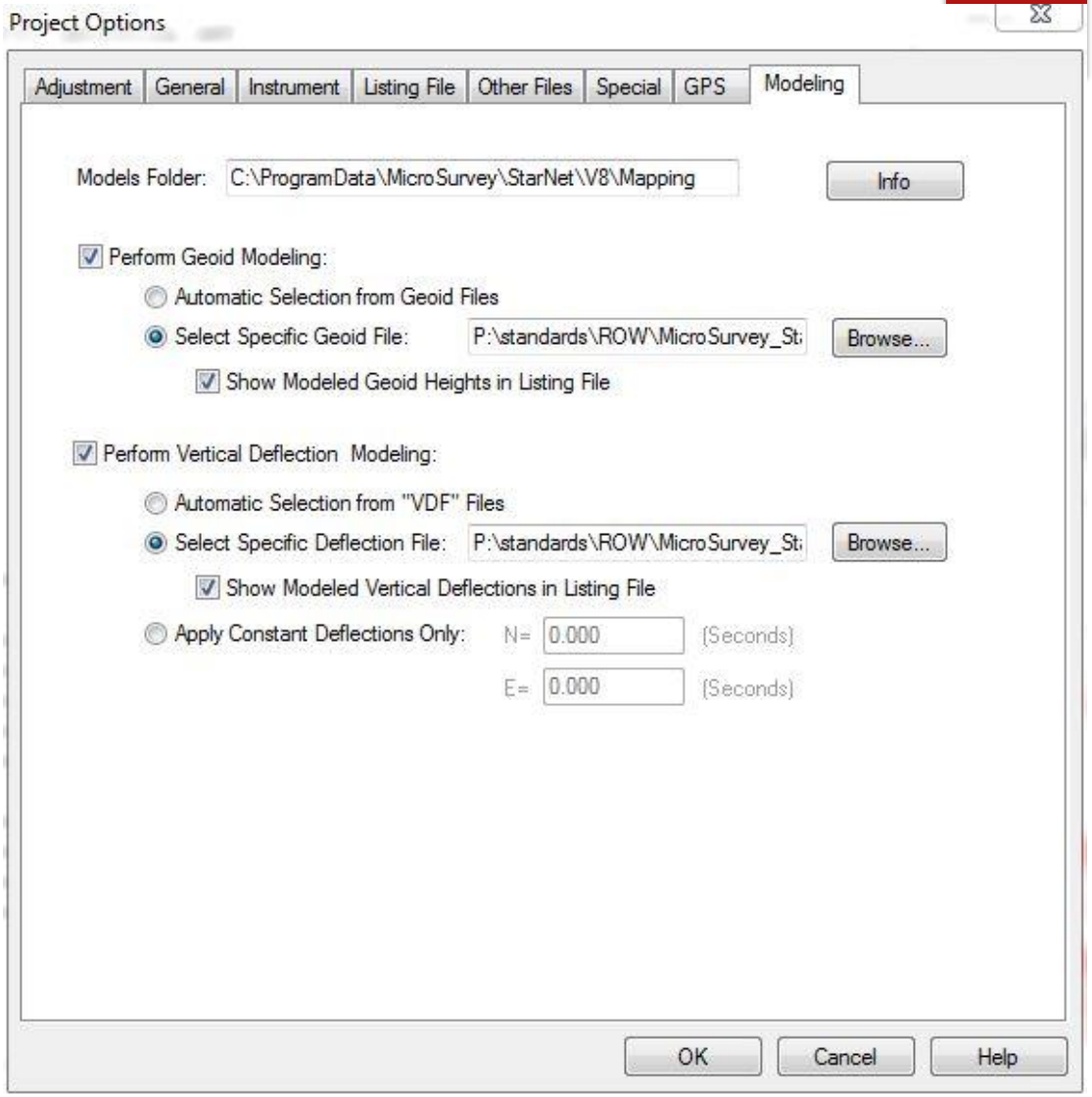
On-The-Fly Initialization	
Reliability[1]	Better than 99,99% using Leica SmartCheck technology
Time for initialization	Typically 4 sec[2]
RTK baseline range	up to 70 km
Data Recording	
Recording rate	Up to 20 Hz
User Interface	

Options - Modeling

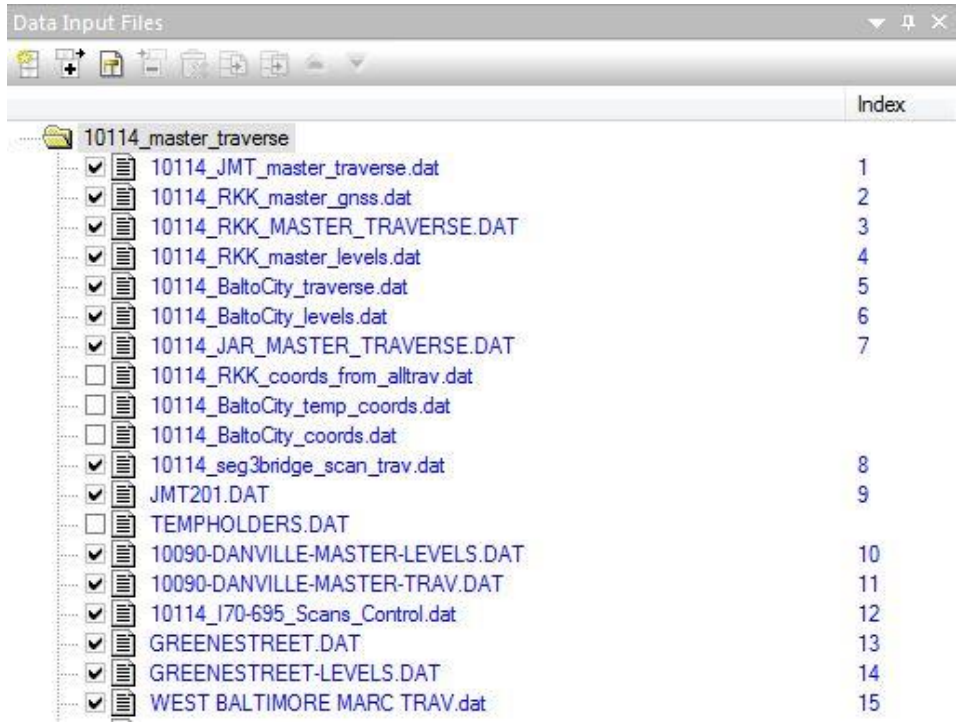
- These files we created from the NGS CONUS files.
- It is recommended to create geoid files that cover your region of operation.
- It is helpful to format the same geoid file to work with your GNSS data collection system so that all input is equal.



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

```
# Working Directory : \\balsrv03\v2010\2010\10114_MTAGEC\Survey\starnet\

.Units  FeetUS
.Units  DMS
.Order  AtFromTo
.Sep    -
.Delta  Off
.3D


# Horizontal Datum:  NAD 83 (NSRS 2007)
# Vertical Datum:    NAVD88



# Input Field File : I:\10114_starnet\field\TR-REDLINE-122010.RAW
# Job  : TR-REDLINE-122010
# Date : 12-20-2010
.3D
M  JMT510-JMT053-RKK84    166-23-46.67    482.2000    90-20-29.17    5.360/5.260
M  RKK84-JMT510-RKK85     175-42-50.33    771.1700    90-58-50.67    5.470/5.190
M  RKK85-RKK84-RKK86      184-23-26.83    585.9100    89-08-16.33    5.400/5.280
M  RKK86-RKK85-RKK87      185-18-35.75    646.3875    91-50-56.25    5.300/5.230
```

- 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

582,058.61

Known Control

- 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

582,058.61

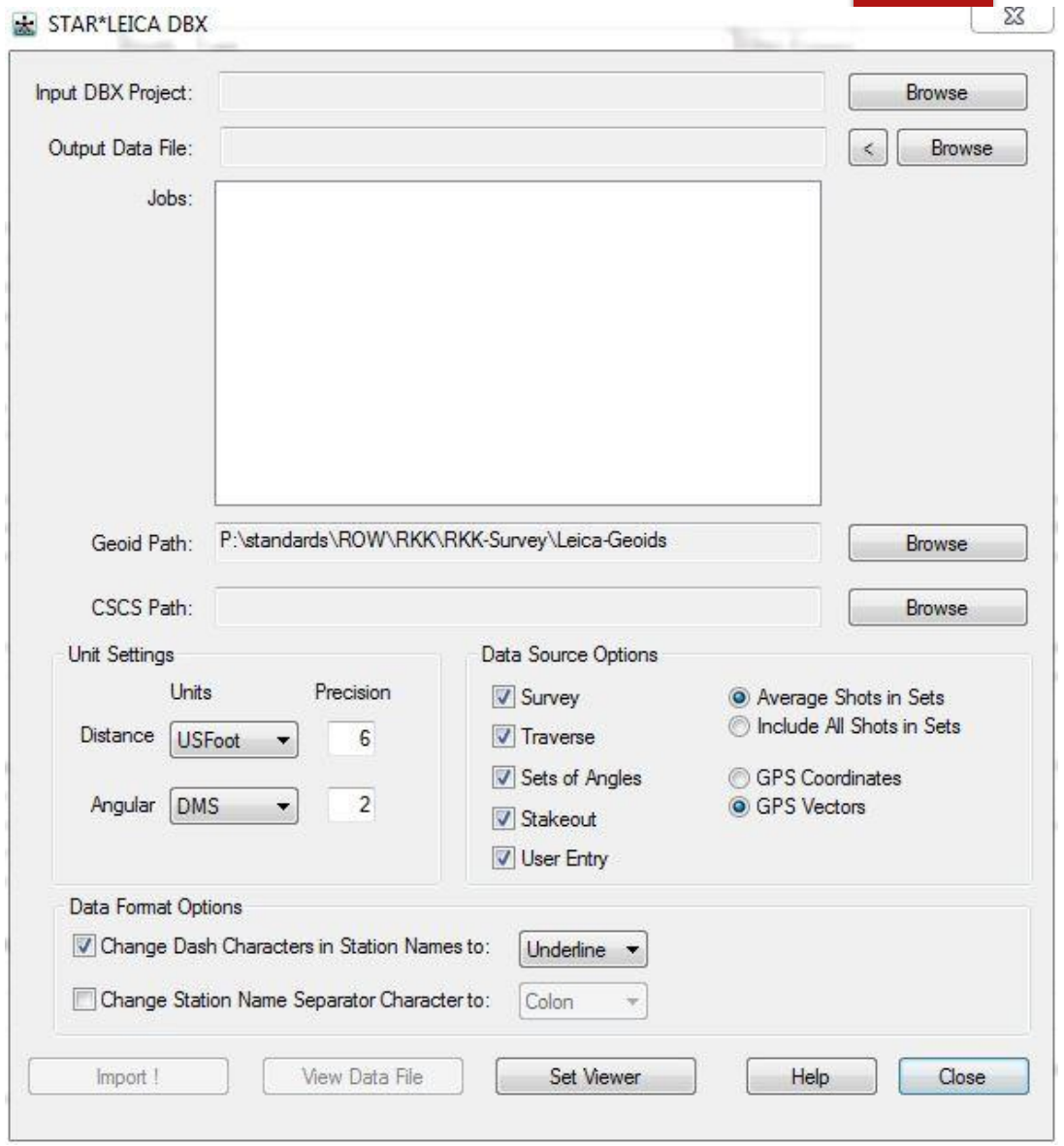
Known Elevations

- 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.



582,058.61

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

582,058.61

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 and 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.

Processing Summary

```
Network Adjustment with Error Propagation

Loading Network Data ...
Checking Network Data ...

Performing Network Adjustment ...
  Iteration # 1
  Iteration # 2
  Iteration # 3
  Iteration # 4
  Iteration # 5
Solution Has Converged in 5 Iterations

Statistical Summary
Observation      Count   Error Factor
  Angles           122          0.574
  Distances        451          0.475
  Zeniths          234          0.932
  Level Data        50          0.547
  GPS Deltas       480          1.387
  Total           1337          0.980

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.

```
  Level Data        50          0.547
  GPS Deltas       480          1.387
  Total           1337          0.980

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

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

Network Processing Completed
```

Positional Tolerance

- 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 (FeetUS)
Allowable Tolerance = 0.0700 + 50 PPM
Tolerance Check Confidence Region = 95%
Listing Failures Only

Stations		Horizontal	Semi-Major-Axis		Ratio
From	To	Distance	Actual	Allowed	Actual/Allowed
450	RKK723	519.9900	0.1104	0.0960	1.1498 *
JU1474	RKK32	328.3911	0.1062	0.0864	1.2288 *
RKK310	RKK400	56.7334	0.0814	0.0728	1.1180 *
RKK723	RKK724	612.0441	0.1283	0.1006	1.2751 *
RKK724	RKK725	665.9312	0.2157	0.1033	2.0885 *
RKK724	RKK731	388.7888	0.1308	0.0894	1.4621 *
RKK725	RKK731	280.3945	0.0981	0.0840	1.1681 *

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.

Station Coordinate Standard Deviations (FeetUS)

Station	N	E	Elev
450	0.035296	0.045217	0.051784
451	0.050656	0.042724	0.053124
452	0.055766	0.054876	0.053353
453	0.043255	0.057649	0.053237
5502	0.082016	0.053666	0.274546
13077_RKK1	0.033419	0.030857	0.022132
13077_RKK10	0.048956	0.045716	0.030147
13077_RKK11	0.051935	0.043604	0.031423
13077_RKK12	0.047680	0.046466	0.032234
13077_RKK13	0.044467	0.044197	0.031991
13077_RKK14	0.042132	0.042870	0.030196
13077_RKK15	0.037946	0.040370	0.027945
13077_RKK16	0.036194	0.035562	0.024401
13077_RKK17	0.036878	0.034097	0.023371
13077_RKK18	0.039332	0.037306	0.024217
13077_RKK19	0.040555	0.037149	0.023269
13077_RKK2	0.034631	0.036306	0.018370
13077_RKK3	0.039917	0.036848	0.019960
13077_RKK4	0.042917	0.037034	0.020536

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.

Station Coordinate Error Ellipses (FeetUS)
Confidence Region = 95%

Station	Semi-Major Axis	Semi-Minor Axis	Azimuth of Major Axis	Elev
450	0.113632	0.082475	109-13	0.101495
451	0.138827	0.083893	145-38	0.104122
452	0.169201	0.089701	135-49	0.104569
453	0.152649	0.088432	117-54	0.104343
5502	0.203780	0.126616	167-21	0.538101
13077_RKK1	0.082067	0.075241	168-23	0.043379
13077_RKK10	0.125537	0.105463	33-20	0.059087
13077_RKK11	0.132084	0.100528	24-45	0.061588
13077_RKK12	0.129992	0.098279	42-17	0.063178
13077_RKK13	0.116598	0.099778	43-52	0.062702
13077_RKK14	0.109681	0.098064	49-29	0.059183
13077_RKK15	0.099216	0.092454	75-41	0.054771
13077_RKK16	0.092518	0.082865	139-37	0.047825
13077_RKK17	0.091941	0.081613	155-38	0.045807
13077_RKK18	0.097669	0.089825	154-37	0.047465
13077_RKK19	0.099431	0.090754	171-57	0.045607
13077_RKK2	0.089503	0.084096	110-20	0.036004
13077_RKK3	0.100266	0.087339	152-48	0.039121
13077_RKK4	0.106002	0.089534	165-32	0.040251

Troubleshooting Star*Net

COMMON ERRORS, COMMON SOLUTIONS

Fast Troubleshooting

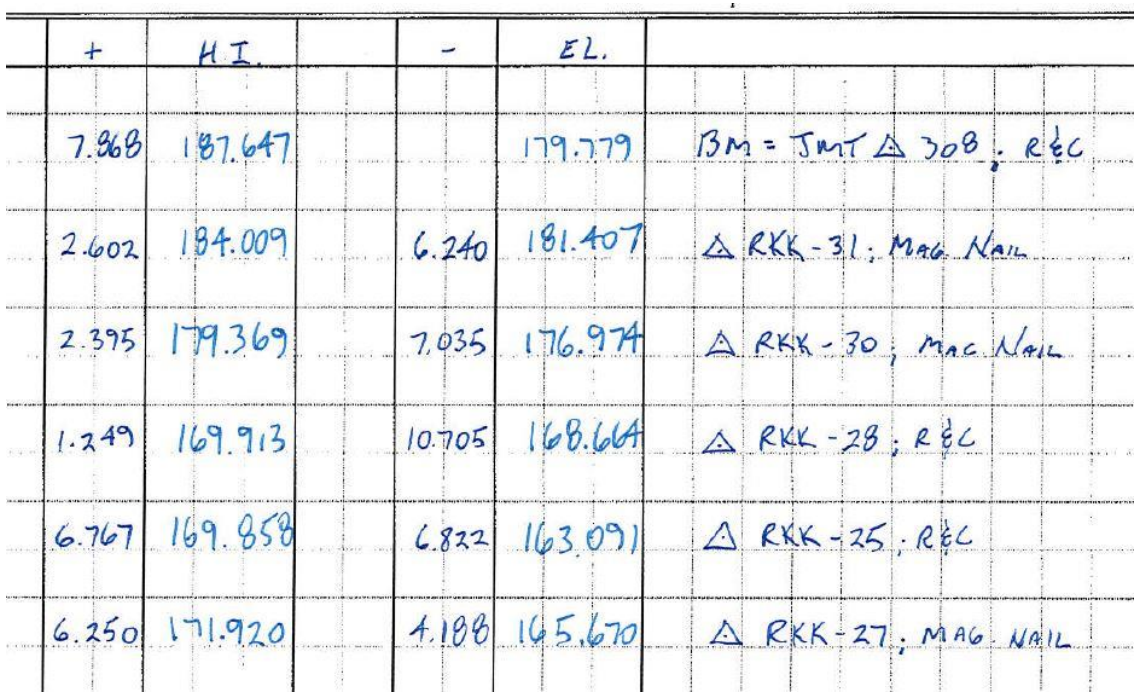
- Be sure sorting by Std Residual was set in the listing files options.
- Review which data type had the highest Error Factor.
- Navigate to the Adjusted Observations and Residuals for target data type.
- Examine the highest errors against the input data for blunders or inconsistent data.
- Rerun adjustment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

Adjusted Zenith Observations (DMS)

From	To	Zenith	Residual	StdErr	StdRes	File:Line
CROSS5	CROSS6	90-14-11.46	-0-00-56.71	13.34	4.3*	1:1257
RKK307	RKK305	90-00-14.13	-0-00-44.87	16.02	2.8	1:1531
RKK305	RKK307	90-05-06.31	-0-00-44.86	16.02	2.8	1:1529
13077_RKK18	13077_RKK19	89-53-49.50	0-00-37.17	13.84	2.7	1:1969
CROSS6	CROSS5	89-46-03.85	-0-00-28.15	13.34	2.1	1:1620
RKK724	450	90-12-47.97	-0-01-10.03	33.23	2.1	1:2267
13077_RKK19	13077_RKK18	90-07-54.58	0-00-24.91	13.84	1.8	1:1970
450	RKK724	90-02-31.50	-0-00-59.50	33.23	1.8	1:2263
CROSS5	CROSS6	90-13-09.04	0-00-23.04	13.34	1.7	1:1619
RKK26	RKK27	90-11-59.98	0-00-22.98	14.23	1.6	1:1168
RKK303	RKK302	89-55-16.97	0-00-15.97	10.74	1.5	1:1532
RKK302	RKK303	90-08-25.39	-0-00-15.61	10.74	1.5	1:1360
RKK304	RKK305	90-06-01.20	-0-00-16.80	11.64	1.4	1:1570
13077_RKK6	13077_RKK7	90-05-28.83	0-00-27.16	19.02	1.4	1:1939
13077_RKK8	13077_RKK7	88-43-13.84	-0-00-43.49	30.72	1.4	1:1942
RKK26	RKK25	90-04-20.10	0-00-19.10	13.50	1.4	1:1178
RKK123	RKK122	90-20-37.56	0-00-21.56	15.54	1.4	2:65
13077_RKK13	13077_RKK12	89-53-35.29	-0-00-15.71	11.35	1.4	1:1952
13077_RKK6	13077_RKK7	89-40-41.93	-0-00-25.07	19.02	1.3	1:2020
RKK126	RKK123	89-22-44.51	0-00-16.51	12.94	1.3	2:64
RKK120	RKK918	89-44-45.67	0-00-17.17	13.64	1.3	2:32
RKK32	RKK31	90-39-51.82	-0-00-13.18	10.93	1.2	1:1222
RKK901	RKK900	89-38-51.42	0-00-16.42	13.99	1.2	1:1402
RKK901	RKK900	89-38-51.42	0-00-16.42	13.99	1.2	1:1502
RKK901	RKK900	89-38-51.42	0-00-16.42	13.99	1.2	1:1763

Hand Entered Data

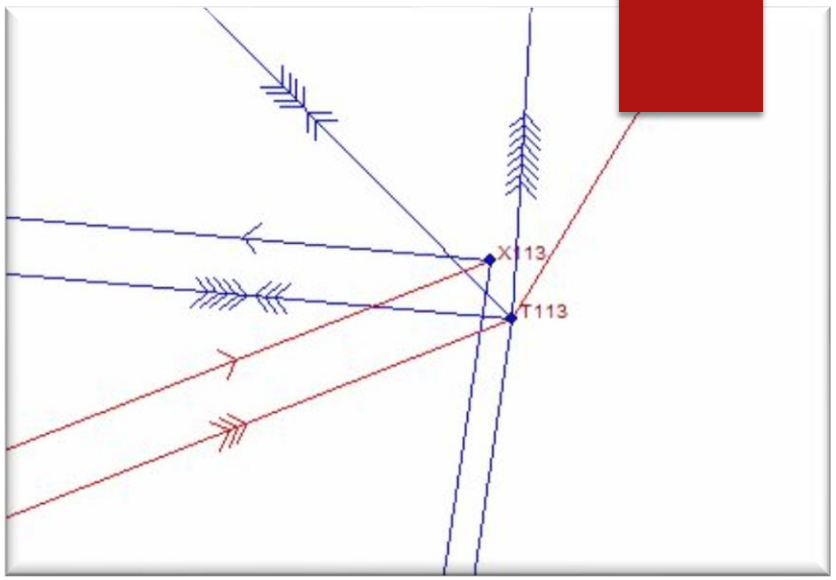
- Often errors are a result of mis-entered information.
- Be sure to carefully review input data that is causing large errors against the original notes.
- If the notes match, see if there is sufficient data to make sure there was not an error in the hand-written notes.

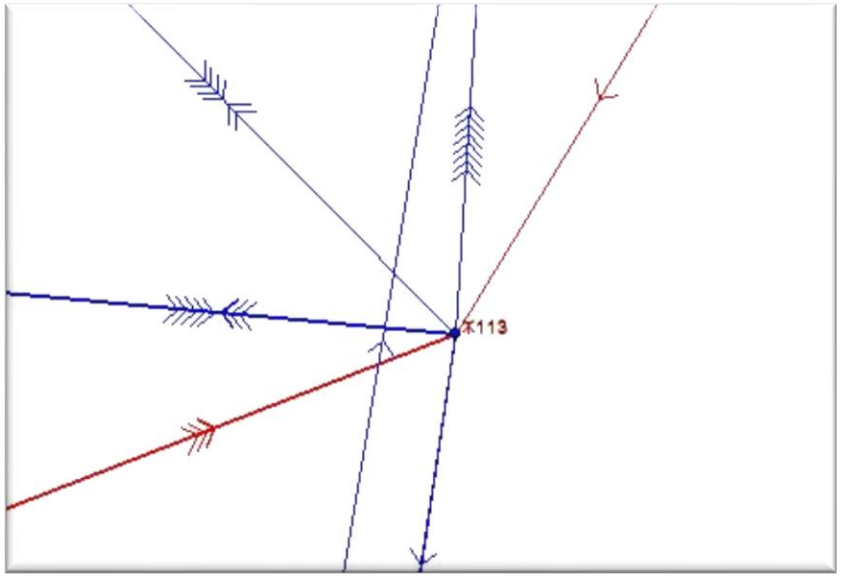


+	H.I.		-	EL.	
7.968	187.647			179.779	BM = JMT △ 308 ; R&C
2.602	184.009		6.240	181.407	△ RKK-31 ; MAG NAIL
2.395	179.369		7.035	176.974	△ RKK-30 ; MAG NAIL
1.249	169.913		10.705	168.664	△ RKK-28 ; R&C
6.767	169.858		6.822	163.091	△ RKK-25 ; R&C
6.250	171.920		4.188	165.670	△ RKK-27 ; MAG NAIL

Point Names/Numbers

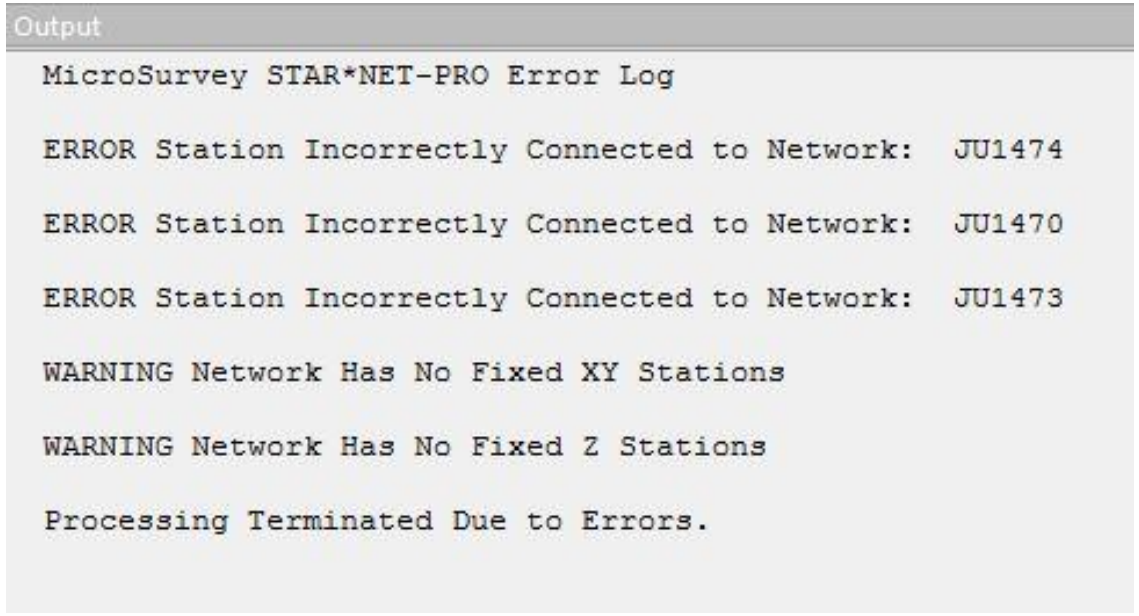
- Star*Net allows for alpha-numeric naming/numbering.
- Make sure all unique points have unique names.
- Make sure all redundant points use identical names.
- Be sure to always thoroughly review the network plot for points sharing a common position.





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.



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.

```
WARNING [Line: 2046] Duplicate Sideshot Name
SS 13077_RKK5-13077_RKK19-13077_100   346-12-57.50   168.4650   90-21-13.00              'RC

WARNING [Line: 2049] Duplicate Sideshot Name
SS 13077_RKK19-13077_RKK5-13077_101    51-30-40.00    94.4600   87-13-04.00   5.100/0.000 'RC

WARNING [Line: 2051] Duplicate Sideshot Name
SS 13077_RKK19-13077_RKK5-13077_102   161-06-52.00   227.6600   90-01-20.00   5.100/0.000 'RC

WARNING [Line: 2053] Duplicate Sideshot Name
SS 13077_RKK19-13077_RKK5-13077_103   168-17-16.50   362.6800   90-02-09.50   5.100/0.000 'PROP

WARNING [Line: 2070] Duplicate Sideshot Name
SS 13077_RKK7-13077_RKK8-13077_104       4-09-22.50    30.6950   94-16-58.50   5.290/4.920   'IP

WARNING [Line: 2072] Duplicate Sideshot Name
SS 13077_RKK7-13077_RKK8-13077_105     235-34-09.00    58.9800   89-29-24.50   5.290/4.920   'IP
```

.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.

```
41  ################################
42  .DATA ON ######################
43  ################################
44
45  #Delaware SPC NAD83/91 from NGS datasheets
46
47  P   JU1892   39-40-24.16563    75-35-50.31090    70.92   **!   'HARE 2 RESET  #H 2nd / V 1st-I - COMMENTED AS 0.42' OUT
48  P   JU2203   39-40-20.64325    75-30-08.16123    13.29   !!!   'A 100         #H 1st / V 1st-II - NAD83(92) NJ SPC
49  P   AJ8041   39-48-15.81978    75-34-50.74837   263.0    !!*   'GPS NC 5      #H A-ORDER / NO VERT
50  P   JU4112   39-48-12.02465    75-28-48.97155   207.1    !!*   'HAR 2         #H B-ORDER / V 3rd
51  P   DK4426   39-40-36.24960    75-44-34.82881     0.00   ***   'CORS DENE     #NO HORZ OR VERT - LEICA SMARTNET BASE 0250 ON 83(2011)
52  P   DF8717   39-46-52.79148    75-07-11.25002    96.26   ***   'CORS NJGC     #LEICA SMARTNET BASE 0252 ON 83 (2011)
53  P   JU0786   39-47-45.21737    75-27-27.67413    17.46   **!   'PRINTZ        #H 2nd / V 1st-II
54  P   JU4130   39-43-46.78985    75-43-39.98064   276.02   !!*   'F 42          #H 1st / V 2nd-II
55  P   JU1470   39-43-07.69083    75-33-18.47074    23.80   !!!   'MILLSIDE      #H 3RD / V 3-4mm - VERT TIE ONLY
56
57  P   JU1474   39-43-33          75-32-46          8.59    !!!   'G 22          #NO HORZ / V 4-8mm - VERT TIE ONLY
58  P   JU1473   39-44-12          75-33-14         15.89    !!!   'E 22          #NO HORZ / V 3-4mm - VERT TIE ONLY
59
60  ################################
61  .DATA OFF #####################
62  ################################
63
```

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.

```
# TOPO-WILMINGTON(2-7-12).raw-EDIT.rw5

M    T113-T114-RKK902    271-42-24.50    423.8200    89-59-09.33    5.330/6.000    ###'TRAV
M    T113-T114-RKK903    311-54-36.83    362.8267    90-01-06.00    5.330/6.000    ###'TRAV

DV    RKK901-RKK900                     298.1700    89-41-39.00    5.360/4.930    ###'CKSHOT
DV    RKK901-RKK900                     298.1700    89-38-35.00    5.320/5.140    ###'CKSHOT
.3R
DV    T113-T114                         427.9200    89-58-21.00    #5.360/5.020    ###'CKSHOT
.3D
DV    RKK902-T113                       423.8000    89-57-45.00    5.340/5.050    ###'CKSHOT
DV    RKK903-T113                       362.8300    89-52-12.00    5.380/5.400    ###'CKSHOT
```

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.
  - #Misnamed point. Actual point unknown.
  - #High residual errors.

```
# Input Field File : \\balsrv01\v2012\2012\12146_Garasches\SURVEY\Field\TR-GARASCHES(10-5-12)-EDIT.RAW
# Job  : TR-GARASCHES(10-5-12)
# Date : 10-05-2012
# Party Chief:  Craig Myers
# Instrument Man:  Stan Carbaugh

#HORIZONTAL ANGLE HIGH RESIDUAL - SHOULD BE REVIEWED
#M   RKK10-RKK8-RKK25        31-58-40.00     321.3900     90-29-43.67     5.280/5.040
M   RKK25-RKK10-RKK26     278-07-52.33     321.8600     90-00-0.00      5.430/5.250
M   RKK26-RKK25-RKK27     158-09-08.83     288.0000     90-11-37.00     5.430/5.120
M   RKK27-RKK26-RKK28     193-19-22.67     322.6067     89-36-14.33     5.370/5.260
M   RKK28-RKK27-RKK29     169-39-01.00     359.4250     90-10-31.67     5.420/5.180
M   RKK29-RKK28-RKK30     171-53-35.33     314.4900     89-44-36.33     5.330/5.180
M   RKK30-RKK29-RKK31     173-52-03.00     303.2000     89-56-58.83     5.350/4.940
M   RKK31-RKK30-RKK32     186-20-26.67     660.4900     89-18-19.83     5.370/5.050
```

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.

Future Adjustments of Already Used Control

- 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.