Software for
Land Development
Professionals

Carlson Software Inc.

User's manual

Carlson SurvNET
True network least squares
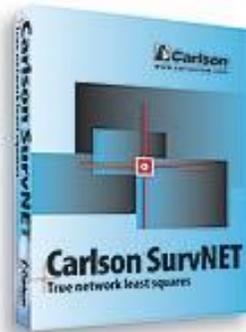
SurvNET

Carlson SurvNET is SurvCADD's Network Least Squares Reduction (NLSA) program. This module will perform a least squares adjustment and statistical analysis of a network of raw survey field data, including both total station measurements and GPS vectors. SurvNET will simultaneously adjust a network of interconnected traverses with any amount of redundancy. The raw data can contain any combination of traverse (angle and distance), triangulation (angle only) and trilateration (distance only) measurements, as well as GPS vectors. It can also calculate resections, where any combination of distances and angles can be measured from an unknown point to known points (points located in the traverse). The raw data does not need to be in a linear format, and individual traverses do not have to be defined using any special codes. All measurements are used in the adjustment. SurvNET gives the user the option to choose one of two mathematical model options when adjusting raw data, the 3D model of least squares adjustment and the 2D/1D model. The 3D model reduces numerous networks using both the 2D/1D model.

The SurvNET Module is located inside of the Tools menu of the COGO & Design Module. To access SurvNET, go to SurvCADD's COGO & Design module and observe the Tools pulldown at the top of the screen. Click on the Tools pulldown, select Edit-Process Raw Data File and choose a .RW5 file. You will now see the Raw Editor. Selecting the editors' Process (Compute Pts) pulldown. While in this menu select Least-Squares, then SurvNET. There are six tabbed sections.

Tools COGO Design Area A
Data Collectors
Edit-Process Raw Data File

Raw File to Process - (rw5)
New | Existing
Recent Folders
C:\Scad2006\Data

File Name

Raw Editor RW5> C:\Scad2006\Data\Glentrav.rw
File Edit Display Add Process (Compute Pts) Tools

	Type		PntNo	Northing
1			PntNo	Northing
2	PT		1	5000.0000
3	PT		202	5100.0000

Process (Compute Pts)
No Adjust
Angle Balance
Compass
Crandall
Transit
Least-Squares   ▶
Stadia
GPS
Process Settings

Prepare Least-Squares Data
Edit Least-Squares Data
Process Least-Squares Data
SurvNET

Network Least-Squares Settings
Coordinate System | Input Files | Preprocessing | Standard Errors | Adjustment | Output Options |
Scale Factor: 1.00000000
Coordinate System
  ⦿ Local   ○ State Plane 27   ○ State Plane 83
Zone: [   ]   Horizontal Units: US Feet
Compute Elevation Factor From
  ⦿ Project Elevation   ○ Raw Data
Project Elevation: 0.000   Elevation Units: Meters
Geoid Modelling
  ⦿ Use Project Geoid Separation   ○ Use Geoid File
Geoid Separation: 0.000   Geoid Model: GEOID99
Coordinate System Adjustment Model
  ⦿ 2D - 1D Model   ○ 3D Model
☑ Apply Horizontal Adjustment   ☑ Apply Vertical Adjustment

Load   Save   OK   Cancel

Key Features of SurvNET

SurvNET can automatically reduce field measurements to State Plane coordinates in either the NAD 83 or NAD 27 coordinate systems. In the 2D/1D model, a grid factor is computed for each individual line during the reduction. The elevation factor is computed for each individual line if the data is 3D. If the raw data has only 2D data, the user has the option of defining a project elevation to be used to compute the elevation factor. A full statistical report containing the results of the least squares adjustment is produced and written to the report (.RPT) file. An error report (.ERR) file is created and contains any error messages that are generated during the adjustment.

Coordinates can be stored in either a Carlson (.CRD) file, a C&G (.CRD) file or an ASCII (.NEZ) file. A file with the extension .OUT will be created and contains an ASCII formatted coordinate list. There is an option to compute traverse closures during the preprocessing of the raw data. Traverse closures can be computed for both GPS loops and total station traverses. This option has no effect on the computation of final least squares adjusted coordinates. It is useful for surveyors who, due to statutory requirements, are still required to compute traverse closures, and for those surveyors who still like to view traverse closures prior to the least squares adjustment.

The 3D model of least squares adjustment model, supported here in SurvNET, is the preferred method of adjusting GPS vectors with total station data. GPS vector data can be incorporated with total station data in a single adjustment. Vector files from Leica and Thales can be input, as can GPS files in the StarNet format. As part of the preprocessing process, traverse closures can be computed. Closures for loop traverses and point to point traverses, with or without angle closures, can also be computed. And multiple loops in the same raw file can be computed. As part of preprocessing, GPS loop closures can be computed as well. The user has the option to compute unadjusted preliminary coordinates.

There is a blunder detection method that is effective in detecting if the same point number has been used for two different points. This method will also flag other raw data problems. Another blunder detection method included in SurvNET is very effective in isolating a single blunder, distance or angle in a network. This method does not require that there be a lot of redundancy, but is effective if there is only one blunder in the data set. Additionally, SurvNET includes a blunder detection method that can isolate multiple blunders, distance or angle in a network. This method does require that there be a lot of redundancy in the network to effectively isolate the multiple blunders.

Other key features: Differential level networks and loops can be adjusted using the network least squares program. Geoid modeling is used in NLSA, allowing the users to choose between the Geoid99 or the Geoid03 model. The user can alternately enter the project geoid separation. The separation is used when combining GPS vectors with total station data, and is also used in the computation of the elevation factor in the 2D model adjustment. There are description codes to identify duplicate points with different point numbers. The user can specify the confidence interval from 50 to 99.

Network Least Squares

Function

The Network Least Squares Adjustment program (NLSA) performs a mathematically rigorous least squares adjustment and statistical analysis of a network of raw traverse field data. The NLSA program simultaneously adjusts a network of interconnected traverses with any amount of redundancy. The raw data can contain any combination of traverse (angle and distance), triangulation (angle only) and trilateration (distance only) measurements. It can also calculate resections, where any combination of distances and angles can be measured from an unknown point to known points (points located in the traverse). The raw data need not be in linear format, and individual traverses do not have to be defined using any special codes. All measurements will be used in the adjustment.

The NLSA program also adjusts both 3D and 2D traverses. This includes 3D traverses that contain some 2D data. If you have Vertical Adjustment turned ON in the project settings, elevations will be calculated and adjusted only if there is enough information in the raw data file to do so. Least squares adjustment is used for elevation adjustment as well as the horizontal adjustment. To compute elevations, the instrument record must have a HI, and the foresight record must have a rod height, slope distance and vertical angle. A 0.0 (zero) HI or ROD HEIGHT is valid (only when the field is blank will it be considered a 2D measurement). A 3D traverse must also have adequate elevation control in order to process the elevations. Elevation control can be obtained from the Control File, Coordinate records in the raw data file, or Elevation records in the raw data file. The NLSA program can also automatically reduce field measurements to State Plane coordinates in either the NAD 27 or NAD 83 coordinate systems. A grid factor is computed for each individual line during the reduction. The elevation factor is computed for each individual line if the data is 3D. If the raw data has only 2D data, the user has the option of defining a project elevation to be used to compute the elevation factor.

A full statistical report containing the results of the least squares adjustment is produced. Coordinates will be written to the current coordinate (.CRD) file. Although the NLSA program does not output the standard "Error of Closure" statement, it produces statistical information that allows a much more effective way to evaluate the strength of your traverses, and the precision of your measurements. See details of this statistical report later in this section.

Network Least Squares Settings dialog Choosing SurvNET from the pulldown menu displays the Network Least-Squares Settings dialog box.
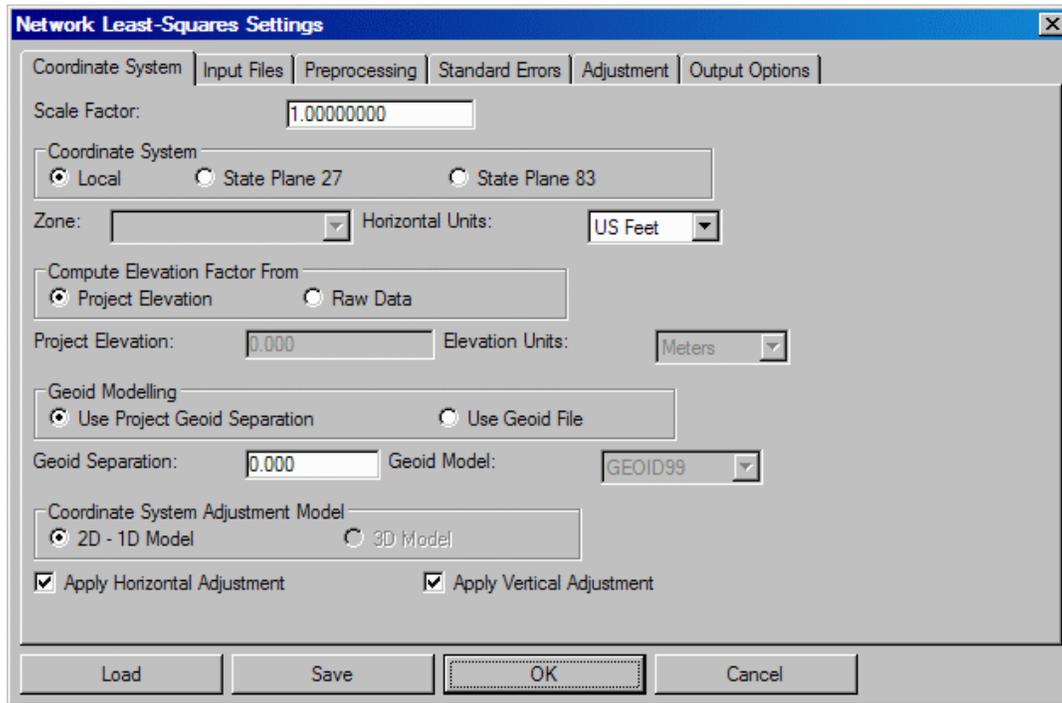
Coordinate System

Scale Factor: Enter a value.

Coordinate System: Select Local (assumed coordinate system), SPC 1927 (State Plane NAD27) or SPC 1983 (State Plane NAD83).

Zone: If you choose SPC 1927 or SPC 1983, you can select the State and Zone you are in. The grid scale factor is computed for each measured line using the method described in section 4.2 of NPAA Manual NOS NGS 5, "State Plane Coordinate System of 1983", by James E. Stem.

Horizontal Units: Applies to the input/output of coordinate values (Meters, US Feet or International Feet).

Compute Elevation Factor From: When you select SPC 1927 or SPC 1983, in order to calculate the combined scale factor (so as to adjust distances to sea-level), you will be given the choice of either entering a Project Elevation, or using the elevations of the calculated coordinate points (Raw Data). If you are reducing a 2D network, select Project Elevation, since none of the calculated points will have elevations. For most survey projects it is sufficient to use an approximate elevation such as can be obtained from a Quad Sheet. For 3D networks, the elevation factor is computed for each individual line.

Geoid Modeling: You can choose either Use Project Geoid Separation or Use Geoid File.

Geoid Separation: This feature is dependent upon which Geoid Modeling option you decide to use.

Coordinate System Adjustment Model: Pick between 2D - 1D Model or 3D Model.

Apply Horizontal Adjustment: Check box for adjustment of North/East values.

Apply Vertical Adjustment: Check box for adjustment of elevations. You can adjust either horizontal and vertical data, horizontal data only, or vertical data only. If Vertical Adjustment is not checked, elevations will not be

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calculated.

Load: Common option included in all tabbed dialogs described below. Click this button to load an existing .NLQ file.

Input Files
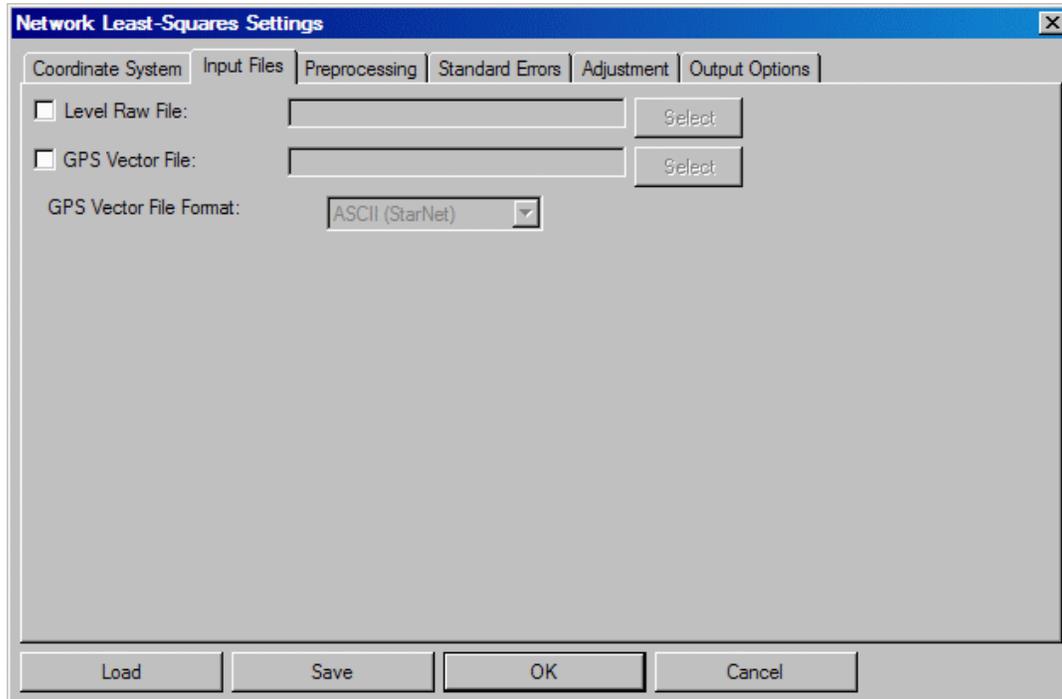
Level Raw File: Click to include existing .LEV file for input.

GPS Vector File: Click to include and existing GSPS vector file for input.

GPS Vector File Format: Select from ASCII (StarNET), Thales or Leica.

Preprocessing
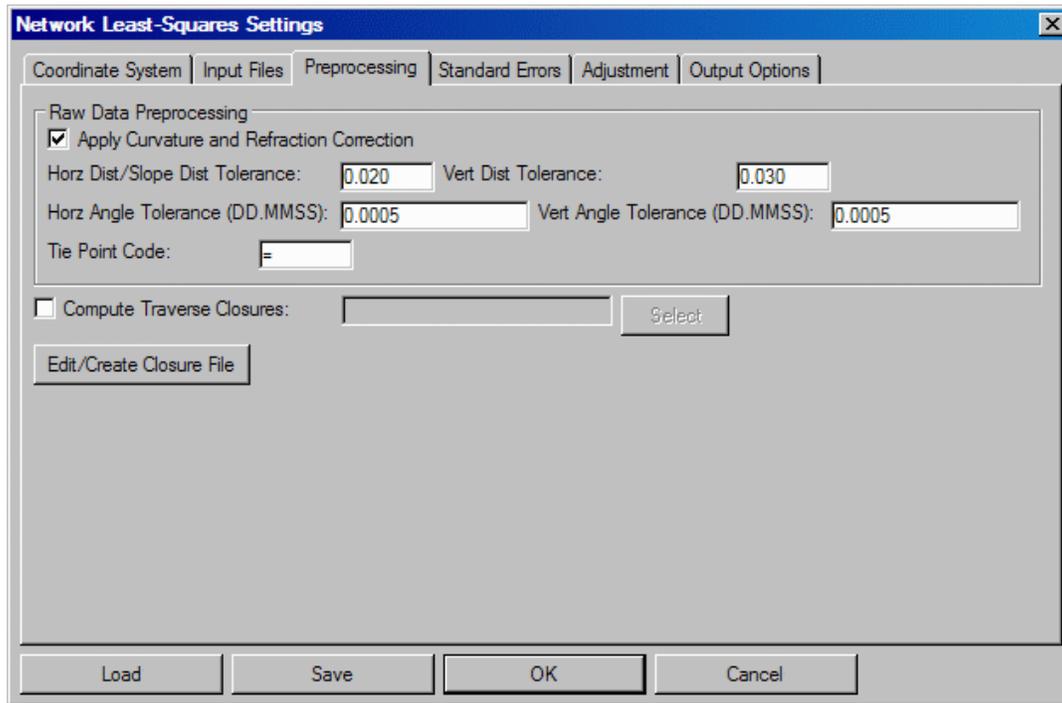
When multiple angles or distances are measured to a point, a single average angle, horizontal distance component, and vertical difference component will be calculated for use in the least-squares adjustment. You may set the tolerances so that you are warned if any angle or distance exceeds these values. Tolerance warnings will be shown in the report after processing the data.

Horz. Dist/Slope Tolerance: Display a warning if the difference between highest and lowest horizontal distance component exceeds this value.

Horz. Angle Tolerance: Display a warning if the difference between the highest and lowest horizontal angle exceeds this value.

Tie Point Code: Enter code.

Edit/Create Closure File: With this feature, you can edit an existing or create a new .CLS closure file.

Standard Errors

Standard errors (SE) are basically realistic errors you would expect to obtain, based on the type equipment and field procedures used to take your measurements (e.g. if you are using a 5 second theodolite, you could expect the angles to be measured within +/- 5 seconds). The Distance, Angle Reading (Vertical and Horizontal) and PPM settings should be based on the equipment being used. Check the published specifications for your total station. Survey methods should also be taken into account when setting standard errors (e.g. you might set the Target Centering standard error higher when you are sighting a held prism pole than you would if you were sighting a prism set on a tripod). If the generated report shows that generally you have consistently high Standard Residuals for a particular measurement value (angles, distances, etc.), then there is the chance that you have selected standard errors that are better than your instrument and methods can obtain. (See explanation of report file).

Note: The settings from this dialog box will be used for the project default settings. These default standard errors can be overridden for specific measurements by placing SE records directly into the Raw Data File (see the above documentation on raw data files).

Distance Standard Error: Precision of distance measurements, obtain from EDM specs.

PPM: Parts per Million, obtain from EDM specs.

Horizontal Pointing (sec): Atmospheric conditions, optics, experience and care taken by instrument operator.

Horizontal Reading (sec): Precision of horizontal angle measurements, obtain from theodolite specs.

Vertical Pointing (sec): Atmospheric conditions, optics, experience and care taken by instrument operator.

Vertical Reading (sec): Precision of vertical angle measurements, obtain from theodolite specs.

Target Centering: Location of target (prism) relative to the point.

Instrument Centering: Location of instrument relative to the point.

Target Height: Accuracy of target height.

Instrument Height: Accuracy of instrument height.

Direction (Azimuth) Standard Error (sec): Precision of bearing/azimuth records.

North Coordinate, East Coordinate: Precision of horizontal coordinate records.

GPS Standard Errors: A GPS Centering Error value and a Vector Std. Err Factor value may be entered.

Differential Leveling Standard Errors: Values for Average Distance to BS/FS, Rod Read Err per 100 ft/m and Collimation Err (sec) may be entered in these three fields.

Adjustment
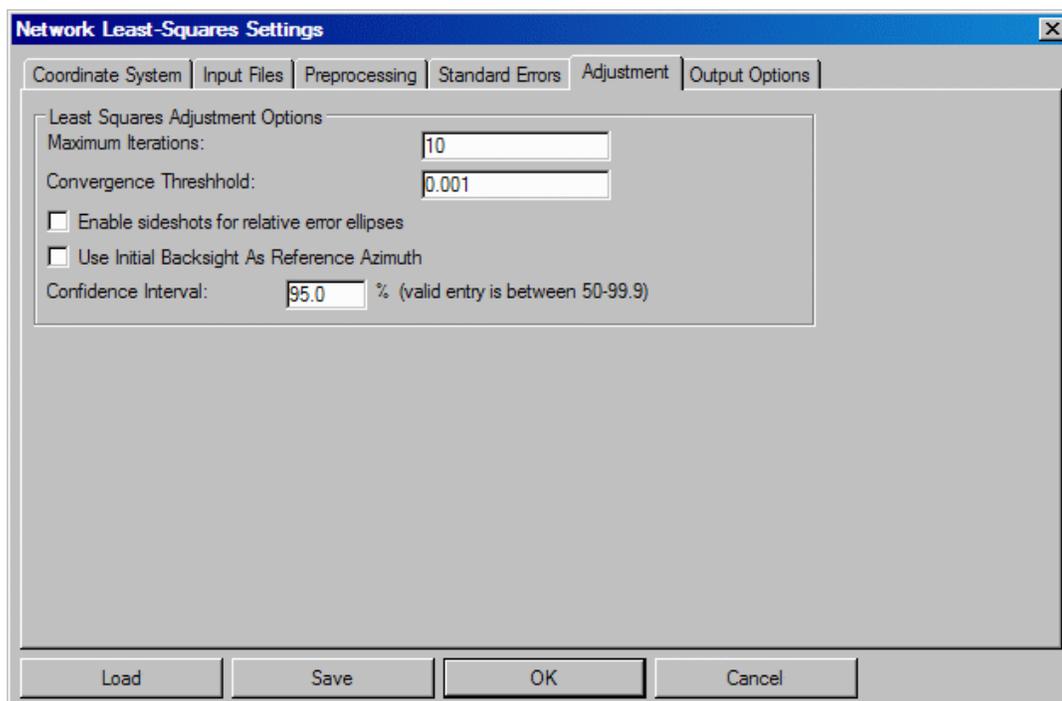
Least Squares Adjustment Options: These two options are describe here.

Maximum Iterations: Number of iterations allowed for convergence. Select how many places you want to see after the decimal.

Convergence Threshold: Stop when the corrections to the adjustment are less than this value. Select how many places you want to see after the decimal.

Enable sideshots for relative error ellipses: Check box for sideshot relative error ellipses.

Use Initial Backsight As Reference Azimuth: Reported directions can be output in Bearing or Azimuth.

Coordinate Interval: Reported coordinates can be output in either North-East or East-North.

Output Options

These settings apply to the output of data to the report and coordinate files. If coordinate points already exist in the coordinate file, they will be overwritten and updated with the new coordinate values.

North/East Precision: Select how many places you want to see after the decimal.

Elevation Precision: Select how many places you want to see after the decimal.

Distance Precision: Select how many places you want to see after the decimal.

Direction Precision: Angular output of nearest second, tenth of second, or hundredth of second for directions (Azimuths or Bearings).

Direction Format: Reported directions can be output in Bearing or Azimuth.

Coordinate Display: Reported coordinates can be output in either North-East or East-North.

Null Elevation: Value to be reported for elevations that were not calculated.

Process Network
If there is a problem with the reduction, you will be shown error messages that will help you track down the problem. The data is preprocessed to calculate averaged angles and distances for sets of data. For a given setup, all multiple angles and distances to a point will be averaged prior to the adjustment. The standard error as set in the Project Settings dialog box is the standard error for a single measurement. Since the average of multiple measurements is more precise than a single measurement the standard error for the averaged measurement is computed using the standard deviation of the mean formula. During the preprocessing, approximate coordinate values for each point will also be calculated. This saves the user from having to come up with a list of approximate coordinate values prior to processing. Sideshots are separated from the raw data and processed after the adjustment. If the raw data processes properly, a report file will be displayed and the coordinate file will be populated with the adjusted coordinates.

Once you have clicked OK, you will see the full statistical report produced by this routine in its own dialog box. This displayed dialog is titled Network Least Squares Results. It, too, is categorized with the use of six tabs.

Network Least Squares Results dialog

Main Report

The main contain the Least Squares Adjustment Report, the Horizontal Adjustment Report and the Statistics. This last Statistics section displays some statistical measures of the adjustment including the number of iterations needed for the solution to converge, the degrees of freedom of the network, the reference variance, the standard error of unit weight, and the results of a Chi-square test. The degree of freedom is an indication of how many redundant measurements are in the survey. Degree of freedom is defined as the number of measurements in excess of the number of measurements necessary to solve the network. The standard error of unit weight relates to the overall adjustment and not an individual measurement. A value of one (1) indicates that the results of the adjustment are consistent with a priori standard errors. The reference variance is the standard error of unit weight squared. The chi-square test is a test of the "goodness" of fit of the adjustment. It is not an absolute test of the accuracy of the survey. The a priori standard errors, which are defined in the project settings dialog box or with the SE record in the raw data file, are used to determine the weights of the measurements. These standard errors can be thought of as an estimate of how accurately the measurements were made. The Chi-square test only tests whether the results of the adjusted measurements are consistent with the a priori standard errors. Note that if you change the project standard errors and then reprocess the survey, the results of the Chi-square test change.
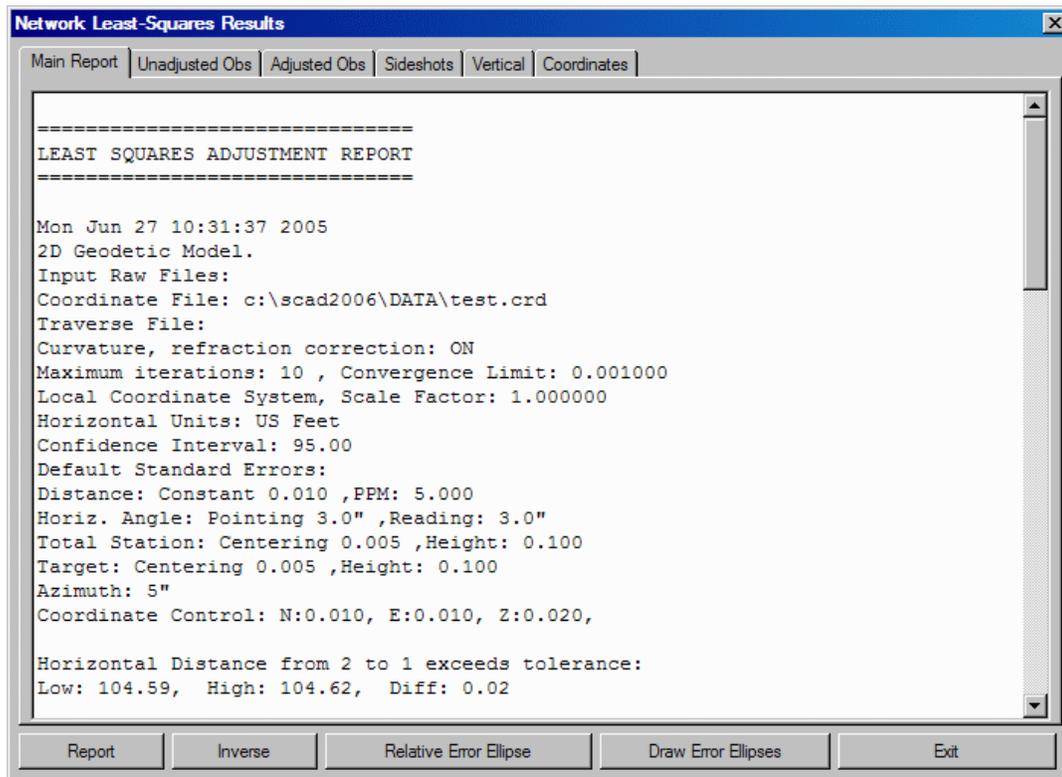
Unadjusted Observations

This tabbed section lists the reduced and averaged measurements that contribute to the network. When multiple measurements are used, the standard error for the averaged measurement will be computed using the average of the mean formula. There is a list included of the control coordinates used in the network adjustment. These coordinates have been read from the raw data file. Note that the standard errors for the control points are displayed. This section shows the azimuths and azimuth standard errors used in the adjustment. Azimuths can only be defined as a direction record in the raw data file. This section also shows the distances and distance standard errors used in the adjustment.

These distances are horizontal distances derived from all slope distance and vertical angles for that line, including all foresight and backsight distances. The standard error settings used to calculate the final distance standard error include the distance standard error, the PPM standard error, the target centering standard error and the instrument centering standard errors. The techniques and formulas used to calculate the final distance standard error are found in section 6.12 of the textbook "Adjustment Computations, Statistics and Least Squares in Surveying and GIS", by Paul Wolf and Charles Ghilani. You also will see the angles and angle standard errors used in the adjustment. These angles are the averaged angle value for all the multiple angles collected. The standard error settings used to calculate the final angle standard error include: the pointing standard error, the reading standard error, the target centering standard error and the instrument centering standard errors. (For the techniques and formulas used to calculate the final angle standard error, please reference section 6.2 of: Wolf, P.R. and Ghilani, C.D., 1997, "Adjustment Computations: Statistics and Least Squares in Surveying and GIS", Interscience, Third Edition.)

Adjusted Observations
This sections lists the adjusted horizontal distance, horizontal angle, and azimuth measurements. In addition to the adjusted measurement, the residual, standard residual and the standard deviation of the adjusted measurement are displayed. The residual is defined as the difference between the unadjusted measurement and the adjusted measurement. The residual is one of the most useful and intuitive measures displayed in the report. Large residuals in relation to the standards of the survey are indications of problems with the data. The standard residual is the a priori standard error divided by the computed standard deviation of a measurement. A standard residual of one (1) indicates that the adjusted measurement is consistent with the standard errors defined for the measurement. One (or a few) measurements having high standard residuals, in relation to the rest of the standard residuals, may be an indication of an error in the survey. When all standard residuals are consistently large, an inconsistency in the a priori standard errors and the adjustment is likely. In other words, the standard errors defined for the project are too small, in relation to the survey methods used. The standard deviation of the measurement indicates a 68% probability that the adjusted measurement is within (plus or minus) the standard deviation of the measurement's true value.

This tabbed section displays the computed sideshots of the network. Sideshots are filtered out of the network adjustment as part of the preprocessing process. Least squares adjustment requires a lot of computer resources. Sideshots are filtered out to minimize the computer resources needed in a large network adjustment. The sideshots are computed from the final adjusted network points. The results of the sideshot computations are the same whether they are reduced as part of the least squares adjustment or from the final adjusted coordinates.

Vertical
This tabbed portion of the report displays the results of the vertical adjustment. The horizontal and the vertical adjustments are separate least squares adjustment processes. As long as there are redundant vertical measurements the vertical component of the network will be reduced and adjusted using least squares. The first part of the vertical adjustment results displays the fixed vertical benchmarks used in the vertical adjustment. These points are fixed and will not be adjusted vertically. Next, the points that will be adjusted as part of the vertical adjustment are listed. The third part of the vertical adjustment report displays the measurements used. The measurements consist of the vertical elevation difference between points in vertical adjustment. The lengths between these points are used to determine the weights in the vertical adjustment. Longer length lines are weighted less in the vertical adjustment than shorter length lines.

Coordinates
If the adjustment of the network converges, this tabbed section displays a list of the final adjusted coordinates and the computed standard X, Y standard error. The X, Y standard error signifies that there is a 68% probability that the adjusted X, Y is within plus or minus the standard error of the X, Y of its true value. This section displays the error ellipses for the adjusted coordinates. The error ellipse is a truer representation of the error of the point than the X, Y standard error. The error ellipses are calculated to a 95% confidence interval. The error ellipse axis is larger than the X, Y standard errors because the error ellipses in this report are calculated at a 95% probability level. The maximum error axis direction is along the axis of the semi-major axis. The direction of the minimum error axis direction is along the semi-minor axis and is perpendicular to the semi-major axis. If a point is located from a variety of stations,

you will see the error ellipse approach a circle, which is the strongest geometric shape.

The following four buttons are located at the bottom of the Network Least Squares Results dialog box.

Report: This report information will be shown in a Standard Report Viewer so that you can analyze the data. Select the Printer icon if you want a hard copy. The first section of the report displays the primary settings used when the project was adjusted. The second section of the report displays warning and error messages generated during the preprocessing of the raw data. The primary messages displayed will be warnings when multiple angles, horizontal distances, and vertical differences exceed the tolerance settings as set in the project settings. The low and high measurement and the difference are displayed.

Inverse: The Inverse button is only active after a network has been processed successfully. Inverse can be used to obtain the bearing and distance between any two points in the network. Additionally, the standard deviation of the bearing and distance between the two points is displayed. This information can be used to determine the relative precision between any two points in the network. If you need to certify the Positional Tolerances of your monuments, per the ALTA Standards, use this function to determine these values (e.g. if you must certify that all monuments have a positional tolerance of no more than 0.07 feet, inverse between the monuments in as many combinations as you deem necessary, and make note of the standard deviations of the distances. If none of them are larger than 0.07 feet, you have met the standards).

Relative Error Ellipse: Reports the relative error ellipse from one point to another.

Draw Error Ellipses: Draws the error ellipse from one point to another.
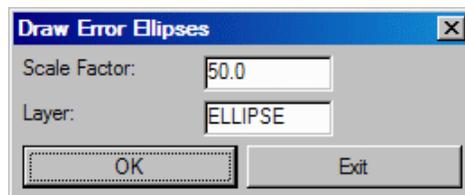
Exit: Ends your session in the Network Least Squares Settings dialog and brings you back to the Raw Editor.

Pulldown Menu Location: Tools in COGO & Design
Keyboard Command: rawedit
File Name: \lsp\rawedit.arx