STAR*NET V6

Least Squares Survey Adjustment Package
Ten-Station Demonstration Program

A Tour of

STAR*NET

Illustrating
Standard, Plus, Pro & Lev Edition Features

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TOUR OF THE STAR*NET PACKAGE

Overview

The STAR*NET suite of programs perform rigorous least squares adjustments of survey networks. The Standard Edition handles 2D and 3D networks containing conventional terrestrial observations. The LEV edition handles 1D differential level networks only. The PLUS edition includes Standard Edition features plus the differential level network features of the LEV edition. The high-end PRO edition adds the handling of GPS vectors and full support for geoid and vertical deflection modeling. The software is menu driven and allows you to edit your input data, run your adjustment and view the processing results, both graphically and in a listing report, all from within the program.

STAR*NET is ideal for the adjustment of traditional interconnected traverse networks. It is equally suited to the analysis of data sets for establishing control for close-range photogrammetry and structural deformation monitoring.

This tutorial includes examples designed to acquaint you with the general capabilities of the STAR*NET suite. It contains the following:

- STAR*NET Demo Program Installation Instructions.

- Example 1: Two dimensional traverse network. This example shows you the basic features of STAR*NET, and lets you run an adjustment and view the output results in both listing and graphical formats.

- Example 2: Combined triangulation/trilateration network.

- Example 3: Three dimensional traverse network.

- Example 4: Same three dimensional network, but processed as a grid job.

- Example 5: Resection.

- Example 6: Traverse with sideshots.

- Example 7: Preanalysis of a network.

- Example 8: Simple GPS network (STAR*NET-PRO edition).

- Example 9: Combining conventional observations and GPS vectors (PRO edition).

- Example 10: Differential leveling network (PRO, PLUS & LEV editions).

- Supplemental information. Some extra details are included if you want to try out additional STAR*NET features on your own using the demo program.

In this tutorial, we will go through the same sequence of operations that you would normally follow when creating and adjusting a survey network – but in these examples, we will be just reviewing options and data, not setting options and creating new data. The normal sequence of operations one goes through in adjusting a survey project is the following: set project options, create input data, run an adjustment, review results including viewing both an adjusted network plot and an output listing report.

The demo program is a fully functional version of STAR*NET. It includes all the capabilities of the STAR*NET-PRO edition, except that it is limited to an adjustment of 10 stations, 100 observations and 15 GPS vectors.

Note that this tutorial documentation is not designed to be an operating manual. It is intended only as a guide to the use of the demo program. A complete, fully detailed manual is provided with purchase of STAR*NET. To order the program, or if you have questions about its use, please contact:

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Installing the STAR*NET Demo Program

If you received a CD, insert the CD in your drive and go to Step 1.

If you downloaded (or were emailed) a single-file install program, simply double-click the file in explorer to start the installation, and go directly to Step 3.

1. From the Windows taskbar, select **Start>Run**. The Run windows appears.

2. In the Open field, type "D:\SETUP", substituting the letter of the CD drive you are using if it is other than drive "D". Select OK.

3. Follow the installer instructions. Note that you can accept the default destination folder named "C:\Program Files\Starplus\StarNet-Demo" or choose a different destination folder by browsing.

   If you choose to a different installation destination, we encourage you to create a separate folder just for the demo, not one already containing other programs from Starplus Software or other companies, to eliminate the possibility of conflicts.

4. After installing, press the Windows "Start" button, select **Programs>Starplus**, and then click the "StarNet Demo" selection to run the STAR*NET demo program.

Example projects provided for this tutorial are located in a subfolder of your install directory named "Examples." Therefore:
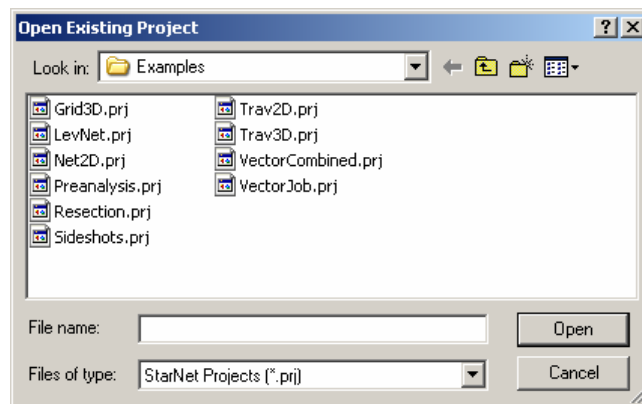
- If you installed the demo in "C:\Program Files\Starplus\StarNet-Demo," then,

- The example projects are in "C:\Program Files\Starplus\StarNet-Demo\Examples."

Each sample project consists of a "Project" file (a file with a "prj" extension) and at least one "Data" file (a file with a "dat" extension). An existing project is opened by selecting its "prj" file from the Open Existing Project dialog.

The "Project" file contains all the option settings for a project such as whether it is a 2D or 3D job, a local or grid job, all instrument standard error settings, and much more information. The project file also includes a list of all data files that are considered part of the project. All options are preset for these sample projects, so you can simply review them and not be concerned about setting or changing any yourself.

All "Data" files used in STAR*NET are simple text files that may be prepared within the program or external to the program using any text editor. All of the input data files for the sample projects are provided, with full comments, to help you get an idea of how to use STAR*NET to handle your adjustment problems. It is not required that you edit any of these sample data files when running the sample projects.

In the following examples in this tour, the instructions simply ask you to open a named project. Choose **File>Open Project**, or press the Open tool button, and the following dialog will appear allowing you to open one of the existing example projects.

If for some reason the example projects as shown above do not appear, browse to the folder you installed the STAR*NET demo, open the sub-folder named "Examples" and you will find them there.

Note! For the sake of simplicity in this tutorial, the dialogs that show the path of the example projects will indicate that the "Starplus" directory exists right at the root.

Example 1: Two Dimensional Traverse Network

The first example project demonstrates the functioning of STAR*NET's main menu system. You will run an adjustment for a project, then view the results in both graphical and listing formats. After running this example, you should have a basic understanding of how the program works. Later examples will show more data types and go into more detail about program options. (Comments following the # character are ignored.)
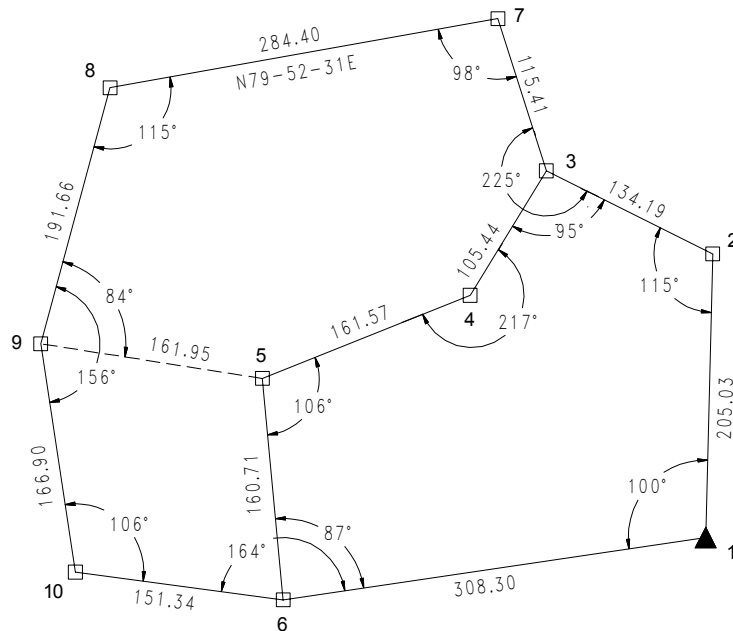
```
# 2D Job with Multi-Loop Traverses

C    1     5045.572   5495.338  ! !  # fixed coordinates
C    6     5000       5190            # approximate coordinates

TB   6  # traverse backsight to point 6
T    1       99-47-25   205.03
T    2      115-10-00   134.19
T    3       94-51-53   105.44
T    4      216-46-09   161.57 'Existing post
T    5      106-26-42   160.71 'Iron pipe
T    6       86-57-49   308.30
TE   1  # end this loop at Point 1

TB   2  # traverse backsight to point 2
T    3      225-47-02   115.41
T    7       97-31-36   284.40
T    8      115-14-57   191.66
T    9      156-15-44   166.90
M    9-8-5   83-45-28   161.95  # add a tie-in course to 5
T    10     106-12-32   151.34
TE   6      164-00-42    1       # end at 6, turn angle into 1

B    8-7   n79-52-31e   !  # fixed bearing
```
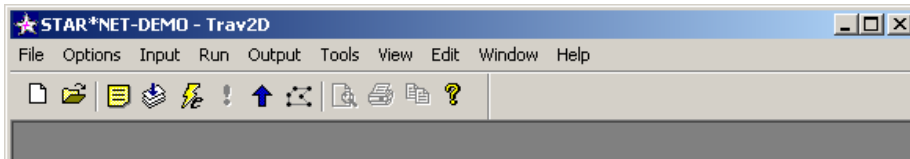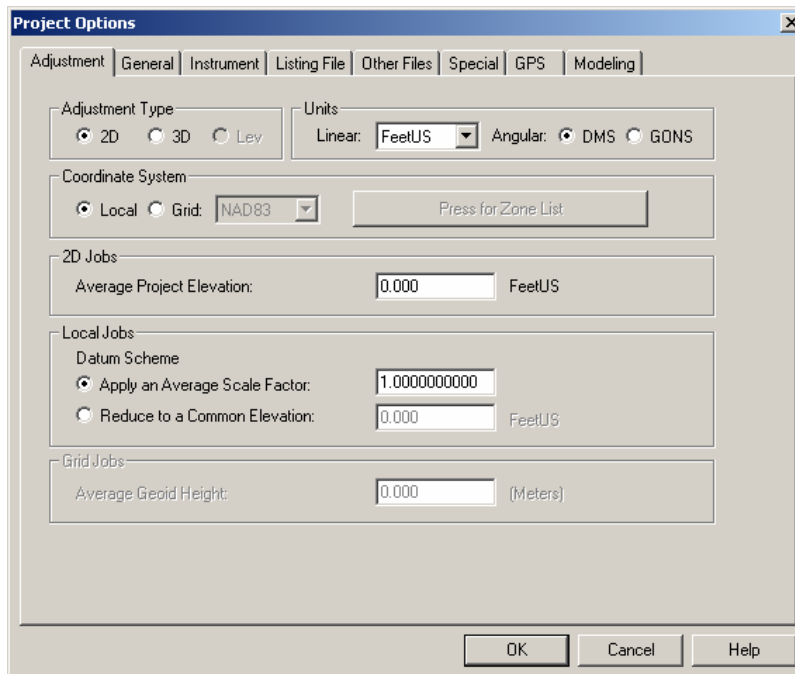
1. Run STAR*NET and open the "Trav2D.prj" example project.

2. The Main STAR*NET Menu will appear:

   All program operations can be selected from these dropdown menus, and the most common operations can be selected by pressing one of the tool-buttons. Pause your mouse pointer over each button to see a short description of its function.

3. Choose **Options>Project**, or press the Project Options tool button.

   The "Adjustment" options page includes settings that describe the project, whether it is a 2D, 3D or Lev type, local or grid, linear and angular units used, and information about the datum scheme. A realistic "Average Project Elevation" should be entered if you are asking the program to reduce observations to some common datum, but this is not the case in this sample job so we've left the value at zero. Other important calculations based on this average project elevation are described in the full manual. Only relevant items on this options dialog are active. For example, other sections of this dialog and other dialogs will be active or inactive (grayed-out) depending on whether the adjustment is a 2D or 3D or a Lev type, or Local or Grid system.

   The "Lev" adjustment type is available in the PRO, PLUS and LEV editions. Most example projects shown are 2D or 3D. Example 10 illustrates a "Lev" type.

4. Review the "General" options by clicking the "General" tab. This page includes settings that are very general in nature that you seldom need to change during the life of a job. Some of these settings are actually "preferences" which describe the order you normally enter your coordinates (North-East, or visa versa), or the station name order you prefer when entering angles (At-From-To or From-At-To).

5. Review the "Instrument" options page. Here you see default values used in the adjustment, such as standard errors for each of the data type, instrument and target centering errors, and distance and elevation difference proportional (PPM) errors. These are some of the most important parameters in the program since they are used in the weighting of your observation data. Since this is a 2D network, you will notice that only 2D standard error items are active.

Note that instrument and target centering errors can be included to automatically inflate the standard error values for distance and angle observations. Entering horizontal centering errors causes angles with "short sights" to be less important in an adjustment than those with "long sights." Likewise, in 3D jobs, a vertical centering error can also be included to cause zenith angles with short sights to be less important in an adjustment than those with long sights.

6. Review the "Listing File" options page. These options allows you to control what sections will be included in the output listing file when you run an adjustment. Note that the Unadjusted Observations and Weighting item is checked. This causes an organized review of all of your input observations, sorted by data type, to be included in the listing – an important review of your input.

The Adjusted Observations and Residuals section, is of course, the most important section since it shows you what changes STAR*NET made to your observations during the adjustment process – these are the residuals.

Note that the Traverse Closures section is also checked. This creates a nicely formatted summary of your traverses and traverse closures in the listing. You'll see these and the other selected sections later in this tutorial project once you run the adjustment and then view the listing.

The last part of this options page allows you so set options that affect the appearance of observations or results in the listing. Note that you can choose to have your unadjusted and adjusted observation listing sections shown in the same order the observations were found in your data, or sorted by station names.

You can also choose to have the adjusted observations listing section sorted by the size of their residuals – sometimes helpful when debugging a network adjustment.

7. Finally, review the "Other Files" options page. This menu allows you to select additional output files to be created during an adjustment run. For example, you can choose to have a coordinate points file created. Or when adjusting a "grid" job, you can choose to have a geodetic positions file created.
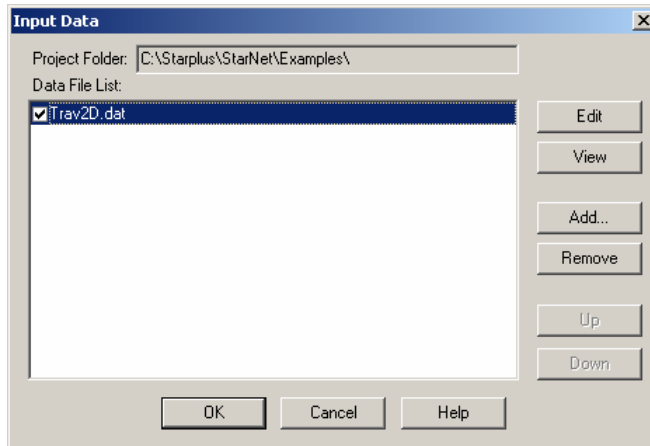
The optional "Ground Scale" file is particularly useful then running grid jobs. You can specify that the adjusted coordinates (grid coordinates in the case of a grid job) be scaled to ground surface based on a combined scale factor determined during the adjustment, or a factor given by the user. These newly-created ground coordinates can also be rotated and translated by the program.

The optional "Station Information Dump" file contains all information about each adjusted point including point names, coordinates, descriptors, geodetic positions and ellipse heights (for grid jobs) and ellipse information. The items are comma delimited text fields which can be read by external spread sheet and database programs – useful for those wishing to create custom coordinate reports. This "Dump" file and the "Ground Scale" file are described in detail in the full manual.

The Coordinate Points and Ground Scaled Points files can both be output in various formats using format specifications created by the user. The user-defined formatting specifications are discussed in the full manual.

8. The "Special" option tab includes a positional tolerance checking feature to support certain government (such as ACSM/ALTA) requirements, but is not discussed in this tutorial. The "GPS" and "Modeling" option tabs are active in the "PRO" edition. See Examples 8 and 9 later in this tutorial for a description of the "GPS" options menu.

9. This concludes a brief overview of the Project Options menus. After you are finished reviewing these menus, press "OK" to close the dialog.
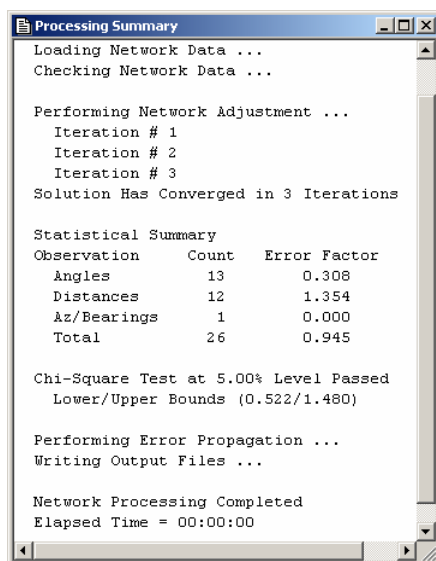
10. Our next step is to review the input data. Choose **Input>Data Files**, or press the Input Data Files tool button. In this dialog you can add data files to your project, remove files, edit and view them, or rearrange their position in the list. The order of the list is the order files are read during an adjustment. You can also "uncheck" a file to temporarily eliminate it from an adjustment – handy when debugging a large project containing many files. This simple project includes only one data file.

View the highlighted data file by pressing the "View" button. A view window opens so you can scroll through a file of any size. Take a minute to review the data and then close the window when finished. To edit the file rather than view it, you would press the "Edit" button, or simply double-click its name in the list.

Note that the Input Data dialog automatically closes when you view or edit a file. Otherwise, for the other functions, you would press "OK" to exit the dialog.

11. Run the adjustment! Choose **Run>Adjust Network**, or press the Run Adjustment tool button. A Processing Summary window opens to show the progress.
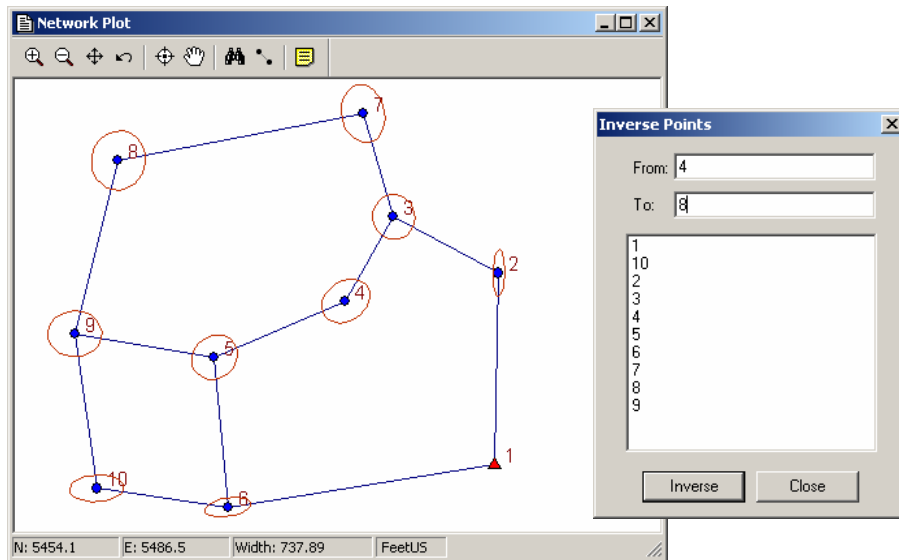
When the adjustment finishes, a short statistical listing is shown in the Processing Summary window indicating how each type of data fit the adjustment. The total error factor is shown plus a statement indicating whether the Chi Square Test passed, a test on the "goodness" of the adjustment.

After adjusting a network, you will want to view the network plot, or review the adjustment listing.

We'll view the network plot next.

12. To view the plot, choose **Output>Plot**, or press the Network Plot tool button.

Resize and locate the plot window for viewing convenience. The size and location of most windows in STAR*NET are remembered from run to run.

Experiment with the tool keys to zoom in and zoom out. Also zoom into any selected location by "dragging" a box around an area with your mouse. Use the "Pan" tool to set a panning mode, and small hand appears as your mouse pointer which you can use to drag around the image. Click the "Pan" tool again to turn the mode off. Use the "Find" tool to find any point in a large network. Use the "Inverse" tool to inverse between any two points on the plot. Type names into the dialog or simply click points on the plot to fill them in (see the example above) and press Inverse.

Pop up a "Quick Change" menu by right-clicking anywhere on the plot. Use this menu to quickly turn on or off items (names, markers, ellipses) on the plot.

Click the "Properties" tool button to bring up a plot properties dialog to change many plotting options at one time including which items to show, and sizing properties of names, markers, and error ellipses.

Double-click any point on the plot to see its adjusted coordinate values and error ellipse dimensions. Double-click any line on the plot to see its adjusted azimuth, length, elevation difference (for 3D jobs), and relative ellipse dimensions.

Choose **File>Print Preview** or **File>Print,** or the respective tool buttons on the program's mainframe tool bar, to preview or print a plot. More details using the various plot tools to view your network and printing the network plot are discussed in the full operating manual.

When you are finished viewing the adjusted network plot, let's continue on and review the output adjustment listing next.

13. To view the listing, choose **Output>Listing**, or press the Listing tool button.

The listing file shows the results for the entire adjustment. First, locate and size the listing window large enough for your viewing convenience. This location and size will be remembered. Take a few minutes to scroll through the listing and review its contents. For quick navigation, use the tool buttons on the window frame to jump forward or backward in the file one heading at a time, a whole section at a time, or to the end or top of the file.

For quicker navigation to any section in the file, right-click anywhere on the listing, or press the Index Tree tool button to pop up a "Listing Index" (as shown above). Click any section in this index to jump there. Click [+] and [-] in the index to open and close sections as you would in Windows Explorer. Relocate the index window to any convenient location and it will stay. Check the "Keep on Top" box on the index window if you want it to always be present when the listing is active.

Using one of the navigation methods described above, go to the section named "Summary of Unadjusted Input Observations." Note that each observation has a standard error assigned to it. These are the default values assigned by the program using the project options instrument settings reviewed earlier in step 5.

Still in the listing, further on, look at the "Statistical Summary." This important section indicates the quality of the adjustment and how well each type of data such as angles, distances, etc. fit into the overall adjusted network.
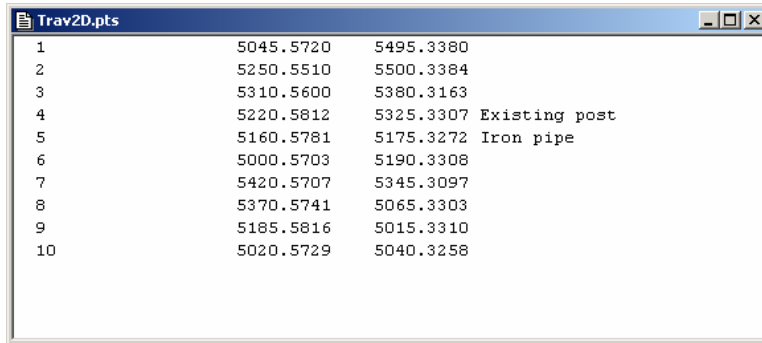
Always review the "Adjusted Observations and Residuals" section! It shows how much STAR*NET had to change each observation to produce a best-fit solution. The size of these residuals may pinpoint trouble spots in your network data.

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Take a look at the "Traverse Closures of Unadjusted Observations" section. This project had data entered in traverse form, and in the Project Options, this report was selected as one of the sections to include in the listing. For each traverse, courses are listed with unadjusted bearings (or azimuths) and horizontal distances. When possible, angular misclosures are shown along with the amount of error per angle. The linear misclosures are shown based on unadjusted angles "corrected" by the per-angle error. Many governmental agencies want to see this kind of closure analysis. But it is important to note, however, that these corrections are <u>only</u> for the benefit of this traverse closure listing. Actual corrections to angles are calculated during the least squares adjustment, and are shown as residuals.

At the end of the listing, review the Error Propagation listing section. You will find the standard deviation values and the propagated error ellipse information for all adjusted stations. Also present are relative error ellipses between all station pairs connected by an observation.

This concludes the quick review of the listing. You'll note that much information is shown in this file – it contains just about everything you might want to know about the results of an adjustment. In some cases, you may only wish to see a subset of this information, so remember that you can tailor the contents of this file by selecting which sections to include in the Project Options/Listing file menu.

14. In the "Project Options/Other Files" menu reviewed in step 7, an option was set to create an adjusted coordinates file. Choose **Output>Coordinates** to view this file. Any additional files created can also be viewed from this menu.

```
Trav2D.pts                                              _ □ X
  1              5045.5720     5495.3380
  2              5250.5510     5500.3384
  3              5310.5600     5380.3163
  4              5220.5812     5325.3307 Existing post
  5              5160.5781     5175.3272 Iron pipe
  6              5000.5703     5190.3308
  7              5420.5707     5345.3097
  8              5370.5741     5065.3303
  9              5185.5816     5015.3310
 10              5020.5729     5040.3258
```

15. This completes the review of the "Trav2D" example project. We have toured the main option menus, the input data dialog, performed an adjustment, reviewed the output listing contents in some detail and viewed network plots. Now that you have a good idea how the program works, the remaining tutorial examples can be examined with a minimum of explanation.

The sample project that you have just stepped through is a realistic example of a small two dimensional multi-loop traverse. Note that only a few simple steps are required to run an adjustment:

- Set options for your project
- Create one or more data files
- Run the adjustment
- Review both graphical and listing output

The "listing file" you reviewed by choosing **Output>Listing** is the final adjustment report produced from the STAR*NET run. Once a project is adjusted to your satisfaction, you may want to get a printout of this listing for your records. This file is a text file having the name of your project, plus a "lst" extension. A listing file named "Trav3D.lst" therefore, was created by running this example.

The listing file can be printed from within the program by choosing **File>Print** while the listing window is open and active.

The adjusted coordinates for this project are in a file named "Trav2D.pts" and like the listing file, can be simply printed from within the program. Since the points are in text format, many COGO programs will be able to read them directly.

However for your convenience, there is a "Points Reformatter" utility that can be run from the "Tools" menu. This utility allows export adjusted coordinates to several standard formats, as well as custom formats defined by you

Another utility available from the "Tools" menu is a "DXF Exporter" which creates a network plot in AutoCAD compatible DXF format.

STAR*NET offers many options and has extensive features not described in this tutorial, but in general, most adjustments can be performed in the straight forward fashion illustrated by this example. At this point, you may wish to go back and review the actual data file used for this example. Note that the "Traverse" mode of data entry is very easy and efficient. Multiple traverses can be entered in one file, and additional distance and angle observations can be freely mixed with the traverse data, so as to keep observations in the same order as your field book.

The remaining examples illustrate more STAR*NET capabilities and data types. It is assumed after following all the steps detailed in this first example project that you are now somewhat familiar with the operation of the program. The following examples do not always go into detail describing the individual program functions.

Example 2: Combined Triangulation/Trilateration 2D Network

This example illustrates the adjustment of a simple triangulation-trilateration network. In the sample data file, many data lines are entered using the "M" code. This is the most commonly used data type meaning all "measurements" to another station. All the remaining independent observation are entered on a single "A" and "D" data lines.

```
# Triangulation/Trilateration 2D Network

C    1     5102.502    5793.197    ! !
C    3     7294.498    6940.221    ! !
C    2     5642        7017

# Angle and Distance Observations at Perimeter
M    2-1-3    111-08-11   1653.87
M    2-1-6     77-24-52   1124.25
M    3-2-4     87-07-04   1364.40
M    3-2-6     40-58-15    951.92    4.0   .03
M    4-3-5    120-26-52   1382.49
M    4-3-6     44-14-21    983.86
M    5-4-1    110-34-04   1130.75
M    5-4-6     39-46-29   1493.54
M    1-5-2    110-43-40   1337.89
M    1-5-6     65-36-54   1548.61

# Angles at Center Point
A    6-5-4     64-01-01
A    6-4-3     89-36-55
A    6-3-2    105-18-27
A    6-2-1     57-28-12

# Distance Cross-ties
D    1-4       2070.76
D    2-5       2034.47
```
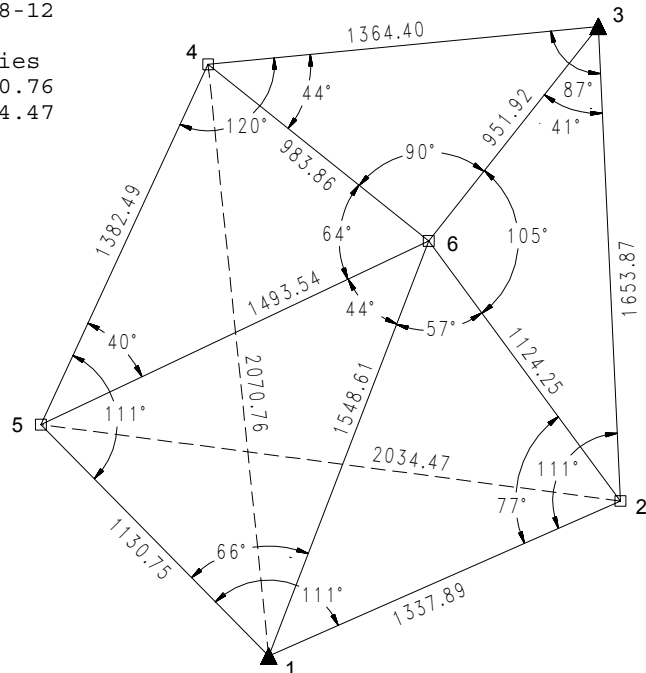
1. Open the "Net2D.prj" example project.

2. Choose **Input>Data Files**, or press the Data Files tool button to open the Data Files dialog. Then press "View" to view the "Net2D.dat" example data file.

    Note that the Measure lines contain horizontal angle and distance observations from one station to another. The standard errors for observations normally default to Instrument setting values defined in the Project Options as discussed in the last example. However, for illustration purposes, explicit standard errors have been added to one of the data lines in this example. Close the view window.

3. Run the adjustment, by choosing **Run>Adjust Network**, or by pressing the Run Adjustment tool button.

4. Choose **Output>Plot** or press the Network Plot tool button to view the network graphically. Experiment by resizing the plot window larger and smaller by dragging the corners or edge of the plot window.

5. Zoom into a section of the plot by dragging your mouse pointer around some part of the network. For example, drag a zoom box around just points 1 and 2. Note the status information at the bottom of the plot window. The North and East coordinates are shown for the location of the mouse pointer as you move it around the plot. The Width value shown is the width of the plot window in ground units, FeetUS in this example. This width value will give you a good sense of scale when you are zoomed way into a very dense plot. Zoom out by pressing the Zoom All button.

    Right-click anywhere on the plot to bring up the "Quick Change" menu. Click the "Show Relative Ellipses" item to make relative ellipses display. These ellipses represent the relative confidences in azimuth and distance between connections in the network. Double click any line and to see its adjusted azimuth and distance values plus its relative ellipse dimensions. Likewise, double click any point to see its adjusted coordinates and ellipse dimensions. Chapter 8, "Analysis of Adjustment Output" in the full manual, includes an extensive discussion of error ellipse and relative error ellipse interpretation.

6. View the Listing File by choosing **Output>Listing**, or by pressing the Listing tool button. Review the various parts of the listing in the same way you did for the last example. Be sure to review the "Statistical Summary" section which indicates how well each group of observation types fit into the adjusted network.

    Likewise, you should always review the "Adjusted Observations and Residuals" section which shows how much STAR*NET had to change your observations. You would normally examine this list carefully, especially if the adjustment fails the Chi Square test, to look for possible problems with your data.

7. This completes the review of the "Net2D" example project.

Example 3: Three Dimensional Traverse Network

This example illustrates the adjustment of a three dimensional network. Data includes two small traverses with slope distances and zenith angles. An extra cross tie is entered between the two traverses. STAR*NET can also accept 3D data in the form of horizontal distances and elevation differences.
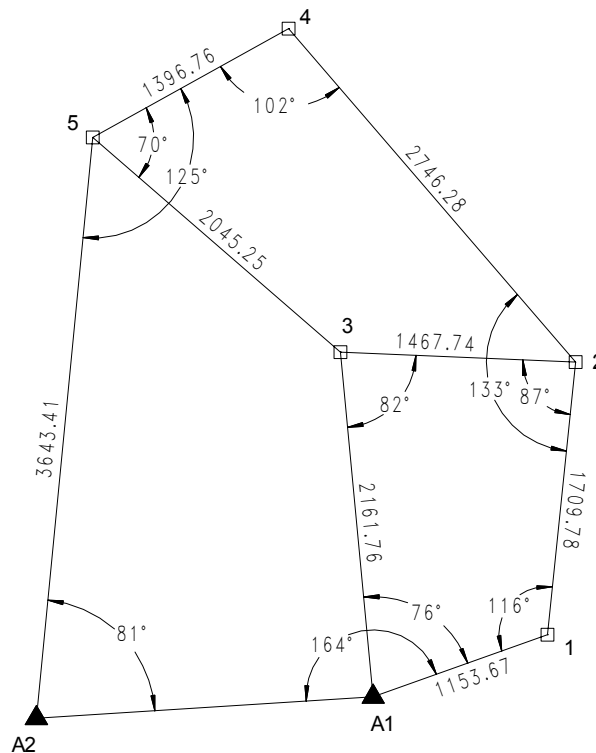
```
#   3D Traverse Network

C   A1   10000.00   10000.00    1000.00  ! ! !
C   A2    9866.00    7900.00     998.89  ! ! !

TE  A2   # backsight to A2
T   A1   163-59-26.0    1153.67    91-35-30.0   5.25/5.30
T   1    115-35-06.8    1709.78    90-56-41.6   5.31/5.32
T   2     86-31-37.9    1467.74    90-05-56.2   5.26/5.31
T   3     82-07-57.7    2161.76    88-20-39.6   5.15/5.22
TE  A1    75-45-17.6       1   # closing angle to  1

TB  1    # backsight to 1
T   2    133-21-35.8    2746.28    91-37-53.3   4.98/5.12
T   4    101-39-39.6    1396.76    88-23-31.8   5.23/5.25
T   5    124-35-19.6    3643.41    88-28-02.3   5.35/5.30
TE  A2    80-48-52.2       A1  # closing angle to  A1

M 5-4-3   69-59-28.7    2045.25    89-00-41.0   6.21/5.25
```

1. Open the "Trav3D.prj" example project.

2. Take a look at the Project Options for this project. Note that on the Adjustment options page the "Adjustment Type" is now set to 3D. On the same menu, down in the Local Jobs group of options, we have the Default Datum Scheme set to "Reduce to a Common Datum" and the elevation value is set to 0.00 feet. What this means is that we want the job reduced to sea level. The controlling coordinates given in the data must be sea level values, and during the adjustment, observations will be internally reduced to this datum to produce sea level coordinates.

   Also while in the Project Options, review the "Instrument" settings page. Note that all settings for vertical observations are now active. Centering errors of 0.005 feet have been set for both horizontal and vertical centering which will affect standard errors for all our measurements. Shorter sightings will receive less weight!

3. Examine the input data file. Note that each traverse line now contains additional data elements, the zenith angle and an "HI/HT" entry giving the instrument and target heights. Coordinate lines now contain an elevation value. The sample data file contains two small connecting traverses. The "TB" (traverse begin) lines indicate the beginning backsights, and the "TE" (traverse end) lines indicate at which station the traverses end. In this example, they both contain an optional closing angle. STAR*NET will use this information in the traverse closure listing, as well as entering them as observations in the adjustment.

   Additional redundancy is provided by an "M" data line containing angle, distance and vertical information between points on the two traverses.

4. Run the network adjustment and then look at the network graphically. Double click any of the adjusted points and note the displayed information now includes adjusted elevations and vertical confidence statistics.

5. View the output Listing file. Review the unadjusted observations and note that the standard errors for all angles and zenith angles are no longer constant values. Because of the "centering error" values entered in the instrument options, the standard errors assigned to these observations will be larger (less weight) for angles with short sights than for those with long sights.

   Further down in the listing, review the adjustment statistical summary. Since this is a 3D job, you now see additional items in this list. Review the remaining sections and note the differences from the previous 2D adjustment listing in the first two example projects. In the Traverse Closures section, for example, vertical traverse closures are shown. And in the Error Propagation section, standard deviations are shown for elevations, and vertical confidences for ellipses.

6. This completes the review of the "Trav3D" example project.

Example 4: Three Dimensional Grid Job

This example demonstrates the ability of STAR*NET to reduce ground observations to a grid system plane during the processing of a network adjustment.

The following example is the same 3D multiple traverse network illustrated in the previous example. All ground observations are identical; only the coordinates have been changed to be consistent with NAD83, California Zone 0403.

```
#  3D Traverse Grid Job

C A1 2186970.930 6417594.370  300.00 ! ! !
C A2 2186836.940 6415494.520  298.89 ! ! !

TB  A2  # traverse backsight to A2
T   A1   163-59-26.0   1153.67   91-35-30.0  5.25/5.30
T   1    115-35-06.8   1709.78   90-56-41.6  5.31/5.32
T   2     86-31-37.9   1467.74   90-05-56.2  5.26/5.31
T   3     82-07-57.7   2161.76   88-20-39.6  5.15/5.22
TE  A1    75-45-17.6      1  # closing angle to Station 1

TB  1
T   2    133-21-35.8   2746.28   91-37-53.3  4.98/5.12
T   4    101-39-39.6   1396.76   88-23-31.8  5.23/5.25
T   5    124-35-19.6   3643.41   88-28-02.3  5.35/5.30
TE  A2    80-48-52.25    A1  # closing angle to Station A1

M 5-4-3  69-59-28.7  2045.25    89-00-41.0  6.21/5.25
```


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1. Open the "Grid3D.prj" example project.

2. Open the Project Options for this job and review the Adjustment options page. You will see some differences from the adjustment options in the last example project:

First, you will note that the Coordinate System is set to "Grid," and the actual grid system chosen from the dropdown selection list is NAD83. Other selections are NAD27, UTM and Custom. (User-defined and international grids come under the category of Custom.) The zone currently selected, as indicated on the large selection button, is California Zone 0403. How is a zone selected? Simply press the large selection button to bring up the zone selection dialog. Give it a try.

Here you just select from the list to change zones. Press "Show Parameters" to see the zones parameters. Don't make a new selection now – just press OK to exit.

Before you exit the Project Options, note another difference in the options from the previous example. At the bottom of the menu is an options group specific to grid jobs. Here you enter the average Geoid Height. This value is always entered in meters, and it is important to use the correct sign. (It's negative in the contiguous United States.) For GPS jobs, it is important to perform geoid modeling so that a geoid height is determined at every point. But for jobs having only conventional observations such as this example, an average project geoid height is sufficient since only ground to grid scaling in affected.

3. Examine the data file if you wish. As mentioned before, the observation data for this example is identical to the previous example except that the entered control coordinates are grid coordinates consistent with NAD83, California zone 0403. The same data set was used for this example so that, if you wish, you can compare output results from two identical jobs, one run as local, and the other as grid.

4. Run the network adjustment. Look at the network graphically – it will look the same as in the last example. However, if you double click any of the adjusted points, the displayed coordinates will now, of course, be grid coordinates.

5. View the output Listing file and browse through the various sections as you did in the last example. But since this job is a "grid" adjustment, you will find some new information present. Go down to the "Adjusted Station Information" section. First, comes the adjusted grid coordinates. Then directly following are the computed geodetic positions and ellipsoid heights as shown in the listing window below.

As shown above, next comes a listing of convergence angles and scale factors computed at every station in the network. The factors include the grid scale factor, the elevation factor, and the resulting combined factor.

In the "Adjusted Bearings and Horizontal Distances" section previously seen in other examples in this tour, the bearing shown is now a "grid" bearing, and both "grid" and "ground" distances are now shown for every network connection.

```
Grid3D.lst                                                          _ □ ×

 Ι◀ | ◀◀ | ◀ | ▶ | ▶▶ | ▶Ι | ⯇

          Adjusted Bearings (DMS) and Horizontal Distances (FeetUS)     ▲
          ========================================================
              (Relative Confidence of Bearing is in Seconds)

   From      To          Grid Bearing    Grid Dist      95% RelConfidence
                                         Grnd Dist    Brg    Dist      PPM
   1         2          N05-55-29.29E    1709.4352    6.07   0.0971   56.8262
                                         1709.5519
   1         A1         S70-20-22.39W    1153.1470    5.19   0.0936   81.1725
                                         1153.2276
   2         3          N87-32-52.90W    1467.6350    6.63   0.0875   59.6060
                                         1467.7338
   2         4          N40-42-54.88W    2745.0031    6.42   0.0929   33.8544
                                         2745.1824
   3         5          N49-03-46.71W    2044.7969    7.65   0.0806   39.4100
                                         2044.9324
   3         A1         S05-24-55.19E    2160.7066    6.03   0.0931   43.0799
                                         2160.8558
   4         5          S60-56-44.57W    1396.1139    6.14   0.0869   62.2243
                                         1396.2036
   5         A2         S05-32-03.92W    3641.8400    4.49   0.1064   29.2229
                                         3642.0877
   A1        A2         S86-20-56.20W    2104.1206    0.00   0.0000    0.0002
                                         2104.2694
   □                                                                    ▼
```

Finally, look at the "Traverse Closures of Unadjusted Observations" section. Since this is a "grid" job, the listing of traverse closures is based on unadjusted bearings and distances that are reduced to the grid plane.

6. See what other files were created by the adjustment by looking at the items that show up in the Output pulldown menu. Before we've seen the Coordinates file. And now we see a Lat/Longs (geodetic positions) file. The creation of both these files were requested in the "Project Options/Other Files" menu. Go ahead and view one or both of these files if you want.

7. This completes the review of the "Grid3D" example project. Since this was the first "grid" job in our tutorial examples, we went into extra detail reviewing the option settings and output sections relating to grid adjustments.

Example 5: Resection
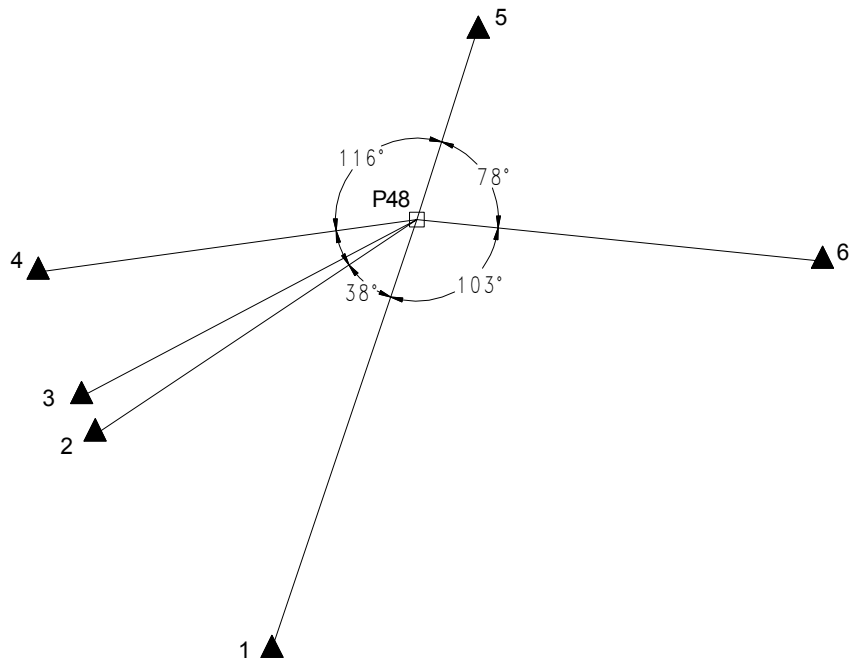
This example demonstrates the use of STAR*NET in solving a resection problem, involving the measurement of angles from 6 known stations to an unknown point.

```
# Resection

# Approximate location for the unknown station
#
C    P48     104500      93600

# Fixed coordinates for the known stations
#
C    1       90132.03     88237.92    ! !
C    2       97418.58     82279.10    ! !
C    3       98696.21     81802.35    ! !
C    4      102911.40     80330.69    ! !
C    5      111203.37     95234.19    ! !
C    6      103278.43    106872.91    ! !

# Occupy "P48" and turn angles to known stations
#
A    P48-1-2      37-35-00.0
A    P48-2-3       5-56-19.4
A    P48-3-4      19-56-18.3
A    P48-4-5     115-34-35.0
A    P48-5-6      78-09-31.0
A    P48-6-1     102-48-30.0
```

1. Open the "Resection.prj" example project.

2. Review the project options if you wish. This is a standard 2D, local project.

3. Examine the input data file.

   Note that all station coordinates are fixed with the "!" symbol, except for the unknown instrument station "P48" which is free. The angles default to the standard error for angles set in the Project Options/Instrument options menu.

4. Run the adjustment.

   Review the processing summary on the screen. Note that in the short statistical summary, the only observation type listed is the angle, and the adjustment passes the Chi Square test.

5. Look at the network graphically.

   You will see only one error ellipse since there is only one unknown point in the whole network.

6. Review the listing file.

    It's quite short since our only observations are angles.

7. This completes the review of the "Resection" example project.

Example 6: Traverse with Sideshots
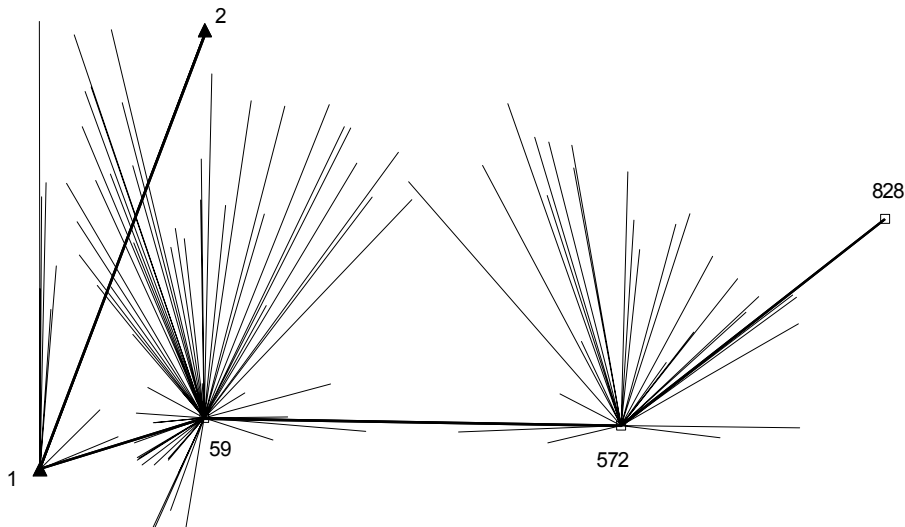
This example illustrates data consisting of a simple traverse containing many sideshots. Sideshots (SS) are single, non-redundant shots that do not affect the adjustment results. You cannot occupy or backsight to a sideshot. These shots are diverted during loading of the input data file, and are not processed until after the network is adjusted. Their computed coordinates are written to both the Listing File and the Points File. Because they are processed after the adjustment, no error propagation is performed on Sideshots. The special sideshot data type is available so that you can process a network containing hundreds or thousands of sideshots without slowing down the adjustment of the actual network. In particular, this approach lends itself to the processing of large topo data sets downloaded from data collectors.

```
#   Traverse with Sideshots

C   1    1000.00   1000.00 1440.28  ! ! !
C   2    1725.18   1274.36 1467.94  ! ! !

#   Begin Field Observations
#
TB  2
T   1        51-59-30   242.42    88-44-35   5.25/5.30
T   59     198-19-55   587.14    89-39-40   5.30/5.50 'IRON PIN
T   572    140-52-34   668.50    80-14-25   5.18/5.22
TE  828

#   Begin Sideshots
#
SS  1-2-3    104-18-07   146.08    90-56-54   5.25/5.33 'TOE
SS  1-2-4     24-33-33   118.64    89-16-07   5.25/5.33 'TOE
SS  1-2-5    339-20-11   254.12    88-03-45   5.25/5.33 'FACE OF CURB
SS  1-2-14   339-35-31   383.90    88-33-17   5.25/5.33 'TOE
etc...
```


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1. Open the "Sideshots.prj" example project.

2. View the input data file. Note that the sideshots are entered with the "SS" code. Scroll down and view the entire file; the data includes quite a number of sideshots! Most of the sideshots also have a text descriptor at the end of the line, which is marked with a single or double quote character.

   Remember that the sideshots are processed after the adjustment, and do not slow down the network processing. It is also important to remember that since sideshots are not actually part of the "adjusted" network, and that you cannot occupy a sideshot, or backsight to one. You cannot take a sideshot to the same point and expect that point to be adjusted. In all these cases, you should enter your observations with an "M" data line which is included in the actual adjustment.

   For simplicity, sideshots in this example were all entered following the traverse. However they may be freely intermixed with traverse data or any other types of data, to preserve the same order recorded in your field book or data collector.

3. Run the adjustment. The adjustment of the traverse proceeds very quickly, and the sideshots are processed independently <u>after</u> the adjustment is completed.
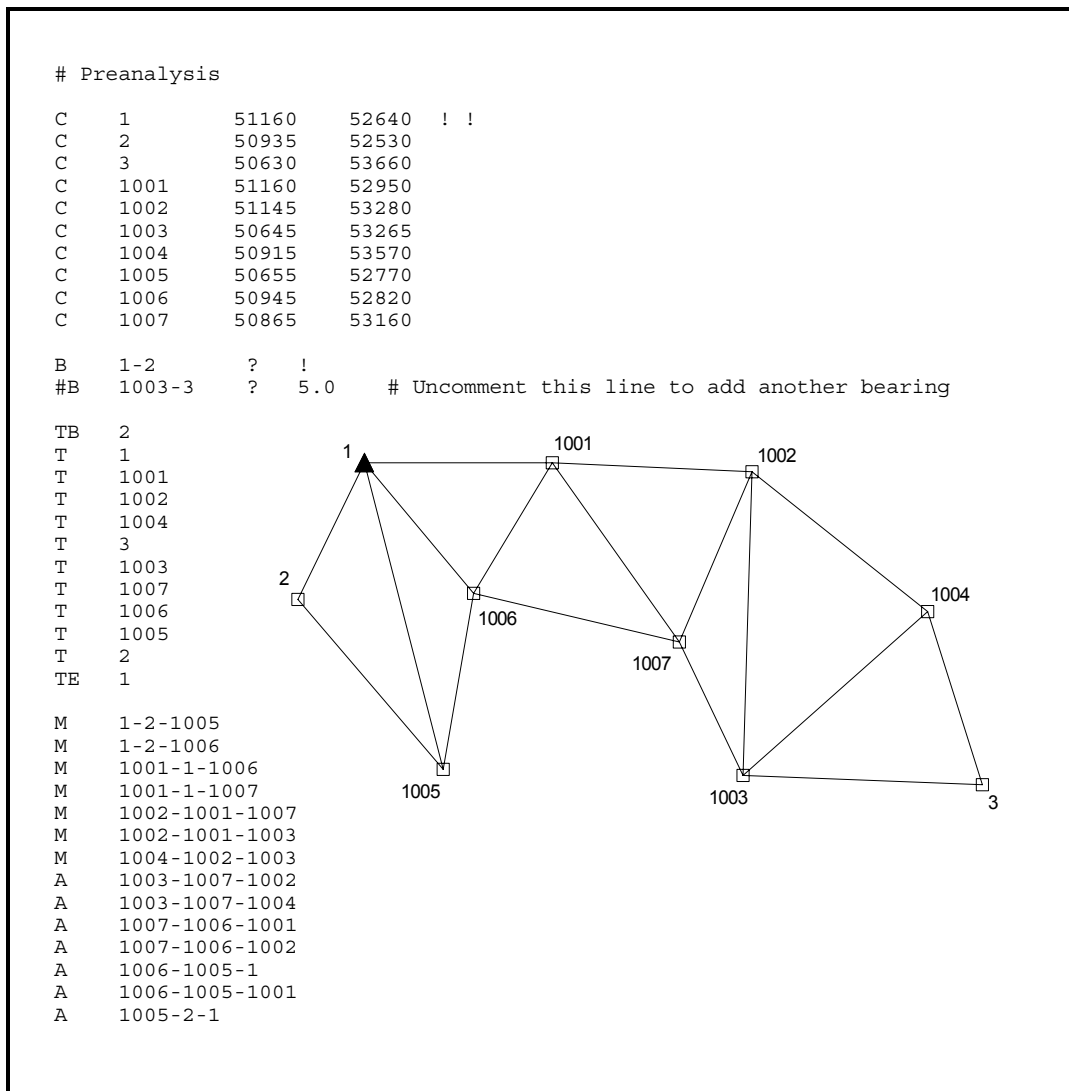
   Note that in this particular example, the main traverse is simply an open ended traverse that doesn't even tie into a known station. So in this case, although all points are computed, nothing is really adjusted. This illustrates how STAR*NET can be used simply as a data reduction tool. And had we been working in some grid coordinate system, for example NAD83 or UTM, all the observations would have also been reduced to grid, producing adjusted grid coordinates.

4. View the resulting network graphically - many sideshots fill the plot screen. Zoom into a small group of sideshots. Right-click the plot screen to bring up the Quick Change menu, and click the "Show Sideshot Descriptors" item to turn on viewing of descriptors. Descriptors often clutter up a plot view, so by default you will usually leave them turned off. You can also turn sideshots off and on in the Quick Change menu by unchecking and checking the "Show Sidehots" item.

5. Take a quick look at the adjustment listing file. Looking through the listing you will see a review of the input sideshot observation data as well as final sideshot coordinates in the "Sideshot Coordinates Computed After Adjustment" section. These computed sideshot coordinates, along with the traverse coordinates, also appear in the "points" output file created during the processing. This file can be viewed by choosing **Output>Coordinates** as illustrated in earlier examples.

6. This completes the review of the "Sideshots" example project.

Example 7: Preanalysis

This example demonstrates using STAR*NET in the preanalysis of survey networks. Preanalysis means that the network will be solved using approximate coordinates to locate the stations, and a list of observation stations to indicate which distances and angles are planned to be observed. No actual field data are required. STAR*NET will analyze the geometric strength of the network using the approximate layout, and the instrument accuracies supplied as observation standard errors. The predicted accuracy of each station will be computed, and error ellipses generated. Preanalysis is a powerful tool that will help you to test various network configurations before any field work is done, or to test the effects of adding measurements to an existing network.

You can use any of the 2D and 3D data types provided for in STAR*NET to define a proposed survey. In this simple 2D example, we traverse around the perimeter, use measure lines to define some cross ties, and then fill in some angles.

```
# Preanalysis

C    1         51160    52640   ! !
C    2         50935    52530
C    3         50630    53660
C    1001      51160    52950
C    1002      51145    53280
C    1003      50645    53265
C    1004      50915    53570
C    1005      50655    52770
C    1006      50945    52820
C    1007      50865    53160

B    1-2       ?    !
#B   1003-3    ?    5.0      # Uncomment this line to add another bearing

TB   2
T    1
T    1001
T    1002
T    1004
T    3
T    1003
T    1007
T    1006
T    1005
T    2
TE   1

M    1-2-1005
M    1-2-1006
M    1001-1-1006
M    1001-1-1007
M    1002-1001-1007
M    1002-1001-1003
M    1004-1002-1003
A    1003-1007-1002
A    1003-1007-1004
A    1007-1006-1001
A    1007-1006-1002
A    1006-1005-1
A    1006-1005-1001
A    1005-2-1
```

1. Open the "Preanalysis.prj" example project. This is a "2D" project.

2. View the input data file. Note that all stations have been given approximate coordinates. This defines the network geometry. Note also that the list of distance and angle data lines contains no field observations. Observation standard errors default to the values set for the various data types in the Project Options/Instrument menu. If a specific standard error is required, a place holder such as "?" is required on the data line in place of the actual observation.

3. Run the preanalysis by choosing **Run>Preanalysis**. Note that if you were to make any other choice from the Run Menu such as "Adjust Network" or "Data Check Only," errors would result due to the missing observations.

4. View the network graphically. Note that the resulting station error are larger for the stations furthest from the fixed station. Also, their shape and orientation suggest an azimuth deficiency in the network. This is the purpose of running a preanalysis, to study the strength of your planned survey network using only proposed field observations.

5. If you wish, you can experiment with adding another observation to the network. Open the Data Files dialog by choosing **Input>Data Files**, or by pressing the Input Data Files tool button. Press the "Edit" button, or simply double-click the highlighted data file in the list. Locate the line in the data file that has a Bearing from Station 1003 to Station 3. Uncomment the line by deleting the "#" symbol at the beginning of the line, just before the "B" code. Note that this data line has an explicitly entered standard error of 5 seconds. (This new data, for example, might represent an observed solar azimuth.) Save the file and exit from the text editor.

   Now rerun the preanalysis by choosing **Run>Preanalysis** again. Review the new results graphically as described in Step 4 above. Notice the increased positional confidence provided by the addition of the proposed bearing observation. The ellipses we were concerned with are now smaller and more round. If you wish to see the actual ellipse dimensions, double-click any point on the plot, or of course you can view the error ellipse information in the listing file as suggested below.
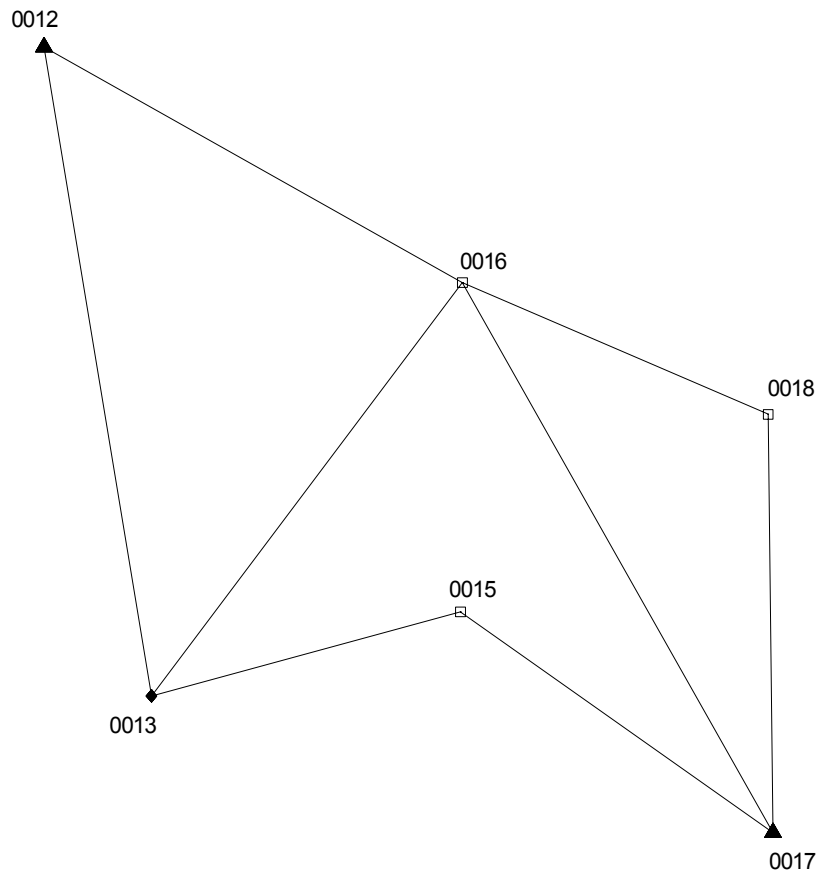
6. Take a quick look through the listing. Even though no actual observations were provided as input, observation values (angles and distances) will be shown in the listing. These values are inversed from the given coordinates and standard errors are assigned to these proposed observations from the Project Options/Instrument menu settings. And of course, station ellipses and relative ellipses are also shown, their computed values being the main purpose for making a preanalysis run.

7. This completes the review of the "Preanalysis" example project.

Example 8: Simple GPS Network
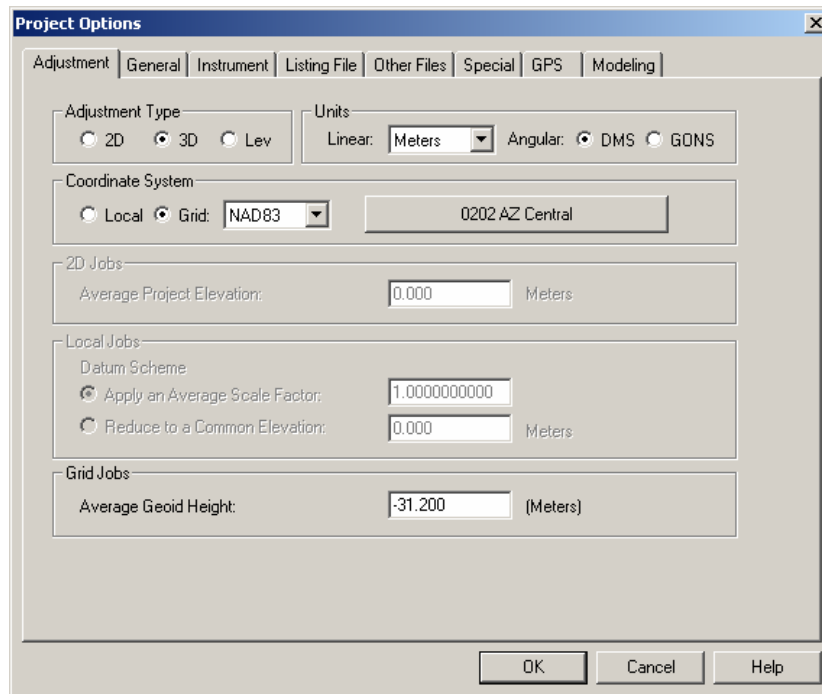
This example demonstrates the major steps you would go through to setup and adjust a simple network made up of only GPS vectors. You will set a few required project options, review the main data file which defines the coordinate constraints, import a few vectors from Trimble GPSurvey baseline files, and adjust the network.

```
# Simple GPS Network
# Fully-constrained, two fixed stations plus a fixed elevation
# Grid Coordinates are used for constraints in this example

C 0012   230946.1786  120618.7749  224.299  ! ! !  'North Rock
C 0017   218691.2153  131994.0354  209.384  ! ! !  '80-1339
E 0013    205.450  ! 'BM-9331
```

0012

0016

0018

0015

0013

0017

1. Open the "VectorJob.prj" example project.

2. Choose **Options>Project**, or press the Project Options tool button.

Options in the Adjustment tab are settings that describe the project. Note that the Adjustment Type is set is "3D" and the Coordinate System is set to "Grid." When a project contains GPS vectors, these two options must always be set this way. This example project is set to use NAD83 Arizona Central zone 0202.

The Average Geoid Height is set to -32.20 meters. For GPS vector adjustments however, it is very important to perform geoid modeling as the connection between vectors (which are ellipsoid-based) and elevations (which are geoid-based) are accurate geoid separations. For simplicity though, we will not be performing geoid modeling in this tutorial example, therefore this value will be assigned as the geoid height to all stations in the project.

If you wish, review the next four option tabs: General, Instrument, Listing File, and Other Files. They contain typical settings you have seen before while reviewing the tutorial in the main manual. The "Instrument" settings only relate to conventional observations, so in the case of this project having only GPS vectors, they have no relevance in the adjustment.

3. Review the "GPS" options by clicking the "GPS" tab. These fields allow you to set
    default values or options relating to GPS vectors present in your network data.

We know that all vectors imported for this example have supplied weighting so we
didn't set any default standard errors offered by the "Apply Default StdErrs" field.
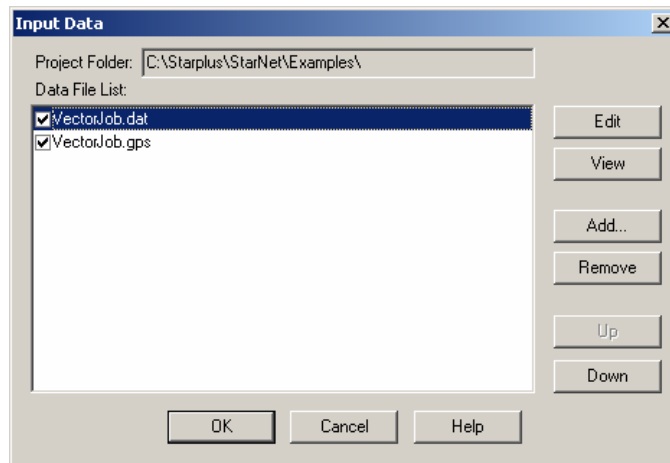
A value of 8.00 has been set for the "Factor Vector StdErrors" field which means
that all the imported vector standard errors will be multiplied by this factor. Standard
errors reported by many baseline processors are over-optimistic and this option
allows you to make them more realistic. A "Vector Centering StdError" value of
0.002 meters has been entered which further inflates the standard errors.

The "Transformations" box is checked and a choice has been made to solve for scale
and three rotations, around North, East and Up axes, during the adjustment. Solving
for these transformations often helps "best-fit" vectors to your station constraints by
removing systematic errors or biases that may exist in vector data.

Finally, in the "Listing Appearance" options, certain output preferences are set for
various listing items including how you like to see vector weighting expressed and
how both unadjusted and adjusted vectors data should be sorted. Note that in this
sections, it has been chosen to show a "Residual Summary" section in the listing.
We'll review this very useful report later.
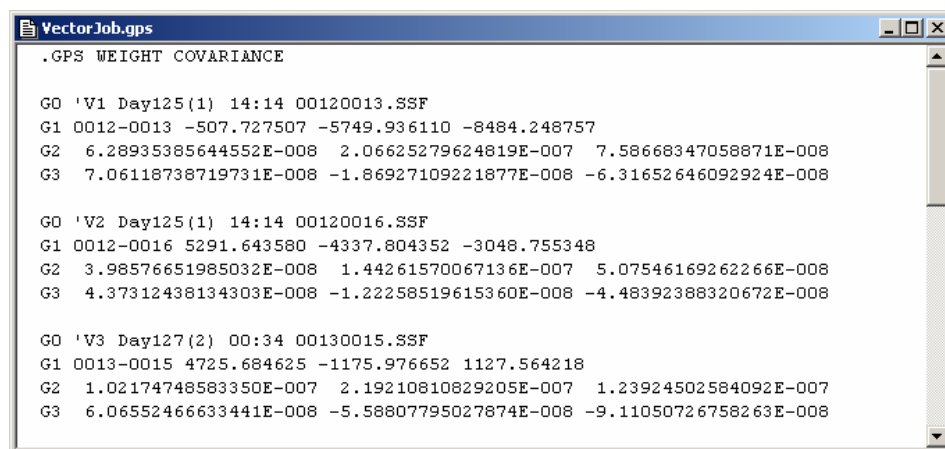
4. Review the "Modeling" tab. It is here that you select to perform both geoid modeling
    and deflection modeling during an adjustment. For simplicity in this demo tutorial,
    we are not going to perform any modeling. The average geoid height specified on the
    Adjustment options page will be applied to all stations in the network.

5. This concludes the overview of the Project Options for this example. After you are
    finished reviewing the options, press "OK" to close the dialog.

6. Next, review the input data. Choose **Input>Data Files,** or press the Input data tool button. Note there are two files in the list. The first file is the main data file shown at the beginning of this example. It simply contains two stations with fixed north, east and elevation values, and one station with a fixed elevation.
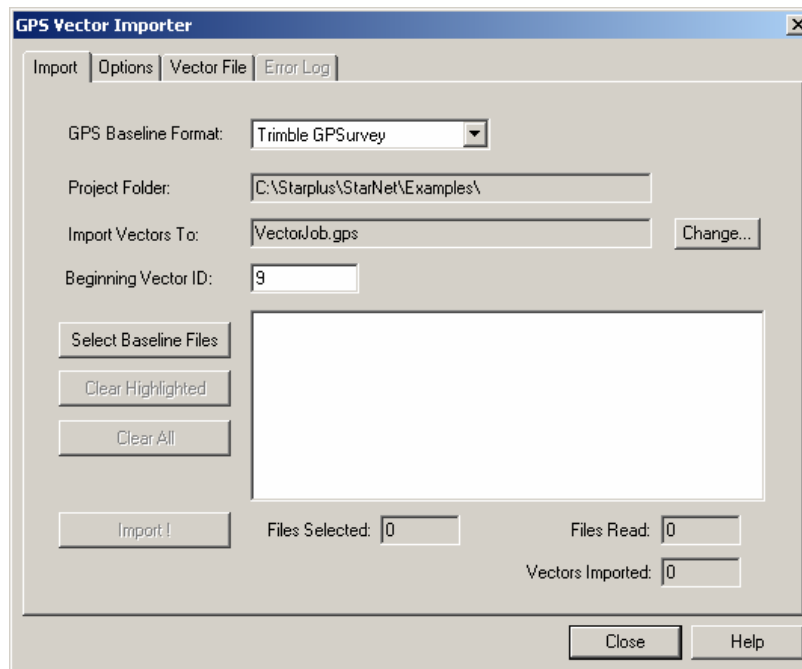
The second file contains the imported vectors for this project. For simplicity, we have <u>already</u> imported the vectors into a file for this example, and it appears in the data file list with the same name as the project, and with a "GPS" extension. In the next step, we'll actually go through the exercise of running the GPS importer to show you how this file was created.

But while we are still in the Data Files dialog, let's review the vector file. Highlight the "VectorJob.Gps" file in the list and press the "View" button.
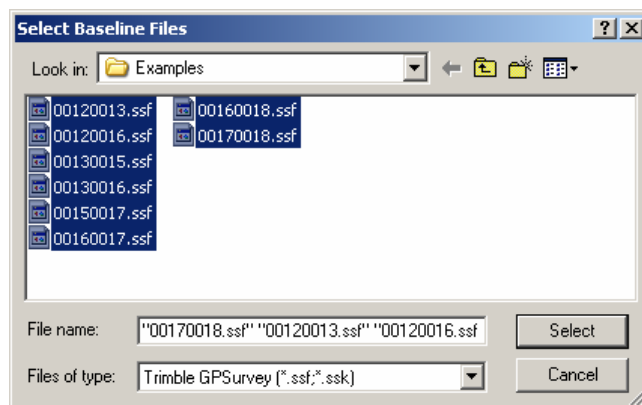
The file contains eight imported vectors. Each vector consists or four lines which includes a vector ID number, the Delta-X, Y & Z vector lengths, and covariance information for weighting. After reviewing the vector data, close the window.

7. Now that the imported vectors have been reviewed, let's see how they were actually imported in the first place. Choose **Input>Import GPS Vectors**.
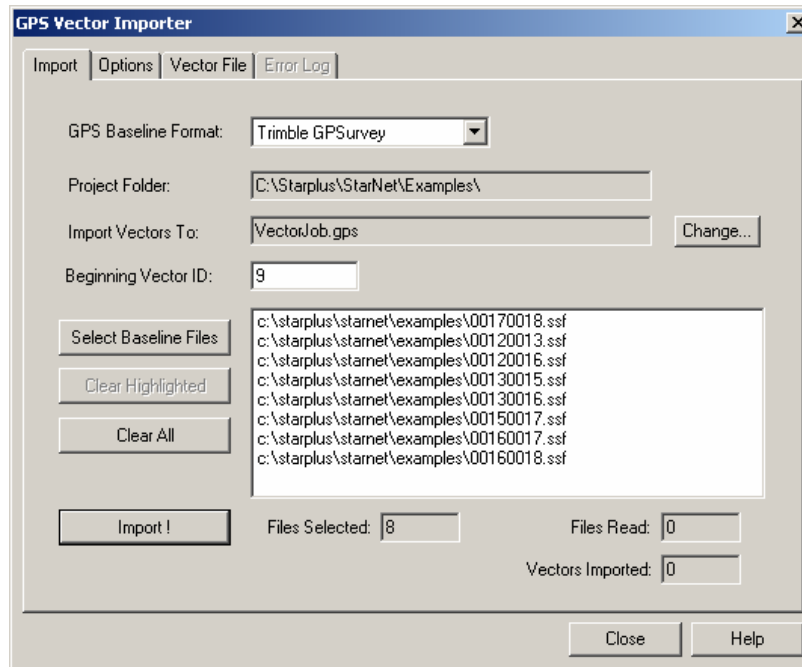
The first step in importing vectors is to choose a GPS Baseline Format from the drop down selection list. In this example we are extracting vectors from baseline files created using the Trimble GPSurvey package. Next, take a quick look at the "Options" tab. Here you can set a few options that will affect vector importing.

Back in the "Import" tab, press the "Select Baseline Files" button to bring up a file selection dialog. (The baselines are in the "StarExamples" sub-folder of your install directory, so if the dialog does not open there, go ahead and browse there.) The selection dialog will show eight Trimble "SSF" baseline files. Highlight these files as shown, and press the "Select" button.

These selected files now appear in the main Import page dialog as shown below and the "Import" button is now active.

If we press "Import," the importer will extract vectors from these files and write them to the file named "VectorJob.GPS" specified in the "Import Vectors to" field above. But to simplify this tutorial example, we had previously imported them.

However, if you want to import the vectors anyway just to see how it works, press the "Import!" button. When importer warns you that the file already exists, it asks if you want to Overwrite or Append the file - select to Overwrite the file.

Complete details on importing vectors, setting import options, and information on the current baseline formats available to import from are fully discussed in the STAR*NET-PRO documentation. Press "Close" to exit the vector importer.

8. Project Options have been set and all input data files created, so now we can adjust the network. Choose **Run>Adjust Network,** or press the Run Adjustment button.

    The Processing Summary window opens, and the network adjustment iterations finish quickly. Note that the total "Error Factor" was low, less than 1.00, and the adjustment passed the "Chi Square" test.

9. Review the network plot if you wish. Note that the geometry for point 0015 seems rather weak, and the error ellipse for that point is larger than those for the other points. In the next example, we will run a traverse from 0013 to 0018 and make ties from the traverse to points 0015 and 0016.

10. View the output Listing file and browse through the various sections, especially the output sections relating to GPS vectors. Go to the "Summary of Unadjusted Input Observations" section where you will first see the list of controlling coordinates.

Directly following will be the unadjusted vectors showing the lengths and standard errors of the Delta X, Y and Z components of each vector expressed in the earth-centered Cartesian system. Standard errors shown for these components include the affects of any "Factoring" and "Centering Errors" set in the options.
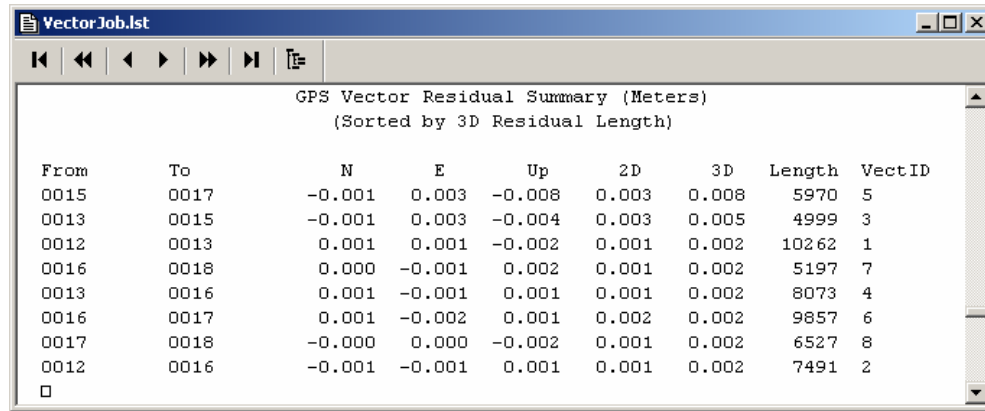
Next go to the "Adjusted Observations and Residuals" section. The first part of this section shows solutions of the transformations requested in the GPS options reviewed earlier. Here you see solutions for a scale and three rotations. The scale change is very small as are the three rotations. This should be expected when performing an adjustment on a GPS-based ellipsoid such as WGS-84 or GRS-80. If any of these solved transformation values are unreasonably large, you need to review your observations and constraints and find the reason why.

```
VectorJob.lst                                                    _|□|×|
|◄ | ◄◄ | ◄ | ► | ►► | ►| | Ɛ

        Adjusted GPS Vector Observations Sorted by Names (Meters)     ▲


Datum Transformations                                  StdDev
   Scale Factor 0.999998798883  :       1.201117 PPM   0.2026 (Solved)
   Rotation Around North Axis   :       0.753598 Sec   0.1120 (Solved)
   Rotation Around East Axis    :      -0.529028 Sec   0.0885 (Solved)
   Rotation Around Vert Axis    :       0.096278 Sec   0.0415 (Solved)


From              Component       Adj Value     Residual   StdErr StdRes
To
(V1 Day125(1) 14:14 00120013.SSF)
0012              Delta-N       -10107.7173       0.0007   0.0035   0.2
0013              Delta-E         1770.6879       0.0011   0.0032   0.3
                  Delta-U          -27.1134      -0.0016   0.0049   0.3
                  Length        10261.6772
(V2 Day125(1) 14:14 00120016.SSF)
0012              Delta-N        -3611.0888      -0.0005   0.0033   0.2
0016              Delta-E         6562.8657      -0.0010   0.0031   0.3
                  Delta-U          -42.0569       0.0012   0.0043   0.3
                  Length         7490.8569
(V3 Day127(2) 00:34 00130015.SSF)
0013              Delta-N         1356.7623      -0.0010   0.0035   0.3
0015              Delta-E         4810.9530       0.0029   0.0036   0.8
                  Delta-U          -19.2345      -0.0040   0.0052   0.8
                  Length         4998.6441                              ▼
```

As shown above, the next output in the same section are the adjusted GPS vectors and their residuals. Always review this important section since it shows you how much STAR*NET had to change each vector to produce a best-fit solution.

Note that all the vector, residual and standard error components have been rotated from earth-centered Cartesian to local-horizon North, East and Up components. This orientation is simple to understand and very easily related to conventional observations.

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The next section is the "GPS Vector Residual Summary" mentioned earlier in this example. Users find this one of the most helpful GPS related sections in the listing. It can be sorted in various ways to help you find the "Worst" vectors in your network. In our example, the summary is sorted by "3D" residuals, made up of local-horizon North, East and Up residual components.

```
VectorJob.lst                                                    _ □ ×
⏮  ⏪  ◀  ▶  ⏩  ⏭  ⟆

                GPS Vector Residual Summary (Meters)
                    (Sorted by 3D Residual Length)

 From      To         N       E       Up     2D      3D    Length  VectID
 0015     0017     -0.001   0.003  -0.008  0.003   0.008    5970   5
 0013     0015     -0.001   0.003  -0.004  0.003   0.005    4999   3
 0012     0013      0.001   0.001  -0.002  0.001   0.002   10262   1
 0016     0018      0.000  -0.001   0.002  0.001   0.002    5197   7
 0013     0016      0.001  -0.001   0.001  0.001   0.002    8073   4
 0016     0017      0.001  -0.002   0.001  0.002   0.002    9857   6
 0017     0018     -0.000   0.000  -0.002  0.001   0.002    6527   8
 0012     0016     -0.001  -0.001   0.001  0.001   0.002    7491   2
 □
```

Review the remaining sections in the listing file if you wish. These section are not unique to GPS vectors, and you have seen them before when running the examples earlier in this tutorial.

11. This completes the "VectorJob" example project. This was a realistic example of a small GPS job containing only vectors.

    To keep the tutorial short however, this example skipped a very important step! When running your own adjustments, always run a minimally-constrained adjustment first, holding only a single station fixed. This will test the integrity of the observations without the influence of external constraints. When you are confident that all observations are fitting together well, then add any remaining fixed stations to the network.

    The next example will add the vectors from this project to some conventional observations and you will run a combined network adjustment. If you want to continue on to the next example, turn the page for instructions.

Example 9: Combining Conventional Observations and GPS
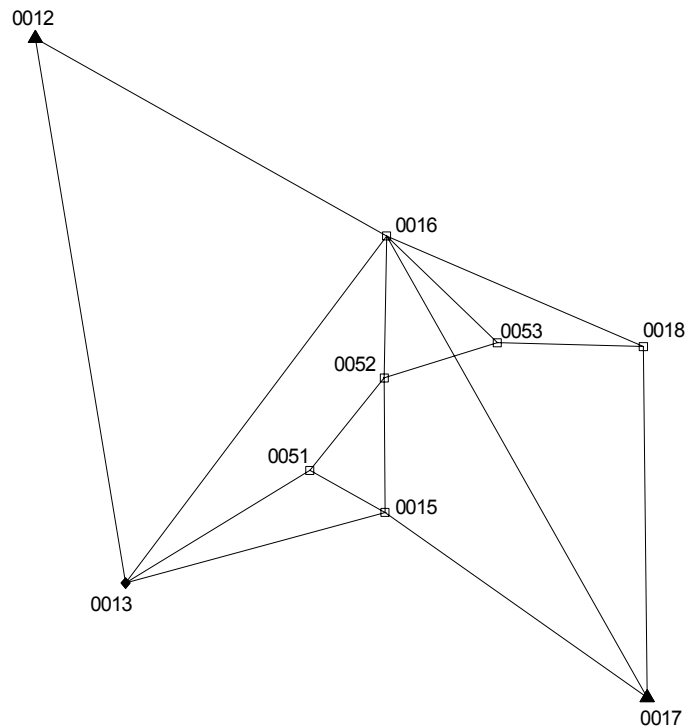
This example demonstrates combining conventional observations and GPS vectors in a single adjustment. We'll be using the same imported vectors and constraints as in the last example, only now a traverse and some ties have been added to the network.

```
# Combining Conventional Observations and GPS Vectors
# Latitudes and Longitudes are used as constraints in this example
# The "VectorJob.GPS" file is added in the Data Files Dialog

P 0012  33-04-44.24402 112-54-36.04569 224.299 ! ! ! 'North Rock
P 0017  32-58-09.73117 112-47-13.55717 209.384 ! ! ! 'AZDOT 80-1339
E 0013  205.450  ! 'BM-9331

TB 0012
T  0013    67-58-23.5  4013.95  90-04-44  5.35/5.40
T  0051  160-18-01.7  2208.27  90-14-33  5.40/5.40
T  0052  213-47-22.1  2202.07  89-43-20  5.36/5.40  'SW Bridge
T  0053  198-52-17.3  2714.30  89-58-19  5.35/5.38
TE 0018

# Ties to GPS points
M 0051-0013-0015  240-35-47.03  1601.22  90-27-52  5.40/5.40
M 0052-0051-0015  320-50-46.25  2499.61  90-05-49  5.36/5.41
M 0052-0051-0016  142-02-01.50  2639.68  90-07-37  5.36/5.40
M 0053-0052-0016   61-14-43.77  2859.65  90-20-19  5.35/5.42
```
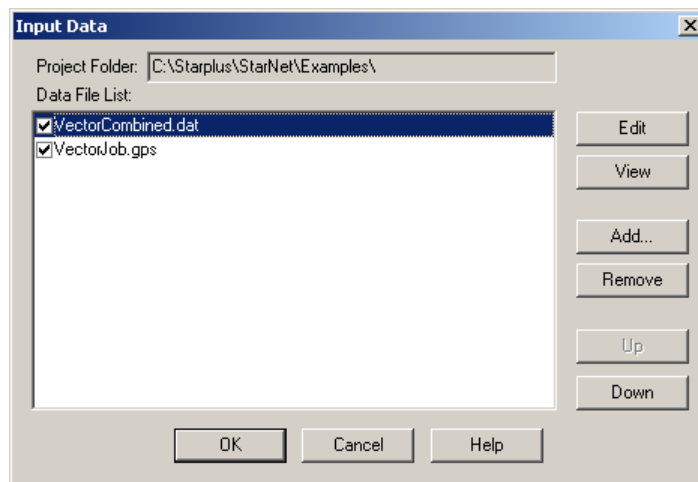

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1. Open the "VectorCombined.prj" example project.

2. Review the Project Options if you wish. Since this project contains conventional observations, the "Instrument" options settings will be relevant in the adjustment. Note that the standard error values entered for the turned angle, distance and zenith angle observations are quite small indicating that high quality instruments and field procedures are being used. The "GPS" option settings are the same as in the first example project.

   When combining conventional observations with GPS vectors, it is particularly important to carefully set weighting parameters in the Instrument options as well as in the GPS options since standard errors determine the relative influence of each type of data in the adjustment.
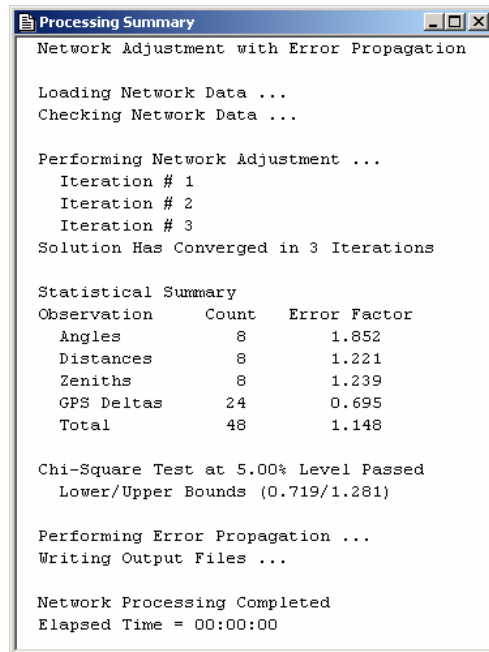
3. Open the Input Data Files dialog. There are two files in the list. The first file named "VectorCombined.Dat" contains the station constraints and conventional observations, and the second file named "VectorJob.Gps" contains GPS vectors imported to that file in the last example project. This file was simply added to the data file list by pressing the "Add" button and selecting the file. View either of these files if you wish, otherwise press "OK" to exit the dialog.
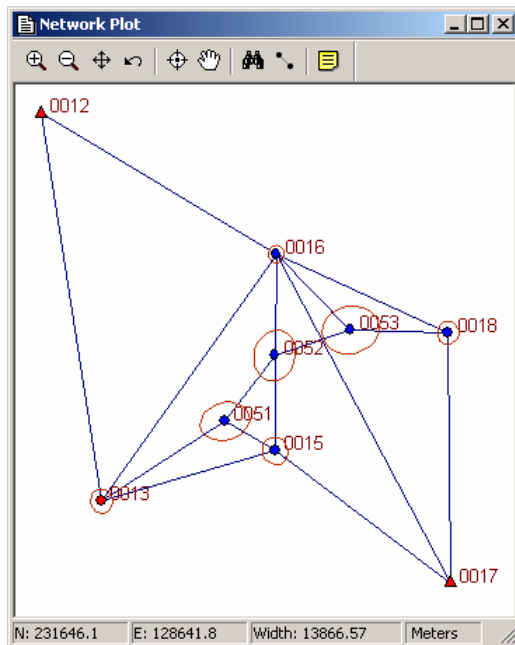
Note that in the "VectorCombined.dat" file, shown on the first page of this example, the same stations have been constrained as were in the last project, except they are entered as equivalent geodetic positions rather than grid coordinates simply to illustrate use of that data type. Results will be identical either way.

Conventional observations in the network include a traverse and four ties from traverse stations to two of the GPS stations. The traverse lines and the tie observations (the "M" lines) include turned angles, slope distances and zenith angles. Instrument and target heights are also included.

4. Run the network adjustment! The Processing Summary window opens, and the adjustment converges in a few iterations. The total "Error Factor" was slightly greater than 1, but the adjustment passed the "Chi Square" test.

5. View the network plot. Note that although the standard errors for the conventional observations were set quite small (indicating use of high quality instruments and field procedures), the error ellipses for points observed only by these observations are noticeably larger than those observed by GPS vectors.

If you wish, open the plot properties dialog, and turn on both relative ellipses and point descriptors.

Experiment by double clicking points and connection lines to see the adjusted information including ellipse and relative ellipse sizes.
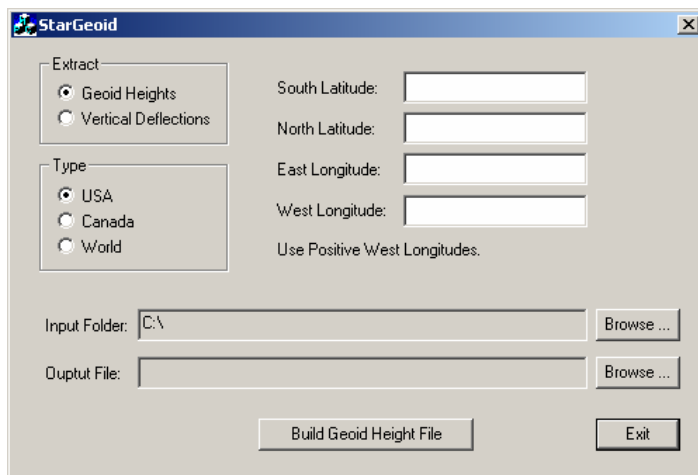
6. View the listing file. Note that listing sections reviewing unadjusted and adjusted observations now include both conventional and GPS vector observations.

   Find the "Statistical Summary" listing section and review how each type of observation (angle, distance, zenith angle and vector) fit in to the adjusted network.

7. This completes the "VectorCombined.Prj" project, the last example in this tour.

As you can see, combining conventional observations and GPS vector observations is very easy. When combining conventional and GPS observations, the most important consideration is establishing realistic weighting relationships between your GPS vector observations and your conventional observations. As mentioned in the first example, the standard errors reported by most manufacturer's baseline processors are usually over-optimistic, so you normally need to set a "factor" in the GPS options to make them realistic, and more compatible with conventional observations.

Note that geoid modeling has been mentioned more than once in the two example projects containing GPS vectors. But for simplicity, geoid modeling was not performed. However, installed along with this demo program is a separate utility program which extracts geoid information from a variety of government-supplied files and creates neutral geoid files that are used with the STAR*NET-PRO edition. This utility, named StarGeoid, is an-easy-to-use single dialog program:

The use of this utility is not discussed in the tutorial, but in short, it allows you to extract geoid (and vertical deflection) information from government sources and save the data in a neutral format for use by STAR*NET-PRO. Then when you want to perform modeling, all you do is to check the "Perform Geoid Modeling" box in the Modeling options, and modeling will be automatically performed during the adjustment – very easy!

Example 10: Differential Leveling Network

This example demonstrates running a stand-alone differential level network adjustment. A stand-alone "Lev" adjustment is available in the STAR*NET-LEV edition plus the higher-end STAR*NET-PLUS and STAR*NET-PRO editions. Level observations can also be included in any 3D adjustment in the STAR*NET suite.

```
   #   Simple Level Network with 4 Fixed Benchmarks

   #   Fixed Elevations
   E   TIDAL1     1.375  !   'NGS Ref 1
   E   TIDAL2     2.165  !   'NGS Ref 2
   E   BM75      23.768  !
   E   BM26      57.129  !   'Brass Cap 1939

   # Leveling Observation Data
   L   TIDAL1-129   12.345   20100
   L   BM75-129    -10.023   25300
   L   BM75-125     15.920   31200
   L   129-130      22.130   37400 'Central
   L   130-125       3.833   28100 'At Hyde
   L   129-128      11.810   41700
   L   128-130      10.336   32100
   L   125-BM26     17.458   37500
   L   BM26-126      2.814   39200
   L   130-126      24.065   40900
   L   128-126      34.422   52200
   L   126-127     -15.485   48100
   L   128-127      18.95    45300
   L   TIDAL2-127   42.321   17700

   # To produce an optional plot diagram,
   # supply 2D coordinates at any scale.

   .2D
   C   TIDAL1  11.0   12.0
   C   TIDAL2   0.2   11.8
   C   BM26     5.4    2.6
   C   BM75    12.2    6.4
   C   125      8.7    3.9
   C   126      3.3    4.3
   C   127      1.2    8.0
   C   128      4.0    9.6
   C   129      9.1    8.5
   C   130      6.1    6.7
```
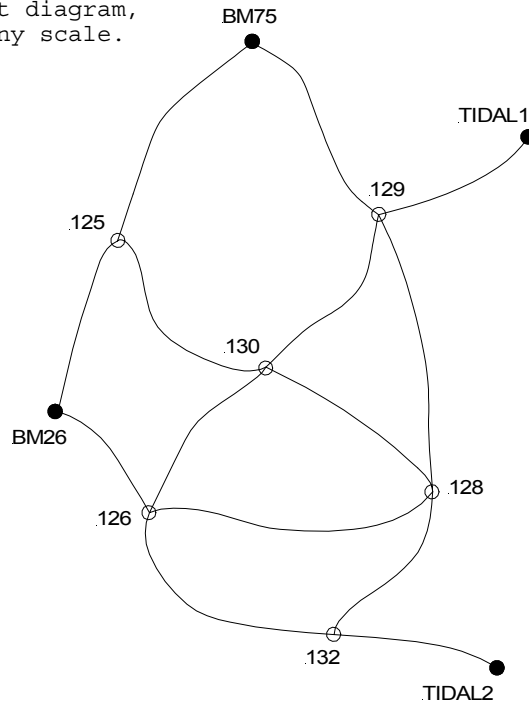
1. Open the "LevNet.prj" example project.

2. Open the Project Options for this job and review the "Adjustment" options page.

Adjustment | General | Instrument | Listing File | Other Files | Special | GPS | Modeling
Adjustment Type: ○ 2D ○ 3D ● Lev
Units — Linear: FeetUS   Angular: ● DMS ○ GONS

Here the "Lev" adjustment type has been selected. This is a 1-D network adjustment requiring only elevations used as benchmark restraints and differential leveling observations as input. The only other setting you will set on this dialog is the default linear units of the input and output.

3. Review the "General" options page.

Adjustment | General | Instrument | Listing File | Other Files | Special | GPS | Modeling
Adjustment Solution
Convergence Limit: 0.010
Maximum Iterations: 10
Chi Square Significance Level: 5.000 %
Error Propagation
☑ Perform
Confidence Level: 95.000 %
Input / Output Coordinate Order
● North-East ○ East-North   Label North in Listing as: ● N ○ Y ○ X
Angle Data Station Order
● At-From-To ○ From-At-To

Again, only a few options settings are needed for a level network adjustment. There are no iterations required for this kind of adjustment as the solution is linear. Why is there a "Coordinate Order" option for a level network? As illustrated by the data, Northing and Easting coordinates may be optionally entered for each station if you want a schematic plot generated for your level network. More on this later.

4. Review the "Instrument" options page.

Adjustment | General | Instrument | Listing File | Other Files | Special | GPS | Modeling
Conventional
Distance Constant: 0.030000   FeetUS
Distance PPM: 0.000
Angle: 4.000000   Seconds
Direction: 3.000000   Seconds
Azimuth / Bearing: 4.000000   Seconds
Leveling
Sections as: ● Length ○ Turns
Elev Diff: 0.006000   FeetUS/Mile
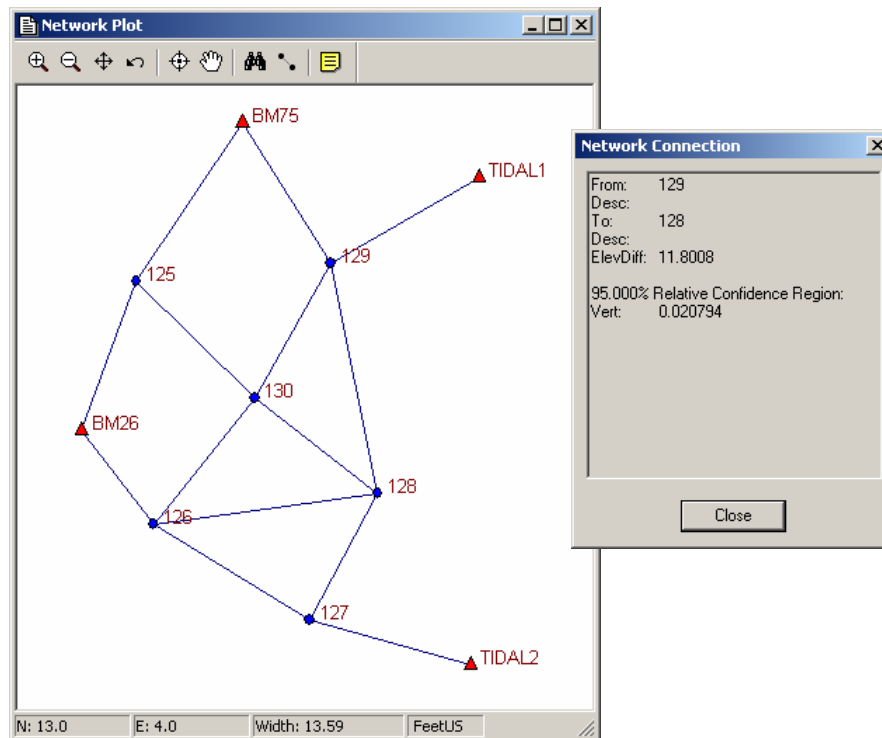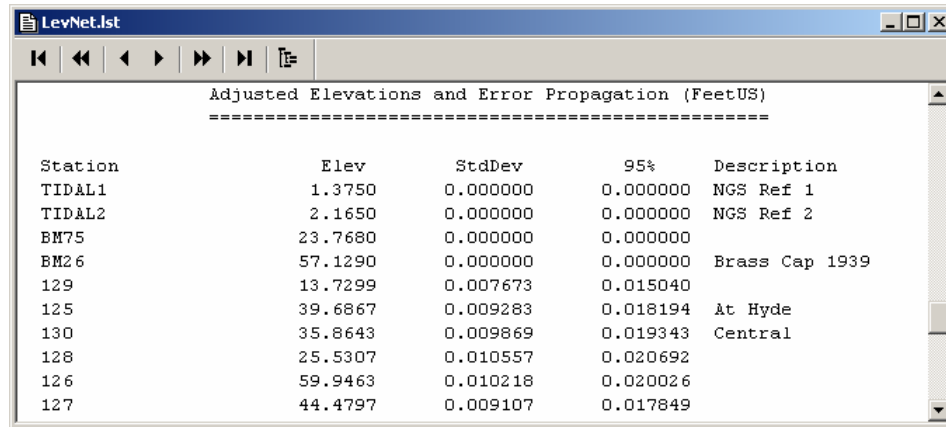
Here the default standard error for the leveling observations is set. Weighting for differential leveling can be defined by section length or by the turns. For this example network, the elevation difference standard error for each observation will be propagated by the program using 0.006 Feet per Mile section.

5. Also review the "Listing File" and "Other Files" options pages in the Project Options if you wish. A few options can be set relating to output for a level network.

6. Examine the data file if you wish. You will note this simple network includes four fixed elevations and 14 leveling section observation "L" lines. These two types of data lines are the only types required to perform an adjustment. Note however that 2D coordinates have also been provided for all the stations in the network. These are optional and need be entered only of you wish the program to create a schematic plot of the level network. Since these coordinates will only be used to create this plot, the scale of the coordinates makes no difference. Coordinates entered in this example were simply scaled off a sketch of the network drawn on grid paper.

7. Run the network adjustment.

8. Look at the network graphically. As mentioned above, this is only a schematic plot based on the relative 2D coordinates entered. Although straight lines are shown between connections, in actual leveling networks these connections may actually follow along roads, wander around hills, etc.
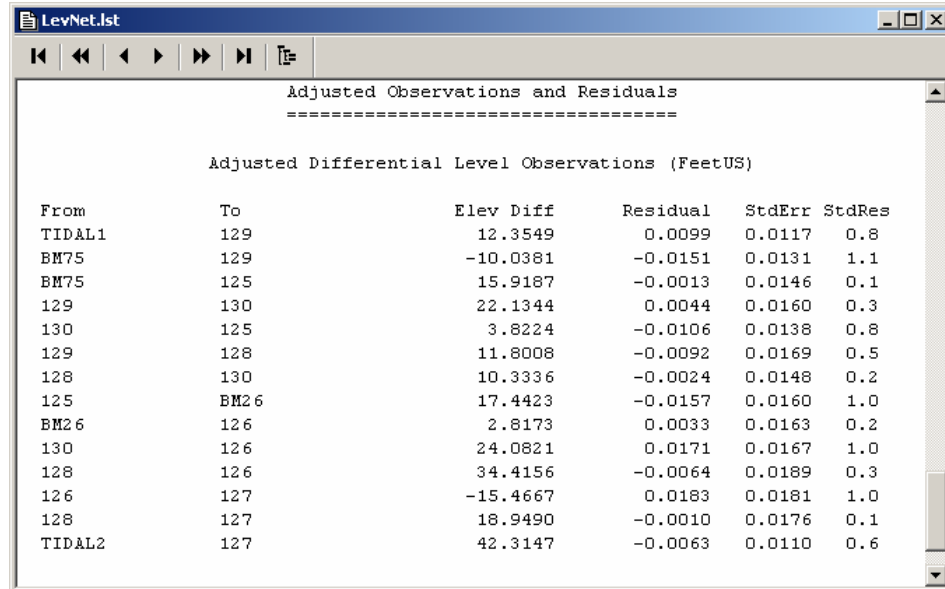
While viewing the diagram, double-click any point to get a pop-up information box showing its adjusted elevation and confidence region values. Double-click on other points and the information will refresh. Double-click on any line to show its adjusted elevation difference and relative confidence values. The example pop-up box shows information generated by double-clicking connection 129-128 on the plot diagram.

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9. View the output listing and browse through the various sections as you did in previous examples. Go to the "Adjusted Elevations and Error Propagation" section. Here adjusted elevations, standard deviations and confidence regions are all shown for all stations. Horizontal coordinates, even though entered for the benefit of creating a plot diagram, are not shown as they play no part in the adjustment.

```
LevNet.lst                                                        _ □ X

                 Adjusted Elevations and Error Propagation (FeetUS)
                 =====================================================

     Station              Elev       StdDev        95%       Description
     TIDAL1              1.3750     0.000000     0.000000     NGS Ref 1
     TIDAL2              2.1650     0.000000     0.000000     NGS Ref 2
     BM75               23.7680     0.000000     0.000000
     BM26               57.1290     0.000000     0.000000     Brass Cap 1939
     129                13.7299     0.007673     0.015040
     125                39.6867     0.009283     0.018194     At Hyde
     130                35.8643     0.009869     0.019343     Central
     128                25.5307     0.010557     0.020692
     126                59.9463     0.010218     0.020026
     127                44.4797     0.009107     0.017849
```

Go to the "Adjusted Observations and Residuals" section. Here the adjusted level observations are shown along with their residuals. Note the standard errors used in weighting the observations are all different because they are propagated based on the length of the sections.

```
LevNet.lst                                                        _ □ X

                    Adjusted Observations and Residuals
                    ====================================

             Adjusted Differential Level Observations (FeetUS)

     From          To            Elev Diff     Residual   StdErr  StdRes
     TIDAL1        129            12.3549        0.0099    0.0117   0.8
     BM75          129           -10.0381       -0.0151    0.0131   1.1
     BM75          125            15.9187       -0.0013    0.0146   0.1
     129           130            22.1344        0.0044    0.0160   0.3
     130           125             3.8224       -0.0106    0.0138   0.8
     129           128            11.8008       -0.0092    0.0169   0.5
     128           130            10.3336       -0.0024    0.0148   0.2
     125           BM26           17.4423       -0.0157    0.0160   1.0
     BM26          126             2.8173        0.0033    0.0163   0.2
     130           126            24.0821        0.0171    0.0167   1.0
     128           126            34.4156       -0.0064    0.0189   0.3
     126           127           -15.4667        0.0183    0.0181   1.0
     128           127            18.9490       -0.0010    0.0176   0.1
     TIDAL2        127            42.3147       -0.0063    0.0110   0.6
```

10. This completes the "LevNet" example project, the last example in this tutorial.

You have now completed all of the sample projects in this Tour. We hope that you now have a basic understanding of the operation of STAR*NET and how, as a versatile tool, it can be used not only to provide the best analysis and adjustments possible, but as a valuable aid to survey planning.

We now encourage you to experiment with the Demonstration Program by rerunning some of the examples, or trying some of your own data.
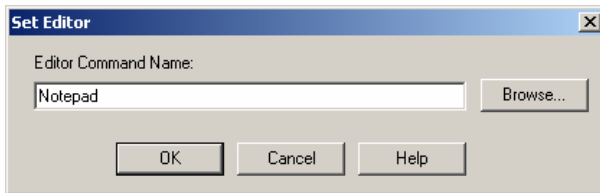
The next section, "Supplemental Information" provides extra details concerning editing your data and the format of data lines shown in the examples.

Supplemental Information

Editing Your Data

As illustrated in the tutorial, STAR*NET uses standard text files for all data. You can create and edit these data these files external to STAR*NET, or more conveniently, right from the Data Files dialog by highlighting a file name and pressing "Edit."

When you installed the STAR*NET demo program, the windows "Notepad" editor was assigned as the default editor. However, if you have a text editor you would rather have STAR*NET to use, choose **File>Set Editor** to make the change:

Browse for the editor of your choice and press OK. Note that you should normally refrain from using most word processors since they often insert special formatting characters that cannot be correctly interpreted by the STAR*NET program.

Input Data Files

This section is included for users of the STAR*NET Demo Program who want to change the sample input data files, or create their own files. More detailed information may be found in the STAR*NET User's Manual, which is supplied with the purchase of the full STAR*NET Standard, PLUS, PRO or LEV package.

STAR*NET input data files are standard text that can be created with a text editor. Data files can also be generated as output from some another program, such as a third party COGO program or a data collector routine. For example, Starplus Software has developed several utility programs which convert from raw field files (TDS, SDR33, SMI, etc.) to formats used in STAR*NET. Therefore, you might often create a data file external to the program, and use the editing feature in STAR*NET to modify the file as needed. However, you can also create the entire file by hand-typing observation data from within the program.

Although STAR*NET is flexible on how you can name your data files, it is suggested that you use "DAT" extensions for files consisting of conventional observations and control coordinates, and "GPS" for imported vectors. For convenience, the program automatically adds these extensions unless you specify otherwise. For example, if you create a project named "SouthPark", the program will offer "SouthPark.dat" as a data file name in the Data Files dialog.

Several files are created during an adjustment run. Each is given the project name, but a different extension. Using the "SouthPark" example project name, some of the output files created will be SouthPark.lst, (adjustment results listing), SouthPark.pts (adjusted coordinate points), SouthPark.pos (adjusted geographical positions if the job was grid), SouthPark.gnd (if you requested a ground-scale coordinates file to be created), etc.

Data Lines

STAR*NET input data files are relatively free in format. Spacing on a line is up to you, but the order of data elements on a line must conform to STAR*NET's rules. Generally, lines begin with a one or two alphabetic character code identifying the type of data, followed by the station names and actual observations. You have seen many examples of these data lines in the example projects.

For a least squares adjustment to work, coordinates (fixed or approximate) must be known for <u>all</u> stations in the network. Fortunately STAR*NET has the ability to look through all your data and figure out the approximate coordinates based on the actual angle and distance observation information in the data file. Often, however, you will have to enter an approximate coordinate or two to help STAR*NET get started calculating other approximate coordinates. For example, in the first sample project on page 4, we gave an approximate coordinate value for the first traverse backsight point. This is discussed in detail in the full STAR*NET User's Manual.

All STAR*NET data lines follow the same general format, as shown below.

Code	Stations	Observations	Standard Errors

The first one or two characters of a line of data form the code that defines the content of the line. Next comes the station name(s), followed by the observation(s) and the standard error(s). As explained in the STAR*NET User's Manual, the standard errors are used to define how much importance (weight) a particular observation will have in the adjustment. Normally you would simply set default standard errors for a project and not include them on your data lines.

The line below defines a single distance observation with an explicit standard error:

D	TOWER-822	932.66	0.03

Likewise, the line below defines a full set of 2D measurements, angle and distance, from one point to another plus the respective standard errors:

M	P25-12-HUB	163-43-30 1297.65	4 0.03

The following table lists most data types available in the STAR*NET program suite. These codes may be entered in upper or lower case.

Code	Meaning
#	Remainder of line is a comment and is ignored
C or CH	Coordinate values for a station
E or EH	Elevation value for a station
P or PH	Geodetic Position for a station (Grid jobs only)
A	Turned Angle
D	Distance
V	Zenith Angle or Elevation Difference (3D data only)
DV	Distance and Vertical (3D Data only)
B	Bearing or Azimuth
M	Measure (Observations to another network point)
BM	Bearing Measure (Observations to another network point)
SS	Sideshot (Observations to a sideshot point)
TB	Traverse Begin
T	Traverse (All observations to next network point)
TE	Traverse End
DB	Begin Direction Set
DN	Direction
DM	Direction with Measure Data
DE	End Direction Set
L	Differential Level Data
G	GPS Vector (Professional Edition)
GH	Geoid Height Value (Professional Edition)
GT	Vertical Deflection Value (Professional Edition)

Note that to keep this tutorial somewhat short and easy to review in a reasonable amount of time, all data type codes have not been illustrated in the example projects. The full STAR*NET documentation set that is included with software fully describes and illustrates all data types shown here.

Following the data type code on a line of data is the name of one, two or three stations depending on the type of data line being entered. Multiple names are separated by a dash. In the distance line shown on page 40, "TOWER-822" defines the FROM and TO stations of the distance observation. Station names may be 1 to 15 characters in length, although only 10 characters are shown in most of the reports.

Next comes the actual observation (or observations) such as a distance, turned angle, zenith, azimuth or bearing, a direction, or coordinates for a station. Angular values may be entered in "D-M-S" format (123-44-55.66) or "packed" format (123.445566), the format commonly used by calculators. Angles may also be entered in GONS. For simplicity, all examples in this tutorial are shown entered in "D-M-S" format.

Directly following the observations, you can optionally enter standard error values for the observations. A standard error may be entered as the actual value, as a special symbol, or simply left blank so that a default will be assigned. When more than one observation is on the line, you must either provide a standard error entry for each one, or leave them all out. The following table explains the various entries you can make for standard errors.

Entry	Explanation
Numeric Value	An actual Standard Error value (i.e. 0.03)
Nothing Entered	Defaults to the value defined in the global options
The "&" Symbol	Defaults to the value defined in the global options
The "!" Symbol	The observation is FIXED in the adjustment
The "*" Symbol	The observation is FREE in the adjustment

When performing 3D adjustments, another optional entry is normally added following the standard error values, if any. This is the height of instrument and height of target, or HI/HT data entry. For example, if an HI is 5.25' and an HT is 5.73', the two values would be entered as a 5.25/5.73 entry. This entry is illustrated in all the 3D examples.

Point Descriptors may be added to most data lines. Point Descriptors begin with a single or double quote character. These descriptors are listed with the final adjusted coordinates in the resulting points file. You have seen the use of these descriptors in several of the example projects.

There are additional data types and data entry modes not mentioned here, which are fully described in the STAR*NET User's Manual. For example, in 3D data entry, horizontal distances and delta elevations can be input as well as slope distances and zenith angles. Also, "Traverse Begin" and "Traverse End" data lines have options for backsighting and closing to fixed bearings.

The following are standard formats for most of the conventional observation data types that have been illustrated in this tutorial. Formats for other data types (direction sets, elevation differences, differential leveling, etc.) are not shown. Observations in parentheses are those entered for 3D data. Items in brackets are optional.

The "C" Code: Station Coordinates

C	Station Name	North East (Elevation)	[Std Errors]

The "A" Code: Horizontal Angle

A	At-From-To	Angle	[Std Error]

The "D" Code: Distance (Slope Distance if 3D)

D	From-To	Distance	[Std Error]

The "V" Code: Zenith Angle (3D Data Only)

V	From-To	Zenith	(HI/HT)	[Std Error]

The "B" Code: Bearing or Azimuth

B	From-To	Bearing or Azimuth	[Std Error]

The "M" Code: Measurement (All Observations to Next Point)

M	At-From-To	Angle Distance (Zenith)	(HI/HT)	[Std Errors]

The "SS" Code: Sideshot (All Observations to a Sideshot Point)

SS	At-From-To	Angle Distance (Zenith)	(HI/HT)	

The "TB" Code: Traverse Begin (Backsight point)
The "T" Code: Traverse to Next Point (One or more data lines)
The "TE" Code: Traverse End (Ending point)

TB	Backsight Station Name or Backsight Bearing			
T	At	Angle Distance (Zenith)	(HI/HT)	[Std Errors]
TE	End Station	[Closing Angle plus Closing Station Name or Bearing]		

Additional Features

STAR*NET has many features not discussed in detail in this short tutorial including:

- An AutoCAD DXF export tool transfers your network with ellipses, station names, and elevations. In addition, a Points Reformatter tool converts adjusted coordinates to several standard COGO formats as well as formats defined by you.

- An "Instrument Library" facility allows you to define unlimited unique weighting schemes (standard errors, centering errors, PPM, etc.), and apply them anywhere in your network data to handle multi-instrument projects with little effort.

- Station names may be entered as alpha-numeric and up to 15 characters in length. A sorting option causes them to be listed in the coordinate files by name, or in order of their first encounter. Another sorting option causes adjusted observations to be sorted either by name or by residual size – useful for debugging a network.

- An inline "UNITS" option converts input observations on the fly. For example, change observed values in Meters to US Feet, or visa versa. Many other inline data options are available for changing input modes within data files. For example, change mode from slope distance/zenith mode to horizontal distance and elevation difference. Change refraction index, change scale factor, etc.

- Internal reduction of 3D field data during an adjustment for those who wish to run a horizontal adjustment only, but retain the original data as 3D for future use.

- A special option causes the program to create a scaled-to-ground coordinate file. Converts adjusted grid coordinates back to ground for construction work.

- A "Positional Tolerance" checking feature to satisfy relative position specification requirements set forth by the ACSM/ALTA committee and other agencies.

- A "Map Mode" data entry option makes it easy to combine "already-reduced" traverse information from record maps with field observations in a GIS network. Maps with different "basis of bearings" can are combined by automatic conversion of adjacent bearings into "neutral" turned angles.

- Add differential leveled observations to conventional and GPS vector observations in a 3D adjustment to add to the confidence of your resulting elevations.

- In the "Professional" edition, flexible weighting options relating to GPS allow for easy integration of vectors with conventional observations. Full geoid and deflection modeling can be performed during the network adjustment as well as manual definition of geoid heights and vertical deflections at individual stations.

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