

Appendix C

Demonstration Documentation (updated September 06, 2009)

**One-, Two- and Three-Dimensional
Network Adjustment,
Network Pre-Analysis &
Coordinate Transformation Software**



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Geodesy...

“... a branch of applied mathematics that determines the exact positions of points on large portions of the Earth's surface; the shape and size of the Earth; and the variations of terrestrial gravity and magnetism.”

The science of geodesy has been available for hundreds of years, yet many surveyors do not utilize this powerful method for processing their data. Why? Because without the power of computers, the mathematics of geodesy are rigorous—much more so than the number-crunching required for projected coordinate systems. In the past, geodesy was viewed as a method to use only for large scale, high-precision surveys.

However, geodesy can—and could—be used for any size project. Whether your survey spans several thousand kilometers or only 100 meters, geodesy is the best mathematical model for processing field measurements.

The reasons are many:

- The geodetic coordinate system is worldwide; there are no boundaries. Stations established from independent surveys are directly related to each other.
- The mathematical model is geometrically exact with no systematic distortions.
- Field measurements are used as measured. No reductions are applied, thus the most accurate coordinates can be determined.
- No special measurement collection procedures are required.
- Resulting coordinates are latitude, longitude and height, ECEF XYZ, State Plane NEE, UTM (TM) NEE and/or Local Horizon Plane NEE.
- The elevation (orthometric height) for each station can be determined using either GPS or terrestrial observations.
- A variety of field observation types can be combined into each project. Stations can be separated by less than a centimeter or up to several hundred kilometers.

To use the geodetic model, all you need is COLUMBUS, one or more control stations, and your measured field data.

COLUMBUS does the rest! Simply load your field data, select your stations and observations, and then compute!

Installation

COLUMBUS can be installed and operated on any PC running Microsoft Windows XP or newer operating system.

To install COLUMBUS Network Adjustment Software, insert the CD into your CD ROM drive. From the **Start** menu, select **Run**, type **d:\setup.exe** and click the **OK** button. Follow the instructions of the installation program.

If you have downloaded COLUMBUS from our Web site (www.bestfit.com), simply run the **coldemo38.exe** executable to begin the installation process.

We have provided 16 ASCII (Text) project files, which demonstrate different network adjustment and/or traversing scenarios. **Each project file contains the instructions (within the comment section of the file) on how to perform an adjustment or traverse.** For most project files, we have also included a report (*_RPT.TXT) file. Before exploring each demo file, you may find it helpful to briefly review the corresponding report file.

Below is a description of each file:

BEAR2D.TXT	This project file contains a small 2D geodetic network (one half of a PLSS section from a township) consisting of recorded mean bearing and horizontal distance survey data.
BIGBASIN.TXT	This project file contains a network consisting of 17 stations (four of which are 3D control stations) and 126 GPS and terrestrial observations. This sample is also used for demonstrating the Solve All Combinations logic described at the end of this document.
BIGBASIN_NET.TXT	This project file has the same stations and observations as BIGBASIN.TXT. It also contains all the applicable Option Settings and fixed station settings. Review the BIGBASIN.RPT file for this project.
GEO.TXT	This project file contains a small 3D geodetic network consisting of geodetic stations and terrestrial observations. This project contains the same data as the GEO_TRAV.TXT project.
GEO_TRAV.TXT	This project file demonstrates 2D and 3D geodetic traversing. This project contains the same data as the GEO.TXT project.
GPSONLY.TXT	This project file contains a small 3D geodetic network consisting of geodetic stations and GPS observations.
MIXED.TXT	This project file contains a small 3D geodetic network consisting of geodetic stations, and a mix of GPS and terrestrial observations.
NEE.TXT	This project file contains a small 3D Local Horizon Plane NEE network, which can be adjusted using the local NEE adjustment engine.
NEE_TRAV.TXT	This project file demonstrates 2D and 3D Local Horizon Plane NEE traversing. It does not contain the same data as NEE.TXT.
STATEPLANE.TXT	This project file contains a small 3D State Plane network consisting of State Plane stations and terrestrial observations. This project contains the same data as the STATEPLANE_TRAV.TXT project.
STATEPLANE_TRAV.TXT	This project file demonstrates 2D and 3D State Plane traversing. This project contains the same data as the STATEPLANE.TXT project.

TERRONLY.TXT	This project file contains a small 3D geodetic network consisting of geodetic stations and terrestrial observations. This network can also be adjusted in 2D at an average project height.
TRIGLEVEL.TXT	This project file contains a sample data set (with instructions) for processing Trig Levelling data. There is no report file for this project.
UTM.TXT	This project file contains a small 3D UTM network consisting of UTM stations and terrestrial observations. This project contains the same data as the UTM_TRAV.TXT project.
UTM_TRAV.TXT	This project file demonstrates 2D and 3D UTM traversing. This project contains the same data as the UTM.TXT project.
VERTICAL.TXT	This project file contains a small 1D vertical network consisting of height stations and height difference (levelling) observations.

Before loading each sample project file into COLUMBUS, take a moment to examine its contents for instructions on how to process each network (or traverse) contained in the file.

DEMO LIMITATIONS

The demonstration version of COLUMBUS has been configured to handle only a fraction of your computer's capacity. **The maximum number of stations allowable for the demo version is 12** (BIGBASIN.TXT and BIGBASIN_NET.TXT can still be loaded even though they have 17 stations). There is no practical limit to the number of observations that can be loaded in the demonstration version of COLUMBUS.

The full version of COLUMBUS has been used to adjust simulated networks with up to 45,000 stations and containing hundreds of thousands of observations.

Online Tips For Using COLUMBUS

We have developed online resources to help you use COLUMBUS more effectively. The first is our Quick Tips section, which can be found by clicking on the Quick Tips link at www.bestfit.com. The second resource is our Real-World Applications link, which explains selected topics in greater detail. The link to this topic can also be found on our home page.

We would like to strongly encourage you to use these resources as you learn more about COLUMBUS. Both sections are continually being enhanced with new topics.

Quick Start - Creating A Project Interactively

To use the data entry grids to create a project from scratch, do the following for optimal efficiency.

1. Create a new project (**File - New**) and select the datum to be active in the OPTIONS - DATUMS dialog.
2. Setup the view. If this will be a State Plane coordinate based project, set the view to State Plane (2D or 3D). For a Geodetic coordinate based project, set the view to Geodetic (2D or 3D), etc.. **This step allows COLUMBUS to automatically generate coordinate stations when you enter observations (below).**
3. If this is a State Plane, UTM (3TM, TM), or Custom Projection based project, select (or set up) the zone in the applicable OPTIONS dialogs. If this is a Local NEE project, set up the approximate latitude for the project in the OPTIONS - GLOBAL SETTINGS dialog.
4. Enter the applicable DATA - OBSERVATIONS tabbed dialog (Horizontal Angle Set, Direction Set, Azimuth Set, etc.) and begin entering station names (AT, TO, BS) and the observation data. **Be sure to be consistent with your station names when referring to the same point on the ground.** A station name of **TOP** is not the same as **Top** (these are two different station names). COLUMBUS station and datum names are case sensitive.
5. If an observation was not measured (for example a chord distance), leave the observation field blank.
6. After entering several observations, select the **Keep and Exit** button. Stations referenced by the observations will be created automatically. If the active view was set to State Plane (3D), then State Plane stations will be created.
7. Edit any station for which you have known coordinates (usually just your control stations).
8. Save your project using the **File - Save** command to prevent accidental loss of changes.

For additional information on using each data entry grid, please see Chapter 4 of the user manual. Each chapter can be downloaded individually or all together (in a zipped file) at: www.bestfit.com/docum.shtml

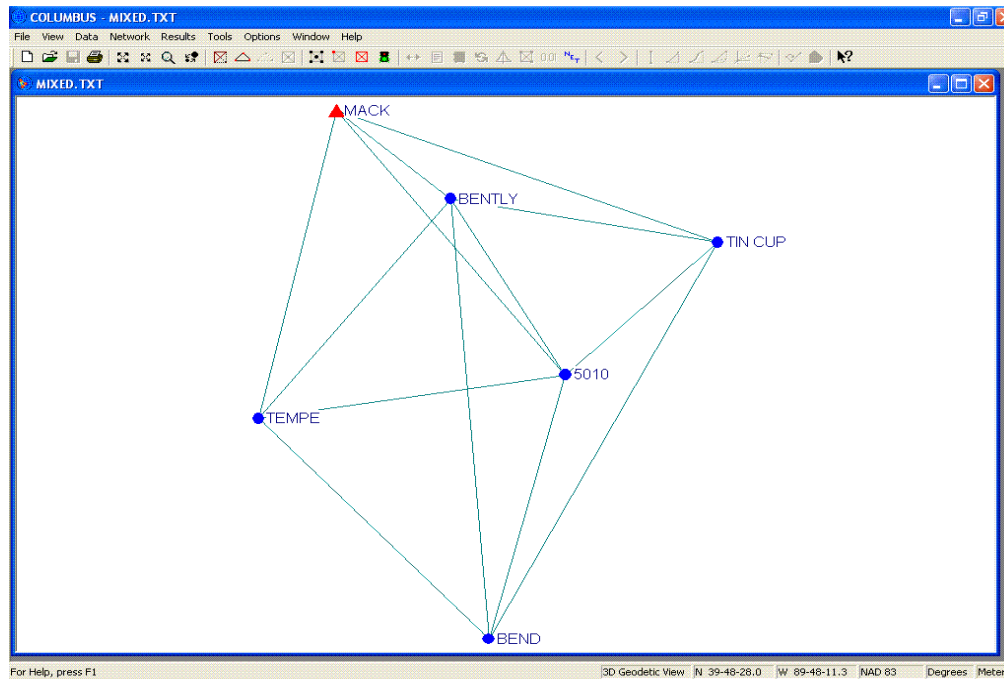
How COLUMBUS Is Organized

COLUMBUS is organized around nine functional areas. Following is a brief description of each function:

FILE

The **File** menu provides file management tools for creating a new project; opening a new project (**Figure 1** below); appending data to a existing loaded project; saving the current project; extracting data from third-party data files; and print/print preview of the current project and network adjustment/pre-analysis results.

Figure 1: MIXED.TXT Network View



VIEW

The **View** menu allows you to change the view context of the active project. For example, you can view a network in one of the following contexts: 1D Vertical, 2D Geodetic, 3D Geodetic, Cartesian XYZ, State Plane (2D), State Plane (3D), UTM (2D), UTM (3D), Local NE (2D), or Local NEE (3D). The available context options are dependent on the type of data in the project.

The majority of computations within COLUMBUS are context-dependent on the active project view.

From this menu, you can also setup or clear a route (sequence of stations), resize network entities (station names, station symbols, and error ellipses), zoom in or out on a defined area of the active project view, display/hide stations, the toolbar, and the status bar.

DATA

The **Data** menu facilitates the entry and editing of data (stations, observations and datums) for the current project. A complete project can be entered here using our intuitive spreadsheet style grids. You can also create your project within an ASCII (Text) input file (similar to the examples described in this document).

From this menu, observations can also be temporarily disabled to exclude them from Network Adjustment/Pre-Analysis and COGO processing.

NETWORK

COLUMBUS adjusts networks using the method of Indirect Observations (also known as the Unified Approach). This is the most common method in use today. Much of the adjustment theory built into COLUMBUS has been adopted from papers published by the National Geodetic Survey (NGS - U.S.A). Overall, the geodetic theory used within COLUMBUS has been taken and combined from several leading independent sources. We provide a complete list of references to these sources within the Appendix of our user manual and on our Web site (www.bestfit.com) from the **Theoretical Foundation** link.

The **Network** menu provides all the tools required to adjust one-, two- and three-dimensional vertical, geodetic, ECEF XYZ, State Plane, UTM (TM), Custom Projections and Local Horizon networks. The type of network adjustment to be performed is dependent on the current project view. For example, if the current view is 2D geodetic, then a 2D geodetic adjustment can be performed. Likewise, to perform a 3D geodetic adjustment, the 3D geodetic view must be active.

You can also perform network pre-analysis on 2D and 3D surveys from the **Network** menu. Network pre-analysis (commonly called design) enables you to design your survey before going into the field. Simply provide COLUMBUS with the approximate locations of your planned survey points (scaling from a map is usually adequate), the observation types you expect to measure, and the expected precision for each observation, expressed as a standard deviation or covariance matrix (for GPS baselines). COLUMBUS can then compute the statistical level of precision you can expect to achieve, based on your design. If your design is not adequate for the future adjusted precision desired, make changes and analyze your design again. Network pre-analysis can save valuable time in the field by allowing you to optimize your network geometry and the types and frequency of the observations that must be measured. Please visit our Web site for more help on setting up a Network Adjustment and Design under the applicable **Quick Tips** topic.

RESULTS

The **Results** menu allows you to view the network adjustment or design results. Several views can be displayed simultaneously, including an adjusted view of the network - complete with resizable error ellipses and height error bars. For each view, you can use **Print** and **Print Preview** to further examine each report as hard copy or on-screen. The results from each view can also be written to a report file (see the **Report** toolbar icon) and to a Microsoft Excel CSV file comma-delimited file (with just the data and no formatting). Network adjustment report generation can also be automated by selecting the desired reports in the **Options - Network Options - Report Settings** dialog.

TOOLS

The **Tools** menu provides powerful tools for transforming geodetic coordinates to several other coordinate systems, performing COGO traverse and inverse computations, and much more. **Tools** menu options can be used alone or in combination with the **Network** menu options.

Most of the options within the Tools module are context-sensitive to the **Main Project Graphical View** or **Network Adjustment Graphical View**. Look at the dialog title for each Tool option to determine its context. *For example, if the Network Adjustment Graphical View is active, all applicable Tool options are based on the adjusted coordinates. If the Main Project Graphical View is active, all applicable Tool options are based on the data for each station, i.e., data that are part of the project.*

The **Datum Transformation** tool is a very most powerful features, giving you the ability to transform geodetic coordinates based on one datum (NAD 83, WGS 84, etc.), to geodetic coordinates based on a second datum (NAD

27, Bessel, etc.). Also, you can transform geodetic coordinates to/from ECEF Cartesian, State Plane, UTM and Local NEU. Resulting coordinates can quickly be exported to other software systems.

The **COGO** (coordinate geometry) option provides tools for vertical, geodetic, ECEF XYZ, State Plane, UTM, and Local Horizon coordinate geometry traverse and inverse computations. You can compute loop closures or open-ended traverses.

The remaining **Tools** menu options allow you to compute areas; scale projected coordinates; model geoidal heights and deflections of the vertical; create NGS NADCON input files; and export data to a DXF or user-defined data file.

OPTIONS

The **Options** menu allows you to change the run-time parameters within COLUMBUS. Usually the defaults will be adequate, but they may require changing, depending on your specific processing requirements. You can also manage multiple sets of Options Settings (customized to each type of project) within the Options Library Manager.

WINDOW

The **Window** menu allows you to arrange your work area, following the standard Microsoft Windows conventions. You can Cascade or Tile views. Using the **Arrange Icons** command, you can arrange your iconified project icon.

HELP

The **Help** menu provides access to the Index to COLUMBUS' extensive Help system. Information is also provided about using Help and about your current version of COLUMBUS.

NOTE ABOUT REPORT VIEWS

Most numerical results are now presented in list report form. These reports contain multiple resizable columns that can be customized by you to only show the columns you want. Changes made to any column alignments are automatically saved for future COLUMBUS sessions.

Each column in a list report can be sorted (ascending and descending) by clicking on the column header. The order of the printable report will match the current sorted column on screen.

Each and every report can also be written to a comma-delimited Microsoft Excel CSV file format. These files contain the actual results without all the normal formatting. In this form, your data can be easily loaded into excel for further manipulation. **Because the excel CSV file is a simple comma-delimited file, you can also import these files directly into other software packages for further processing, drawing, etc.**

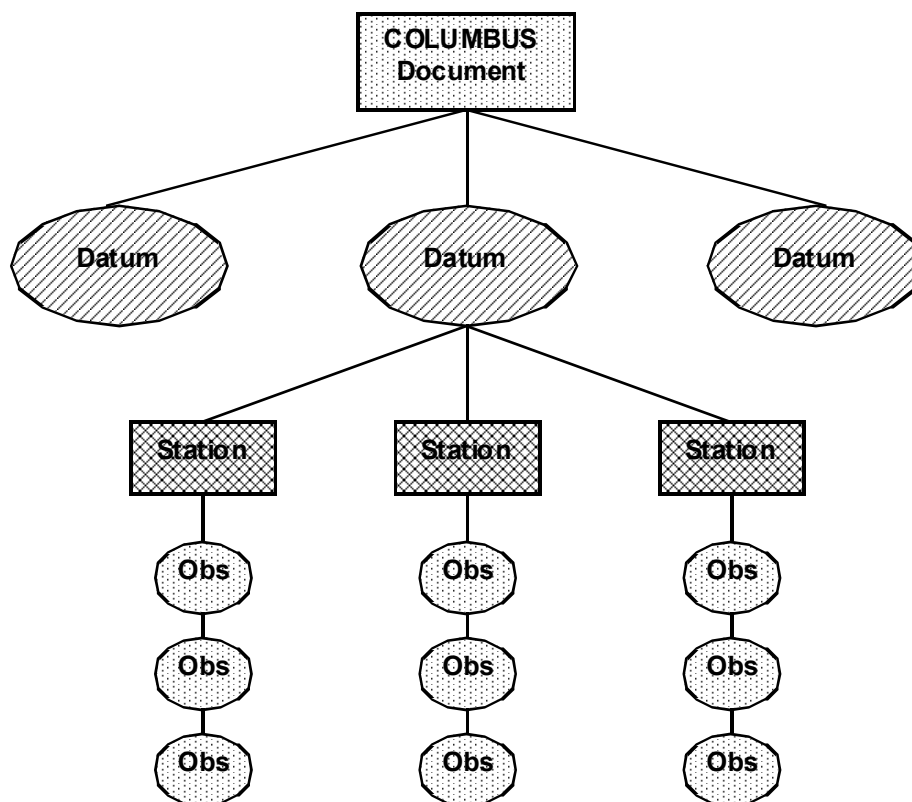
To activate the generation of CSV files, select the **Report Headings** command from the **Options** menu and enable the **Create comma-delimited text report...** check box. When you send the results of any list report to a report file, a corresponding excel CSV file will also be created with the extension *.csv (using the same report file name and in the same folder.)

Project Data Model

COLUMBUS is a completely integrated system. From within one program, several types of computations can be performed. Users of COLUMBUS find that many of the tasks that previously required separate programs can be solved within the COLUMBUS environment. Unlike other network adjustment programs, COLUMBUS opens all station and observation data into a project for manipulation and computation. The data are available until you close the project.

One of the most powerful features of COLUMBUS is its built-in data sharing. Once data have been entered within the applicable **Data** module or opened within the **File** module, they are available for computations in any of the applicable numerical modules. If a network has been recently opened, the data can be used to quickly perform inverses or loop closures. Station data can be easily transformed from one coordinate system to another.

Figure 2: *COLUMBUS Data Hierarchy*



Project usage in COLUMBUS is similar to the process of making changes to a file using a text editor. Once data have been opened into a project, they can be modified, appended or deleted without affecting the original data on disk. Within COLUMBUS, data in a project are saved to disk only when you select from the **File** menu either the **Save** or **Save As** options, or select from the **Network** menu the **Save Network** option. Like having several versions of a project with minor modifications in each, you can have several versions of the same data in separate disk files. This is accomplished by continually saving data in your project to separate disk files (or the same file if preferred) following each alteration.

Not only can different modules gain access to your data, each numerical module has the ability to **Keep** new data into the active project from current computations. For example, you perform a geodetic network adjustment, but need to report the adjusted geodetic positions in State Plane (projected) form. Once the adjustment is completed, you can **Keep** the adjusted

geodetic coordinates into the active project by selecting **Keep** from the **Results** menu or by using the toolbar button, giving other modules access to the adjusted coordinates. You can then move to the **Tools** menu and select **State Plane <--> Geodetic** to transform the adjusted geodetic coordinates to State Plane coordinates.

Note: Another way to accomplish this is to perform the network adjustment, then open the **Adjusted Network** view. From the **Tools** menu, select the **Geodetic to State Plane** transformation. Since the **Adjusted Network** view is active, the transformation computations will be based on the adjusted geodetic coordinates.

The advantage of this system is the elimination of re-entering computed coordinates. This minimizes the possibility of data entry errors and saves valuable time. This feature also removes the needless construction of multiple intermediate data files that tend to clutter your disk directories. With COLUMBUS, each project can be stored in one data file or across several data files.

ASCII (Text) Files

COLUMBUS supports two file formats for data files. Each format can be used independently or combined together in the same file.

- The **expanded format** usually spans more than one line of the text file for each input record. This format is supported for backward compatibility, but it is no longer generated by the **File - Save** commands.
- The **compact format** allows you to define an entire input record on one line of text. Data fields are separated by the semicolon character (;). All demo data files (files with *.TXT extension) are in this format.

COLUMBUS also supports the concept of an **include file list**. From within each file, you can include other files. These included files are automatically loaded by COLUMBUS. If your project is made up of dozens of input files, you can create one master input file (for example, master.txt), which then includes all the project files. See Appendix A for details on using the \$INCLUDE_FILE keyword.

You can use the online data entry grids to create projects interactively or you can create a COLUMBUS input file directly (using your favorite text editor). You can also combine both methods - enter data online, then save to a file, then make additional file edits, then load the file and make additional interactive edits.

The ASCII (Text) file has four main types of data: Datums, Units, Stations and Observations. Each type can be repeated in the file as often as you like. For a complete listing of available ASCII (Text) keywords, please see Appendix A of the COLUMBUS user manual (www.bestfit.com/docum.shtml).

Stations can either be explicitly or implicitly defined within the file. To explicitly define each station you must provide some coordinate values. To implicitly define each station, simply add this record type to the top of the file:

```
$STATION_TYPE_FOR_OBS  
3D_GEO (or 1D_VERT, 2D_GEO, 3D_ECEF, 2D_STATE, 3D_STATE, 2D_UTM, 3D_UTM, 2D_NE, 2D_NEU)
```

When the file is opened, the applicable station type will be automatically created (with coordinates of zero) when an observation is read, which reference the station.

When creating the ASCII (Text) file, all types of data are optional. If the Datum data is not included, the opened data is linked to the active datum. If the Units data is not defined, all linear values are assumed to be in the active linear units. All applicable angular values are assumed to be in the active angular units.

Data Editing

The DATA module allows you to add, modify or delete station, observation, and datum data currently in the project through an assortment of intuitive spreadsheet like grids. **A complete project can be entered using these grids or by creating your project within an ASCII (Text) input file.**

You can also disable individual observations. Observations that are disabled will not be available for use in Network Adjustments, Network Pre-Analysis, or COGO Traverse computations.

There are three basic data components in COLUMBUS:

STATIONS	locations on the ground
OBSERVATIONS	measurements between stations
DATUMS	ellipsoidal parameters

When entering or editing data, it is very important to work with the units defined in the OPTIONS - UNITS dialog. If the linear units are set to meters, all linear quantities must be entered in meters, except the major axis for a datum, which must **always** be entered in meters. Internally, COLUMBUS converts all linear quantities to meters and angular measurements to radians. If the selected linear units are U.S. Survey Feet, COLUMBUS converts all applicable linear data from U.S. Survey Feet to meters before storing them internally. Upon output, the results are then reported back in U.S. Survey Feet.

Likewise, angular measurements must be made in the active angular units. COLUMBUS currently supports degrees and grad (or gon) units. See the OPTIONS chapter of this manual for more information on the supported angular formats.

Keeping track of the input units is easy when using the spreadsheet grids. When you select a cell to edit, the units of entry are displayed in the upper left corner of the current Tabbed Page.

If you enter a value that is out of range (in a cell), then move to another cell, an error message will be displayed in the upper left corner of the current Tabbed Page. This message will indicate the proper numeric (or text) range for the cell you just left. The cell will also be restored to its original value (before the bad data was entered).

Using The Data Grids

The data grids allow you to quickly enter or modify project data. Each grid serves a specific purpose, but they are all used in the same way (mouse + keystrokes or keystrokes alone). These grids utilize many of the same keystroke combinations found in popular spreadsheet software.

Keep and Exit:

After making changes in any grid, select the **Keep and Exit** button to accept the changes into the project. Data are not saved to disk until you invoke the **File - Save** or **File - Save As** command.

Cancel:

To cancel changes at any time, select the **Cancel** button. If any data changes have been made in the grid, you will be prompted with a message asking you if you really want to discard your changes.

When you select **Cancel**, COLUMBUS looks for any change in the grid. If changes exist (e.g., you added a new empty row), a scan is made to see if those changes would alter the project. If not (as in this example), no user prompt is made.

Suppose you opened an observation grid and changed a slope distance from 1300.25m to 1300.255m. Before closing the grid, you then changed that distance back to 1300.25m. If you now select **Cancel**, no user prompt will be made, since the project data has not changed.

Add Row:

New data are always added to the bottom of the grid. You can add new rows by invoking the **Add** button or by repeatedly pressing the ENTER key to move to the last row and then add additional rows.

The user entered row order is not maintained in COLUMBUS. When the Station, Observation or Datum grids are activated, the data is always ordered alphabetically by; the AT station name (Stations), the AT, TO, BS station names (Observations), and the Datum name (Datums).

Empty rows are ignored and removed as soon as you move to another Tab or close the dialogs.

Delete Row:

To delete a row of data from the project, clear out all fields on that row. When **Keep and Exit** is selected, the data that was on that row will be removed from the project. When you delete a station (using this method) all observations connected to that station will also be deleted (including horizontal angles that backsight into the station).

Rename Station or Datum:

To rename a station, open the Station Tabbed dialogs and select any one of the Station Tabs (Geodetic, State Plane, etc). Change the desired station name (modify its text). The new name must not match any other station name currently in the grid or you will get an error message. When the **Keep and Exit** button is selected, the name will be changed in the project. **All observations linked to that name will also be automatically updated.**

To rename a datum, follow the same process.

Adding Similar Rows Of Data:

When adding several rows of data (for which many fields are identical) use copy/paste. First, add several blank rows to the grid. Second, using your mouse or keystrokes, highlight the entire row of data you wish to replicate. Use **Ctrl + C** to copy the row. Move to the beginning (first cell) of the first blank row and perform a paste **Ctrl + V**. Move to each additional blank row and paste the data in the same way. Make specific edits to the fields that are different.

When doing this operation within the Station or Datum grids, you will not want to add the station name (first cell in each row) to the copy/paste operation. If you do, you will get a duplicate name message after each paste. Instead, copy the 2nd thru n cells of each row (skipping cell 1 of each row.)

Column Widths:

You can change the width of any column. These changes are remembered by COLUMBUS.

Column Sorting:

You can perform column sorting by clicking on the desired column header. This will sort all rows based on the items in that column. Click on the column again to reverse the sort. When sorting columns that contain Real numbers, you can sort by the absolute value by first enabling the **View - Sort By Absolute Value** command.

Keystroke Navigation Summary

Below is a list of the most commonly used keystroke combinations. You may discover that exclusive use of the keyboard (no mouse) is more efficient when entering large amounts of data.

Cell Modes:

- Edit Mode When editing a cell
- Entry Mode When on a cell, but not in edit mode

Navigation:

- Ctrl + PgUp Next Tab page to the left
- Ctrl + PgDn Next Tab page to the right
- Ctrl + Tab Next Tab page to the right
- Ctrl + Shift + Tab Next Tab page to the left
- Tab Move to cell to right (Edit Mode)
- Shift + Tab Move to cell to left (Edit Mode)
- End Move to last cell in row (Entry Mode)
- Home Move to first cell in row (Entry Mode)
- Up Arrow Move up one cell
- Down Arrow Move down one cell
- Ctrl + Home Move to upper left corner of grid
- Ctrl + End Move to lower right corner of grid

Alt + K Keep changes and exit (Entry mode)

Select and Edit:

Alt + A Add a row (Entry mode)

Alt + Space Window menu

Ctrl + Space Select entire column

Shift + Space Select entire row

Ctrl + A Select all cells

Ctrl + Left Click Select multiple cells

Ctrl + C Copy content of selected cells

Ctrl + X Cut content of selected cells

Ctrl + V Paste clip board to cells

Ctrl + ' Copy contents of cell above (Entry mode)

Shift + Left Arrow Select multiple continuous cells to the left

Shift + Right Arrow Select multiple continuous cells to the right

Shift + Left Mouse Click Extend selection to selected cell

Shift + End Select current cell and all cells to its right

Shift + Home Select current cell and all cells to its left

Shift + PgUp Select current cell and all cells above

Shift + PgDn Select current cell and all cells below

Del Delete contents of selected cells (Entry mode)

Del Delete current character (Edit mode)

End Move to right side of cell (Edit mode)

Home Move to left side of cell (Edit mode)

Enter When in Edit mode, changes to Entry mode

Esc Exit grid and abandon changes (Entry mode)

Esc Abandon cell changes (Edit mode)

Bksp Delete cell contents (Entry mode)

Bksp

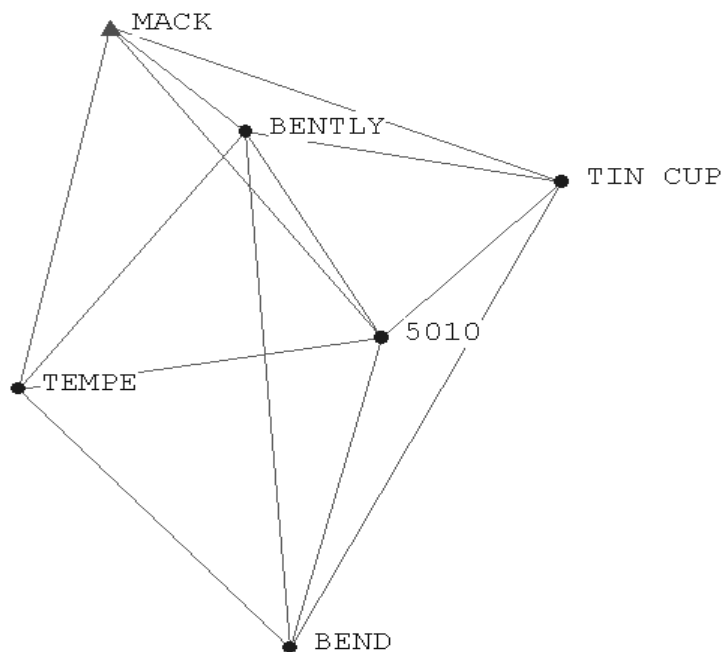
Delete character to left (Edit mode)

Example - MIXED.TXT

The **Network** module is the most commonly used and sophisticated module within COLUMBUS. Although easy to use, the underlying software is very powerful for satisfying your “what-if” processing requirements. Networks can be constructed using up to 19 different observation types, including coordinate observations. You can freely mix GPS and terrestrial field data (within 3D networks) or use them separately. Each survey project can be solved as one large network or in user-selectable subsets from within the integrated operating environment.

Below is the layout for this network example. There are six geodetic stations and 64 observations in this data set. Station MACK was fixed in three dimensions (latitude, longitude and ellipsoidal height).

Figure 3: MIXED.TXT Network Layout



For the complete view of this data file (in compact format), print or open the file **MIXED.TXT** from the COLUMBUS installation directory. The exclamation point (!) is used to comment out individual lines within the file. You can also use the two keywords \$BEG_SKIP and \$END_SKIP to comment large blocks of text or data within the input project file.

Since COLUMBUS computes approximate coordinates during adjustment, the accuracy of the entered coordinates for the floating stations is not critical. However, if COLUMBUS cannot compute approximate coordinates for a station, the entered coordinates should be estimated as closely as possible to their actual positions before attempting an adjustment (usually by scaling from a map). To adjust the MIXED.TXT network in 3D geodetic space, follow the steps outlined below:

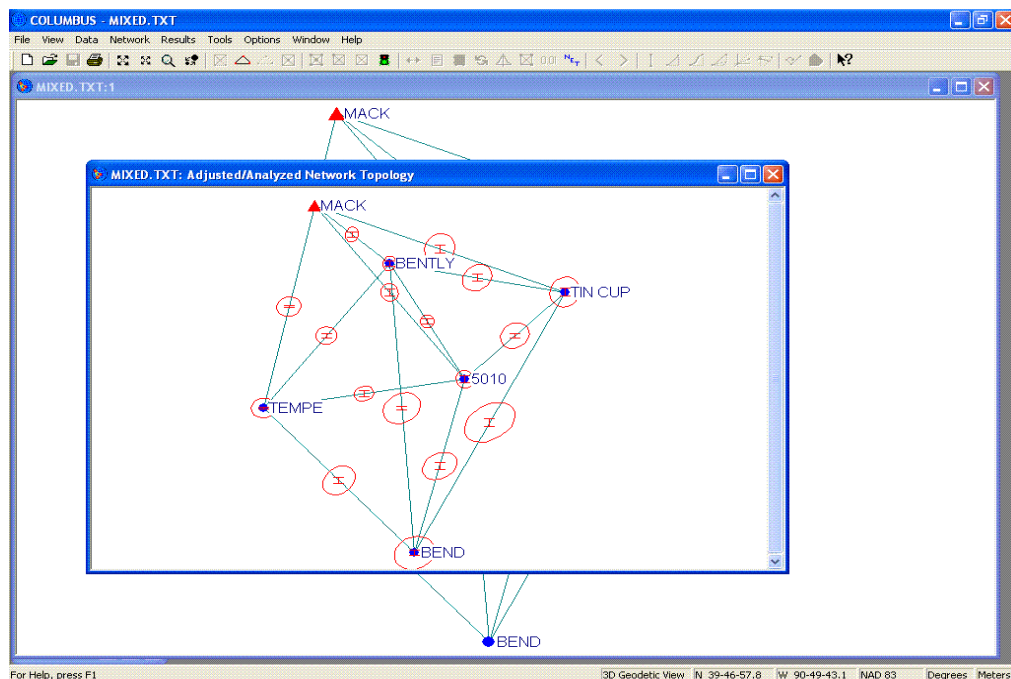
1. Open the data file **MIXED.TXT** into a new project by selecting **Open** from the **File** menu.
2. From the **View** menu, select **3D Geodetic** as the View context. Notice as you move the mouse over the network view, the status bar displays the latitude and longitude position of the mouse. To preview the coordinate data for any station, double-click the station symbol. To resize the station names or symbols, either click the **Resize Entities** toolbar button or select **Resize Entities** from the **View** menu. To preview observation sets, double-click the line between any two stations.

To compute a loop closure, use the **right mouse button** to define a traverse route by right-clicking on each station in the order of the route. Then select the applicable **COGO Traverse** option from the **Tools** menu or click the **Compute 1D, 2D or 3D traverse** toolbar button. You will then be presented with a list of all available observations. Select the observations desired, then invoke the OK button to compute the coordinates and closures for each station.

You can also set up (or edit) a traverse route from within the **Setup COGO/Design Route** dialog, accessed from the **View** menu.

3. From the **Options** menu, select **Units** and set the **Linear Units** to **meters**.
4. From the **Options** menu, select **Global Settings** and set the **3D Geodetic Height** to **Ellipsoidal Height**. The ellipsoidal height field will be used for the vertical control of Control Station MACK.

Figure 4: MIXED.TXT Adjusted View



5. Define the stations and observations that will be used in the current adjustment. **Stations not selected to be in the network are not used in the adjustment.** Stations fixed in 2D (latitude/longitude) and/or 1D (height) are considered to be floating and fixed, respectively, for a 3D network adjustment.
6. From the **Network** menu, select **Network Stations**. (Alternatively, click the **Network Stations** toolbar button.) Click the **Select All** button to select all the stations to be used in the current adjustment. Click the **OK** button. All multiple selection lists within COLUMBUS conform to Windows standard behavior. To select multiple items, hold the **CTRL** key down while simultaneously clicking on each list entry. You can also use the **Shift** key and mouse click sequence to select groups of items.
7. From the **Network** menu, select **Fixed Stations**. (Alternatively, click the **Fixed Stations** toolbar button.) Click on Station MACK to be fixed in 3D. Click the **OK** button.
8. From the **Network** menu, select **Observations**. (Alternatively, click the **Observations** toolbar button.) Click the **Select All** button to select all the observations to be used in the current adjustment. Only observations linked to the selected network stations will be presented. The observations in this window are ordered alphabetically by the AT and TO station names. Click the **OK** button.
9. Begin the network adjustment by selecting the **Adjustment** command from the **Network** menu or by clicking the **Start Adjustment** (greenlight) toolbar button.

As the adjustment proceeds, COLUMBUS displays each processing step. After the adjustment is completed, review the adjustment summary dialog box using the scroll bar. From the **Results** menu, select **Adjusted View** to graphically review the adjusted network.

- To examine the error ellipses for any adjusted station or between stations, double-click within the applicable adjusted error ellipse.
- To examine the adjusted coordinates for a station, double-click on the station symbol.
- To examine the adjusted observation between any two stations, double-click on the line connecting the station pair.

These views and several others can be selected from the **Results** menu. For each view, try the **Print Preview** command to see a “report style” look at the view (see **Figure 5** below). Adjustment results can also be written to a report file by selecting the **Report** toolbar button.

If you prefer to see all adjustment results in the Network Processing Summary View, do the following: close the current adjustment, enter the OPTIONS - NETWORK OPTIONS - REPORT SETTINGS dialog and select the reports you want to automatically generate (some reports may not be applicable to the current view context, so they will not be generated), then restart the adjustment.

Figure 5: MIXED.TXT Print Preview of Adjusted Coordinates

MIXED.TXT: Adjusted Coordinate Results Page 1

COLUMBUS 3D Geodetic Network Adjustment Software

COLUMBUS: Full - Ver 3.6.1.22
 Report File: C:\Program Files\Best-Fit Computing\COLUMBUS 3.6\PRN38921.TMP
 Document: C:\Program Files\Best-Fit Computing\COLUMBUS 3.6\MIXED.TXT
 DATE: 12/02/2005 TIME: 19:24:07

NAD 83 Major = 6378137.0000 1/x = 298.25722210
 Linear Units: Meters
 Angular Units: Degrees

Hgt Update : Ortho Hgt Update (fix ghgt, float ellip hgt)
 Settings : Geoid Hgt Update (float ortho, fix ellip hgt)
 : Ellip Hgt Update (float ortho, fix geoid hgt)

Adjusted Coordinates

Station			Covariance Matrix			
SO10						
Latitude	N	39-29-59.99799	0.012255173			
Longitude	W	89-49-59.99861	0.000692266	0.009376094		
Ellip Hgt		1099.98242	0.000205273	0.000059690	0.002655399	
BEND						
Latitude	N	38-59-59.99432	0.042085148			
Longitude	W	90-00-00.00121	-0.006868993	0.050671743		
Ellip Hgt		500.34696	0.000104000	0.000045337	0.002002906	
BENTLY						
Latitude	N	39-49-59.99782	0.008506998			
Longitude	W	90-04-59.99697	-0.000938904	0.005142591		
Ellip Hgt		899.97739	0.000116261	-0.000008124	0.001396923	
MACK						
F Latitude	N	40-00-00.00000	0.000000000			
F Longitude	W	90-20-00.00000	-0.000000000	0.000000000		
F Ellip Hgt		1000.00000	-0.000000000	-0.000000000	0.000000000	
TEMPE						
Latitude	N	39-25-00.00071	0.014863490			
Longitude	W	90-29-59.99186	-0.000818751	0.018163547		
Ellip Hgt		700.06244	0.000015497	0.000004374	0.000275038	
TIN CUP						
Latitude	N	39-44-59.99611	0.000011554			

Page 1 3D Geodetic View | N 40-01-24.5 | W 89-48-55.3 | NAD 83 | Degrees | Meters

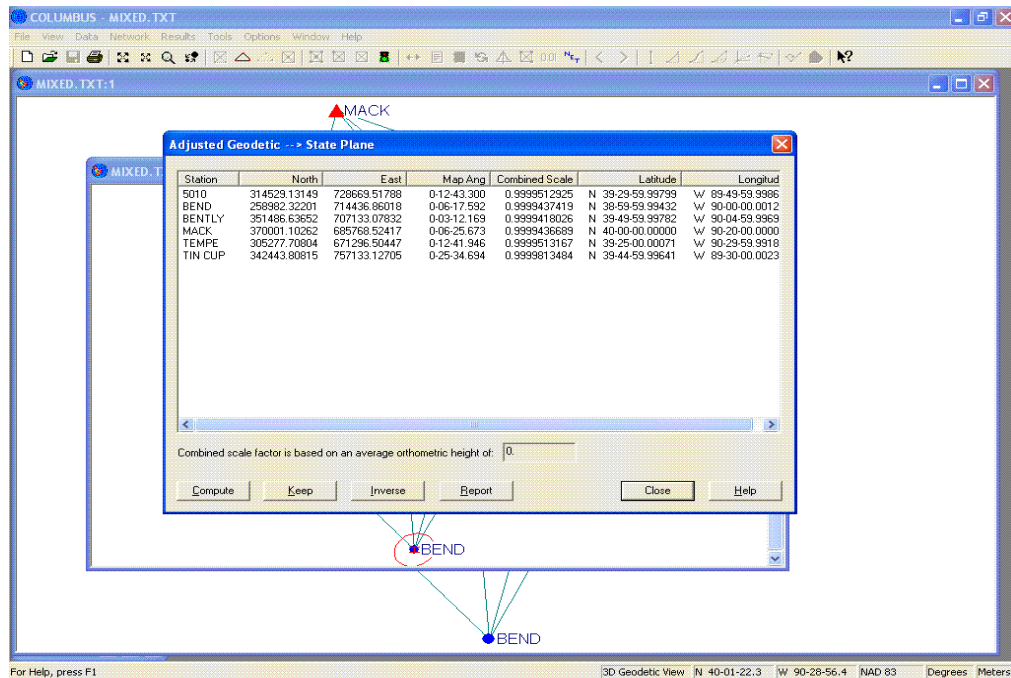
The adjusted coordinates for each station are stored in a temporary area of the project. If you prefer, you can **Keep** the adjusted coordinates into the project to be used as fixed stations in subsequent adjustments by selecting **Keep** from the **Results** menu (the **Keep** command is only available when the adjusted coordinate view is the top most view active). The adjusted coordinates can also be transformed to other coordinate types by selecting **Transformation** from the **Tools** menu.

If at any time you need further information about the contents of a dialog box, simply click the **Help** button or press the **F1** function key. COLUMBUS will display a Help screen summarizing the current display. For views, simply click

the ? toolbar button and move the mouse over the applicable view. Click on the view and context-sensitive Help will immediately be displayed.

10. To transform the adjusted geodetic coordinates to State Plane coordinates, click anywhere on the network adjusted view to make it the active view. This is the view that contains the graphical error ellipses and is shown in **Figure 4** above. **You can examine the Adjusted State Plane Coordinates view.**
11. From the **Options** menu, select **Projection Zones**, then select **State Plane Zones**. Next, select the **ILLINOIS 1202 TM Zone** to be the active projection zone.

Figure 6: MIXED.TXT Adjusted State Plane (Projected) Coordinates



12. From the **Tools** menu, select **Transformation**, then select **State Plane <--> Geodetic**. Click the **Compute** button to bring up the list of your adjusted stations. Click the **Select All** button, then click the **OK** button. The adjusted State Plane coordinates will be displayed in the dialog box. Also displayed are the Mapping Angle and Scale Factor for each projected station.

Network Adjustment Results

Below is an abbreviated example of the reports resulting from the 3D geodetic adjustment of MIXED.TXT. These reports can be generated automatically during adjustment, after the adjustment from within each result view, or by using the **Print/Print Preview** command while examining each result view. To set up automatic report generation, from the **Options** menu, select **Network Options**, then select **Report Script**.

The first section shows a summary of the network adjustment settings and results.

3D GEODETIC NETWORK ADJUSTMENT SUMMARY

Datum	NAD 83	1D Expansion Factor	1.95937
Linear Units	Meters	2D Expansion Factor	2.44788
Angular Units	Degrees	3D Expansion Factor	2.79532
Field Observations	64	A Priori Variance	1.00000
Coord Observations	0	A Posteriori Variance	0.72423
TOTAL OBSERVATIONS	64	Confidence Level	95.0
		Chi Square Test On Variance Factor	
		0.505 < 1.0 < 1.124 (Passes)	
Num Stations	6	Variance Factor Used	0.72423
Fixed In 1D	0		
Fixed In 2D	0		
Fixed In 3D	1	No Check Observations	0
Float Coord Parms	15	Stan Res Rejections	1
		(Tau Stat = 3.213)	
Direction Parms	0	Resid/SD Rejections	0
Scale Parms	0	Residual Rejections	0
Rotation Parms N	0	TOTAL OUTLIER OBS	1
Rotation Parms E	0		
Rotation Parms Up	0	Iterations	3
TOTAL PARMS	15	Convergence Criteria	0.0010000
		Zenith Angle Refraction	0.00000
		Rotate Bearings	No
DEGREES OF FREEDOM	49	Use Full Covariance	Yes
A-POSTERIORI VARIANCE (and STAN DEV) FACTOR (by observation type)			
Obs Type	Count	Sum of Squared Weighted Residuals	Redundancy (D.F.)
			A-Post Variance
			StanDev
Azimuth	2	1.518	1.139
Hor Ang	14	6.981	9.796
Zenith	13	3.068	11.584
Chord	13	7.685	10.788
Hgt Diff	4	0.176	0.589
GPS Obs	18	16.060	15.103
TOTALS	64	35.487	49.000
			0.724
			0.851

ADJUSTMENT COMPLETE = 0 Seconds

The next section lists the adjusted coordinates in compressed form. They can also be listed with the adjusted covariance matrix for each station.

For this network, stations can be fixed in 1D (height), 2D (latitude and longitude) or 3D (latitude, longitude and height). To fix an individual latitude, set the latitude standard deviation to be very small (for example, 0.0000001 meters). Set the longitude standard deviation to be large (for example, 30.0 meters). From the **Network** menu, select **Constrained Stations** and then select the station to be constrained in 2D just prior to adjustment. This will, in effect, freeze the latitude, while allowing the longitude to move freely during adjustment. You can achieve this same result by using coordinate observations in COLUMBUS.

Adjusted Coordinates

Station	Latitude	SD	Longitude	SD	Ellip Hgt	SD
5010	N 39-29-59.99799	0.1107	W 89-49-59.99861	0.0968	1099.98242	0.0515
MACK	3 N 40-00-00.00000	0.0000	W 90-20-00.00000	0.0000	1000.00000	0.0000

1 - 1D Fixed 2 - 2D Fixed 3 - 3D Fixed

The next section lists the adjusted observations. First, the three critical outlier value types are shown. An outlier constant can be set for each observation type. In this example, the Azimuth Residual rejection constant is 10.0 seconds, while the Chord Distance residual rejection constant is 1.0 meter. If any azimuth residual exceeds 10.0 seconds, it is tagged as a possible outlier. Any chord distance with a residual greater than 1.0 meter is tagged as a possible outlier.

Next, the default observation standard deviations are shown. A value of zero indicates no default was set. Also shown are A priori scalers to be applied to linear observations. In this example, the scalers are set to 1.0, so in effect, no scaling is applied. Scalers can be used to remove any systematic scale problems that are known before adjustment.

Finally, all adjusted observations are displayed mark-to-mark, corrected for instrument heights, target heights, refraction, and deflections of the vertical, where appropriate. For each observation, its residual, residual standard deviation, standardized residual, residual/apriori standard deviation ratios, and observation redundancy are displayed.

Adjusted Observations (Mark To Mark)

Standardized Residual Rejection Constant (Tau Stat)	= 3.21273
Residual / A Priori Stan Dev Rejection Constant	= 5.00000
Residual Rejection Constants For Each Observation Type	
Azimuth	= 10.000
Hor Ang	= 10.000
Zenith	= 10.000
Chord	= 1.00000
Delta X	= 1.00000
Delta Y	= 1.00000
Delta Z	= 1.00000
Hgt Diff	= 1.00000

Obs Type	Num Obs	Default SD	Scaler
Azimuth	2	0.000	
Hor Ang	14	0.000	
Zenith	13	0.000	
Chord	13	0.00000	1.000000000
Delta X	6	0.00000	1.000000000
Delta Y	6	0.00000	1.000000000
Delta Z	6	0.00000	1.000000000
Hgt Diff	4	0.00000	1.000000000

Stations	Observations	SD	Resid	Stan Res
		SD	Resid SD	Resid/SD
AT BENTLY	Azimuth 149-49-17.000	1.0000	1.1157	1.4600
	Corrected 149-49-18.669	1.0000		
TO 5010	Adjusted 149-49-19.784	0.3745	0.7642	1.1157
	Redundancy			0.81
AT 5010	Hor Ang 148-48-43.000	1.7000	0.5201	0.4742
BS TIN CUP	Corrected 148-48-43.008	1.7000		
TO BEND	Adjusted 148-48-43.529	0.9434	1.0968	0.3059
	Redundancy			0.57

AT	5010	Delta Z	21638.55000	0.4243	0.2238	0.6617
TO	TIN CUP	Adjusted	21638.77379	0.1264	0.3382	0.5275
				Redundancy		0.88
AT	BEND	Hgt Diff	399.63000	0.0300	0.0004	0.1188
TO	BENTLY	Adjusted	399.63043	0.0253	0.0036	0.0143
				Redundancy		0.02

- 1 - Exceeds Standardized Residual Rejection Constant
- 2 - Exceeds Residual / A Priori SD Rejection Constant
- 3 - Exceeds Observation Residual Rejection Constant

The next section shows information pertaining to GPS observations only. For each baseline, the residuals are shown in a Local North, East, Up horizon. This facilitates the identification of possible instrument/antenna centering errors (shown as Delta North and Delta East) and instrument/antenna height measurement errors (shown as Delta Up). Field observations are the original measured values, not the adjusted values.

GPS Local NEU Residuals

Stations	Field Observations	Local NEU Residual
AT 5010	Delta X 28524.00000	Delta N 0.23906
TO TIN CUP	Delta Y 17563.70000	Delta E -0.35724
	Delta Z 21638.55000	Delta Up 0.06219
AT BENTLY	Delta X 21472.25000	Delta N -0.36388
TO 5010	Delta Y -23765.60000	Delta E 0.15805
	Delta Z -28365.25000	Delta Up -0.01587

The next section lists the adjusted 2D geodetic inverses between all connected station pairs. The geodesic is the shortest distance between the two stations on the ellipsoidal surface. The geo chord is the chord distance between the two stations.

Adjusted 2D Geodetic Inverses

AT	TO	Geodesic	Geo Chrd
Fwd Az	Bwd Az		
5010	BEND		
194-34-57.705	14-28-38.076	57344.2628	57344.0687
5010	BENTLY		
329-58-54.215	149-49-19.725	42777.0325	42776.9520

The next section lists the adjusted 3D ECEF delta XYZ inverses between all connected station pairs. To determine the backward vector, simply reverse the sign of each vector component.

Adjusted 3D GPS XYZ Inverses

AT	TO	Delta X	Delta Y	Delta Z
5010	BEND			
-14338.0811	-34682.4394			-43371.3815
5010	BENTLY			
-21472.4082	23765.8199			28365.5402

The next section lists the adjusted 3D Astro geodetic inverses between all connected station pairs.

Adjusted 3D Astro Geodetic Inverses (connected stations)

AT Fwd Az	TO Bwd Az	Fwd Zen	Bwd Zen	Chord
5010 194-34-58.498	BEND 14-28-37.235	90-51-25.271	89-39-36.656	57354.4149
5010 329-58-55.090	BENTLY 149-49-18.116	90-27-38.418	89-55-32.170	42784.1371

The next section lists the distance errors between all connected station pairs. The distance errors have been scaled to the 95% confidence interval (approximately 2 sigma) by the 1D expansion factor. PPM is computed as (standard deviation / distance * 1,000,000).

Distance Errors

Confidence Level 0.950
Expansion 1D 1.959

AT	TO	Distance	Stan Dev	PPM	Ratio
5010	BEND	57354.415	0.3066	5.3452	1:187083
5010	BENTLY	42784.137	0.1552	3.6280	1:275638

The next two sections list the station and relative error ellipses for the network. The semi-major and semi-minor axes have been scaled to the 95% confidence region (approximately 2 sigma) by the 2D expansion factor. The height error has been scaled to the 95% confidence interval by the 1D expansion factor. PPM is computed as (semi-major axis / chord distance * 1,000,000).

Station 2D Error Ellipses

Confidence Level 0.950
Expansion 1D 1.959
Expansion 2D 2.448

AT	Major	Minor	Azimuth	Height
5010	0.2727	0.2350	12.8	0.1010
BEND	0.5714	0.4789	119.0	0.0877

Connected Station 2D Error Ellipses

Confidence Level 0.950
Expansion 1D Chi Square 1.959
Expansion 2D Chi Square 2.448 (1st row)
Expansion 2D 'F' 2.525 (2nd row)

AT	TO	Semi-Major	Semi-Minor	Azimuth	Height	Chord	PPM	Ratio
5010	BEND							
0.5072	0.3680	122.3	0.1035	57354.4149	8.8427	1:113088		
0.5230	0.3795	122.3	0.1035	57354.4149	9.1195	1:109655		

The next section lists the station and relative error ellipsoids for the network. The azimuth and zenith angles describe the orientation of the error ellipsoid relative to North and Up, respectively. The semi-major, semi-medium and semi-minor axes

have been scaled to the 95% confidence region (approximately 2 sigma) by the 3D expansion factor. PPM is computed as (semi-major axis / chord distance * 1,000,000).

Station 3D Error Ellipsoids

Confidence Level 0.950
Expansion 3D 2.795

AT	Major	Medium	Minor
5010	0.3115	0.2684	0.1439
Azimuth	12.8	102.8	17.8
Zenith	88.7	89.9	1.3
BEND	0.6524	0.5469	0.1251
Azimuth	119.0	29.0	25.2
Zenith	90.0	89.8	0.2

Connected Station 3D Error Ellipsoids

Confidence Level 0.950
Expansion 3D 2.795

AT	TO	Major	Medium	Minor	Chord	PPM
5010	BEND	0.5791	0.4202	0.1477	57354.4149	10.0977
Azimuth		122.3	32.3	71.3		1:99032
Zenith		90.1	90.1	0.1		
5010	BENTLY	0.2286	0.2098	0.1314	42784.1371	5.3425
Azimuth		8.4	98.4	11.3		1:187180
Zenith		88.4	89.9	1.6		

Adjust the MIXED.TXT network using orthometric height as the vertical control instead of ellipsoidal height. To do this, from the **Options** menu, select **Global Settings** and change the **3D Geodetic Height** option to **Orthometric Height**. COLUMBUS will then use the Ortho Hgt field for any station held fixed in 1D or 3D. For this network, the orthometric height of 1033.07590 meters for Station MACK would be used rather than the ellipsoidal height of 1000.00000 meters.

Try adjusting the remaining vertical, geodetic, State Plane, UTM, and Local Horizon networks and compare your results with the applicable *.RPT file. The abbreviated instructions for solving each network are described within each *.TXT sample file.

A Word About Approximate Coordinates

2D and 3D adjustments are iterative processes requiring an initial starting solution. The initial starting solution is given by the initial approximate coordinates for the unknown stations. Most of the time, COLUMBUS can compute these approximate coordinates using the selected control stations and the measured observations. Occasionally, however, COLUMBUS is unable to compute approximate coordinates for one or more stations. In the event this occurs, you must provide the approximate coordinate for these stations (which usually can be scaled from a map). For additional information regarding approximate coordinates, please visit the Quick Tips section of our Web site (www.bestfit.com).

User-supplied approximate coordinates can be entered directly from one of the applicable **Data - Stations** dialog, or they can be entered within the ASCII (Text) input project file.

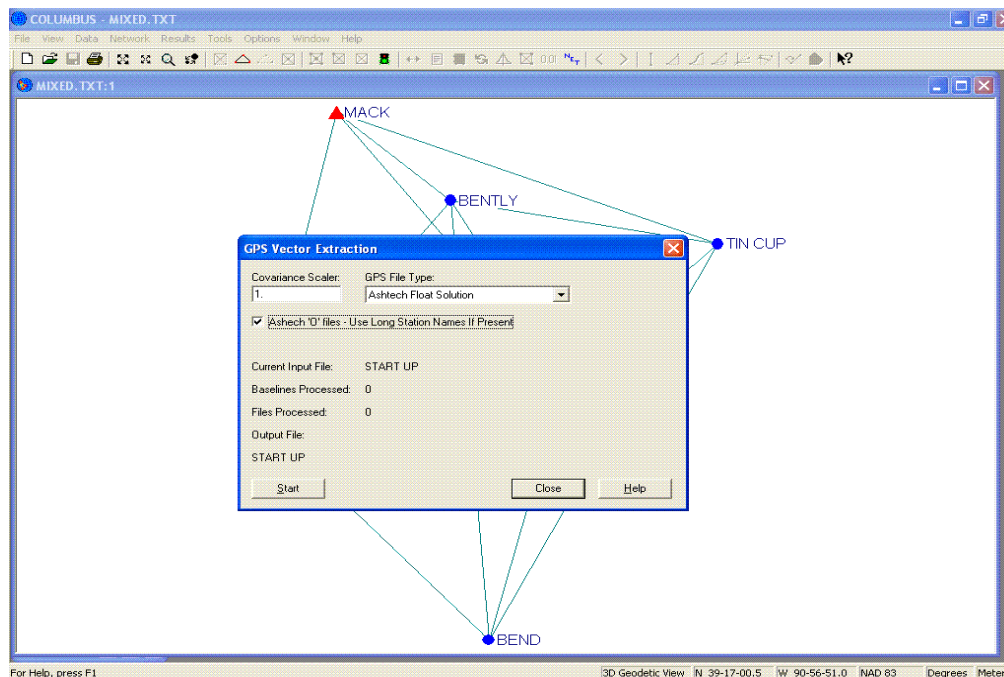
When creating a network containing only terrestrial observations (no GPS), you must provide network orientation by including either an azimuth, bearing, local NEU vector OR a second 2D or 3D control station.

GPS And Conventional File Format Support

GPS baselines (vectors) can be integrated into your ongoing geodetic projects. COLUMBUS currently supports Ashtech, Leica, Topcon, and Trimble post-processing files. Other receiver manufacturers generally have the ability to create the above receiver file types or they can create NGS Bluebook files, which we also support. We also support formats that are often used for conventional observations, including: TDS rw5 and raw, Topcon XML, and Nikon raw.

For each supported format, the process for loading the data into a COLUMBUS is essentially the same: Convert the supported file format to the COLUMBUS file format, then load the resulting file into COLUMBUS. Some of these conversion tools are built directly into COLUMBUS, while others are implemented as stand-alone tools. New support for additional 3rd party formats are being developed as stand-alone conversion tools. We have adopted this approach so that we can maintain these tools without changing the COLUMBUS software itself. It also allows us greater flexibility in making new conversion tools available without scheduling them into a future release of COLUMBUS. Downloads of the current stand-alone tools can be found at www.bestfit.com/file_conversion.shtml

Figure 7: GPS Vector Extraction Dialog Box



3rd party data extraction can be completed in one COLUMBUS session or over the life of the project. With our new **Include File** support, you can create one **master.txt** file and include hundreds of smaller files, each possibly representing a day of field collection. At any time, you can load the **master.txt** file and the included files will automatically be loaded. You can then verify loop closures or perform ongoing adjustments.

GPS file formats supported from the **File - Convert 3rd Party files - GPS Receiver Files** menu are described below. All other supported formats are implemented as stand-alone conversion tools (mentioned above).

Ashtech GPS Receivers

Ashtech 'O' binary files contain GPS vectors. We support this file type directly.

Leica GPS Receivers

Leica uses an ASCII file format created within their SKI software system.

Sokkia GPS Receivers

Sokkia supports the creation of many different file formats. You can even create a GeoLab-compatible file that we can convert to the COLUMBUS format.

Topcon-GeoComp GPS Receivers

These receivers create a text file containing one baseline solution per file. Topcon also allows you to create Ashtech 'O' files and Topcon XML files, which we directly support.

Trimble GPS Receivers

Trimble baseline files come in a variety of forms, depending on the type of GPS survey performed. COLUMBUS supports ASCII and binary formats.

The supported ASCII format is for the single baseline 640 processor. These include *.FIX, *.FLT and *.TRP files.

The binary *.SSF format is supported from output from the multi-baseline processor. These files contain float, triple, fixed or fast-static solutions.

The *.SSK binary file is created from the multi-baseline processor from data collected during kinematic and pseudostatic surveys. These file are also supported.

Wave processor files for rapid static surveys (may have SSK or SSF file extension).

Trimble Geomatics Office text file output files. These are processed within COLUMBUS by selecting from the **File** menu, the **Convert 3rd Party Files** command, and then selecting **Trimble Geo Office (*.ASC Files)**.

To extract baseline data from any of the above receiver manufacturer files, the steps are essentially the same. They are summarized below:

1. Determine the receiver manufacturer file type to be processed. Some vendor files contain only one baseline per file. Others contain several baselines within each file.
2. From the **File** menu, select **Convert 3rd Party Files** and select the file type to process.
3. Next, decide if the variance - covariance matrix for each baseline should be scaled. Most of the time, you will use the default scaler of 1.0 (i.e., in effect, no scale change). You can also scale individual baselines, groups of baselines, or all baselines by imbedding the **\$\$XYZ_COV** keyword throughout the resulting ASCII (Text) file. See Appendix A for more information on the **\$\$XYZ_COV** keyword.

To scale all the current baseline variance - covariance matrices, type the scaler value in the **Covariance Scaler** edit box. As each baseline is extracted, the variance - covariance matrix for that baseline will be multiplied by the scale factor, then written to the resulting ASCII (Text) file.

4. To begin the extraction process, click the **Start** button. You will be prompted to select one or more GPS receiver files. To select a range of files, select the first file in the range and then, holding the **Shift** key down, select the last file in the range. To select multiple files, hold the **CTRL** key down and click on each file individually. All selected files will be highlighted.
5. After making your file selection, click the **Open** button. COLUMBUS will prompt you for the name of a COLUMBUS ASCII (Text) data file in which to write the extracted GPS baseline data.
6. After entering a file name, click the **Save** button and COLUMBUS will begin processing your files. As each baseline is extracted, the Baseline Counter is incremented by one.

The resulting ASCII (Text) data file can be opened or appended into COLUMBUS by selecting from the **File** menu either **Open** or **Append**. You can either edit your control stations from within COLUMBUS (after opening the data file) or within the ASCII (Text) data file itself. Within the ASCII (Text) data file, each station is represented in geodetic form. They can be

identified by the **\$GEO** or **\$GEO_COMPACT** code. Latitudes are positive in the Northern Hemisphere and negative in the Southern Hemisphere. Longitudes are positive in the Eastern Hemisphere and negative in the Western Hemisphere.

When editing stations within the ASCII (Text) data file, it is only necessary to edit the first instance of the station, i.e., the first time the station is defined in the file by the \$GEO code. When the data file is opened, each additional instance, if applicable, is ignored.

Note:

When you open the ASCII (Text) data file, it will be associated with whichever datum is active. Therefore, be sure to select the appropriate datum prior to opening your ASCII (Text) files by selecting **Datums** from the **Options** menu and selecting the desired datum. If your datum is not internally supported, you can add a new datum.

To add a new datum:

1. Open a new empty project by selecting **New** from the **File** menu.
2. From the **Data** menu, select **Datums**. Click on the **Add Datum** button and enter the datum name, semi-major axis and $1/f$ coefficient.
3. Click the **Keep and Exit** button to close the dialog and keep the changes.
4. From the **Options** menu, select **Datums** and select the new datum to be active.
5. The datum entered is now configured into COLUMBUS and is active. Close the current empty project.

Solve All Combinations For Constrained Adjustments

COLUMBUS supports an advanced technique to automate the search for the best-fit network adjustment solution. This technique, available for 1D, 2D and 3D networks, is accessed through the **Adjustment Combinations Tool** (from the **Network** menu, select **Adjustment (Fixed – All Cases)**). It is based on combinatorial theory, which is applicable to many real-world problems.

Combinatorial Theory

Suppose you own a small surveying firm and have just received a GPS control survey contract. To complete this survey on time, you have estimated at least three experienced GPS surveyors must be dedicated to the project. Within your small company, there are five people qualified from which to choose (Tom, Mary, Dave, Alice and Andy). At the moment, all five are free to work on this project. The question, then, is which people should be put on the project? How many combinations of solutions are possible?

You could decide to put only three on the project. Or you might add a fourth or fifth to finish sooner.

Tom, Mary, Dave
Tom, Mary, Alice
Tom, Mary, Andy
Tom, Mary, Dave, Alice
Tom, Mary, Dave, Andy
Tom, Mary, Dave, Alice, Andy

As you might expect, the total number of possible combinations can grow very large. In fact, the actual number of combinations is given by applying the formula below.

$N!$

 $K! * (N - K)!$

where:

! = factorial
N = total number of qualified people available (in this case, five)
K = number of qualified people for any given solution

For this example, the formula needs to be applied **three times**: once for $K = 3$, once for $K = 4$ and once for $K = 5$. The results from each are then added together.

The answer to this example is: $10 + 5 + 1 = 16$

Note:

$5! = 5 * 4 * 3 * 2 * 1$
 $4! = 4 * 3 * 2 * 1$
 $3! = 3 * 2 * 1$

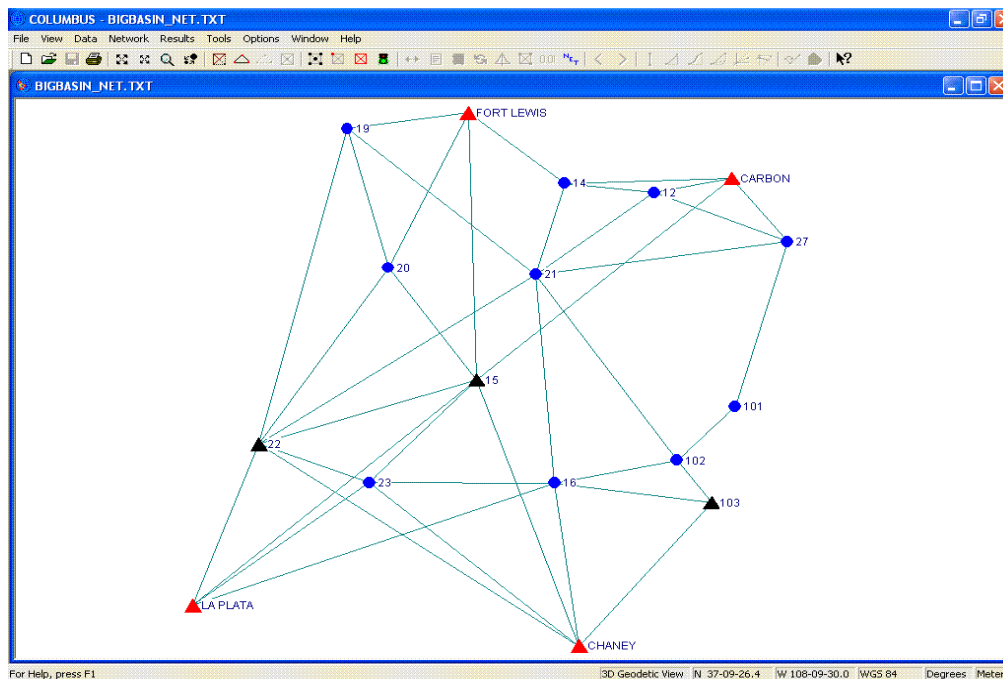
How Does This Apply To Network Adjustment?

For a network adjustment the same type of process can be applied, but instead of different people, we have several different control stations. Each control station is uniquely identified by its known coordinates.

The **Adjustment Combinations Tool** can be used when you are ready to perform a constrained adjustment. Before using this tool, you should have performed repeated free adjustments and removed any possible bad observations.

If you have several control stations tied to your network, several possible combinations of control station scenarios exist. You could use all the control you have, or you might decide to use a subset of your total available control. Using other adjustment software systems you would perform several constrained adjustments, altering which stations are set up to be fixed for each adjustment. After finding the most favorable results, you would perform a final adjustment and be done.

The manual process described above would require many hours of user intervention as you changed the configuration of control for each adjustment combination. Also, you might leave one of the possible combinations out, never knowing if it would have been the best solution. With the **Adjustment Combinations Tool**, COLUMBUS performs these iterative steps for you quickly, easily, and without leaving any possible solution untested! You simply set up the processing parameters, begin processing, then take a coffee break. Meanwhile, your computer continues to work on your behalf.



Example:

You have a 3D geodetic network consisting of 17 stations (use BIGBASIN.TXT) and over one hundred observations. You have completed the free adjustment process and have removed all poor quality observations. Of the 17 stations in your network, you have known 3D geodetic coordinates for four of the stations and known 1D height for three additional stations. Set the 1D fixed stations 15, 103, 22. Set the 3D fixed stations CARBON, CHANEY, FORT LEWIS, and LA PLATA.

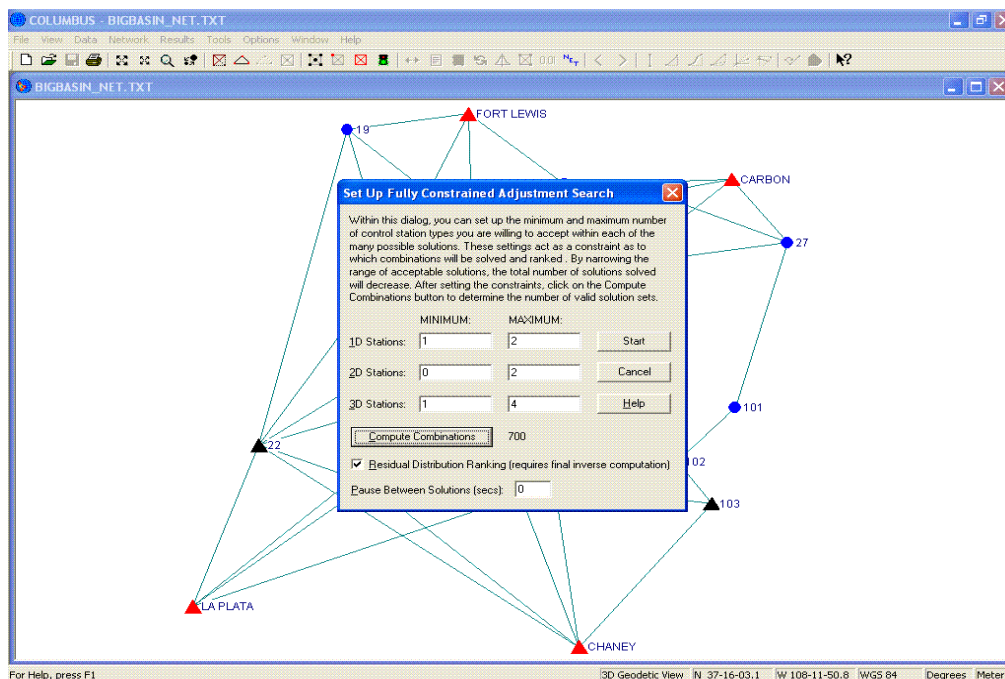
Within COLUMBUS, you would select these stations to be fixed in 1D and 3D, respectively. Select all observations to be in the network (**Network - Observations** menu). From the **Network** menu, select **Adjustment (Fixed - All Cases)** to bring up the adjustment search dialog as shown below. Here is where you specify the combinations of control configurations that are desirable in any final solution. This is accomplished by setting up the minimum and maximum number of control station types you want to have in each acceptable configuration.

For any constrained 3D geodetic network, you need a minimum of three fixed combination parameters (two fixed parameters are required for 1D or 2D networks). Stations fixed in 1D or 2D count as one parameter. Stations fixed in 3D count as two parameters - since they have both a 1D and 2D component. *This parameter concept is only applicable to solving all combinations.* A constrained 3D geodetic network would require (at a minimum) any of the following:

- One 1D fixed station + one 3D fixed station
- One 2D fixed station + one 3D fixed station
- Two 1D fixed stations + one 2D fixed station
- Two 2D fixed stations + one 1D fixed station
- Two 3D fixed stations

Note: Three or more stations fixed in only 2D or only 1D will not work, since you need at least 3D worth of control for a 3D constrained adjustment.

By selecting the minimum and maximum number of control stations you are willing to accept in any possible solution, the range of possible solutions can increase or decrease.



For this example, we have decided that each solution must have at least one station fixed in 1D and one station fixed in 3D. You would declare this by setting the **Minimum** boxes for 1D and 3D stations to '1'. Additionally, we have decided we want a maximum of two 1D stations in any given solution. You would declare this by setting the **Maximum** box for 1D stations to '2'. Finally, for any given solution, we want no more than two stations to be fixed in 2D. You would declare this by setting the **Maximum** box for 2D stations to '2'.

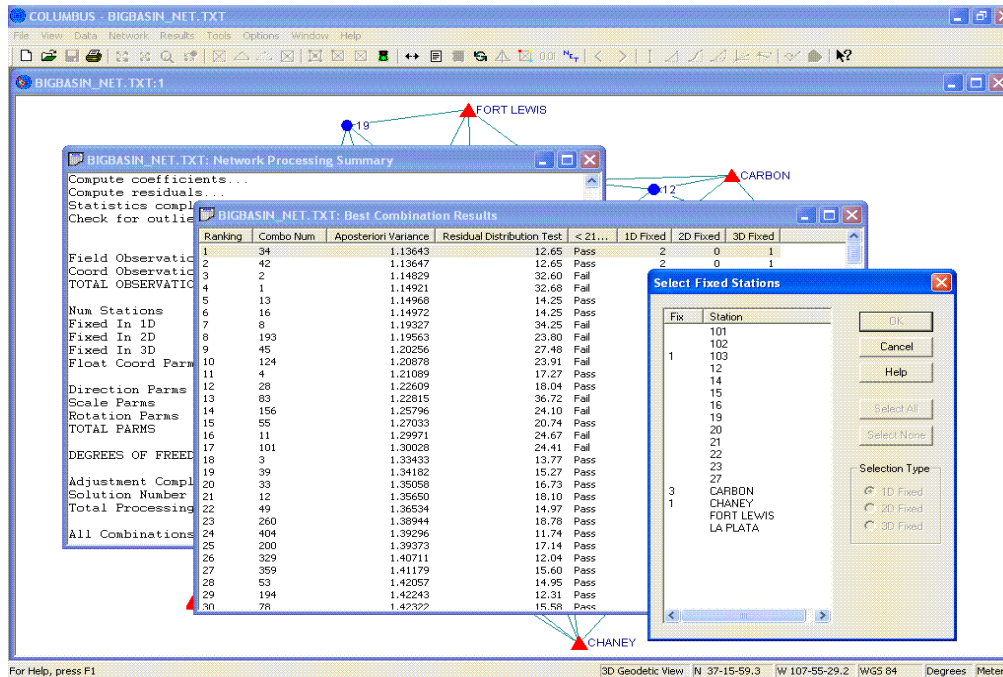
For the settings above, each combination solved by COLUMBUS will have:

- At least one station fixed in 1D
- At least one station fixed in 3D
- No more than two stations fixed in 1D
- No more than two stations fixed in 2D
- No more than four stations fixed in 3D

Click on the **Compute Combinations** button to calculate the total number of combinations that will be solved. For this example, 700 solutions fit the criteria! Each one of these combinations would satisfy the constraints defined above.

As you can see, there are many possible solutions even with as few control stations as described above. To perform this task manually would be error prone and very time-consuming.

Click on the **Start** button and watch COLUMBUS do the work. After the processing has completed, open the **Results - Best Constrained Combos** view to see the top 500 solutions. To view the stations that were held fixed (in 1D, 2D, or 3D) for any given solution, highlight the solution, then click on the **View Fixed Station Details** toolbar button. You can also use the **File - Print Preview** command or generate a report to see more detailed information about each solution.



How Solutions Are Ranked

As COLUMBUS processes each new combination, it keeps track of the top 500 solutions based on two independent tests: the **A Posterior Variance Factor Test** and the **Residual Distribution Test**. When processing is complete, these solutions can be displayed and printed. You can then pick which of these solutions to use as your final constrained adjustment. Or you might take a closer look at the top 10 solutions by solving them individually and looking at several other statistical indicators presented by COLUMBUS after the traditional network adjustment process.

The A Posteriori Variance Factor ranking is always performed. The closer the A Posteriori Variance Factor is to 1.0, the better the ranking for a given solution. This test does not require a final inverse on each solution - resulting in faster processing times for larger networks.

The Residual Distribution Test is optional. It will give you a numerical indicator as to how evenly the Standardized Residuals (for all observations) are distributed about their mean. Since this test requires additional statistical information found within the final inverse for each solution, it will lengthen processing times for large networks when enabled.

These are just two tests used by COLUMBUS to help you narrow down the 700 possible solutions to about 10-20 solutions. You can then examine individual solutions (from the top 20) by performing a separate network adjustment based on each scenario.

Why Not Just Use All Known Control?

The answer depends on the quality of the control in your area. Some control points may be more reliable than others, based on how they were established. Some control points may have been disturbed since they were originally surveyed. This could be a result of geological movement, vandalism or even wildlife. Simple instrument centering/height measurement errors could also influence the observed quality of any given control station. You may never know if the control point has these problems, because your first inclination may be to suspect your own observations.

By solving all possible combinations, you have the best opportunity to eliminate control that may be introducing significant errors into your project.

Contacting Best-Fit Computing

We hope you've enjoyed working with our geodetic network adjustment software. If you have any questions, comments or would like to order COLUMBUS, please contact us at:

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