FILLNET WinPrism Network Adjustment

User's Guide

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Table of Contents

List of Figures

List of Tables

1

Introduction to Fillnet Program

This manual describes the FILLNET program. FILLNET is a three-dimensional least-squares adjustment program for the GPS delta-X, delta-Y, delta-Z vectors that result from Ashtech's WinPrism vector processing programs. Whereas WinPrism processes baselines individually, FILLNET puts the baselines together and determines how well they fit into a network.

FILLNET incorporates a Graphical User Interface (GUI). GUI makes FILLNET easy to use by persons having little experience with personal computers. GUI provides a group of menus (computer displays) which list all the options available for each operation of the adjustment procedure. The menus assist and guide the user through intricate procedures, avoiding errors and false starts. Descriptive titles make it easy to determine what to do at any step. A mouse is used to select the appropriate option from the menu and initiate the particular operation.

FILLNET is designed for but not limited to network densification. The program uses empirically derived diagonal weight matrices instead of the full covariance matrices produced by the initial reduction software. This approach is used because the full covariance matrices express only the internal consistency of the observations rather than absolute accuracy, and are therefore of limited usefulness.

FILLNET performs two types of adjustments: free and constrained. Generally, in the free adjustment, FILLNET holds one point fixed and fits all vectors to this point. In the constrained adjustment, FILLNET holds several points fixed and solves for scale, rotation, and other parameters. Free adjustments test the internal consistency of all of the network vectors in the network. A constrained adjustment fits the network into established local control.

FILLNET scales and rotates all input baselines onto the chosen ellipsoid. As such, heights are generally assumed to be ellipsoidal. However, FILLNET will also accept orthometric (mean sea level) heights which can be converted to ellipsoidal heights through the use of the GEOID96 geoid height data files to determine the geoidal separation.

After performing an adjustment, FILLNET automatically stores the results on your hard disk. FILLNET automatically assigns this file the same file name that you assigned at the beginning of the procedure, and adds the extension .FOP. For example,

    TESTFILE.FOP

These files can be archived, used for further processing, or copied onto a floppy disk for portability.

FILLNET now includes functions that were formerly separate programs. These are ADJUSTIN, NAMES, SHOOTER, and FILLPPM. The functions are transparent to the user, no longer identified by name, and are activated by using a mouse to select an icon on a menu.

Reference Documents

This manual is used in conjunction with the Ashtech WinPrism manuals.

Getting Started

Using FILLNET

After you have installed the WinPrism software suite, you can run the FILLNET module in the following way.

1. Start WinPrism as described in the Getting Started Chapter of the Introduction to WinPrism manual. You will be presented with a screen like the one Figure 2.1.
2. Select the directory where your input files to the adjustment exist.
3. Click on the ADJUST button. You will be given the choice of running SNAP or FILLNET, as shown in Figure 2.2.

Figure 2.1: FILLNET Directory

Figure 2.2: FILLNET Activate program

Click on the “No” button to select FILLNET.

The main menu screen will then appear as shown in Figure 2.3.

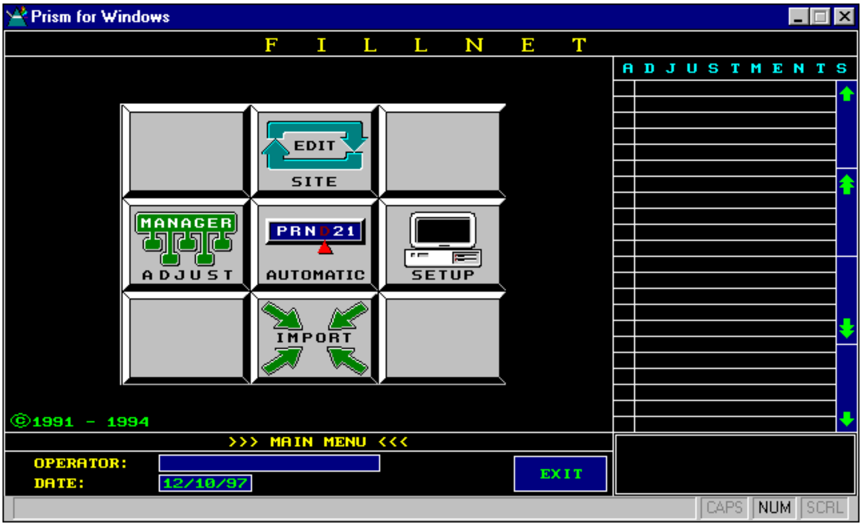

Figure 2.3: FILLNET Main Menu

The main menu tells you what options you have at this point. These options are described in Table 2.1:

Table 2.1: Main Menu Option Descriptions

Menu Option	Description
ADJUST MANAGER	This option allows you to create, copy, delete, rename, and combine adjustments.
IMPORT	This option brings in the baseline files that are to be processed; not active until you have selected an adjustment.
SETUP	This option lets you define a priori bias constraints and adjustment parameters, such as ellipsoid, etc.; not active until you have selected an adjustment.
EDIT	This option lets you edit point and vector data - for example, fix or constrain stations and vectors, or delete data that is obviously faulty; not active until you have selected an adjustment.
AUTOMATIC	This option lets you perform the adjustment, view the results, update the preliminary coordinates by replacing them with the adjusted coordinates, and perform a loop closure analysis; not active until you have selected an adjustment. Near the bottom of the display you will see:
OPERATOR	In this block you can enter your name or some kind of identification. (Optional)
DATE	If your computer has a real-time clock, today's date will be displayed in this block; if not, the block will be blank. If a date is displayed, you can leave it as is, or type in whatever date you want.
EXIT	Exits the FILLNET program and returns you to WinPrism.

Move the mouse across the surface of your work area and verify that an arrow on the display moves in response to the mouse. If there is no arrow, or if the arrow does not move, the most likely problems are a loose mouse connector on the back of the computer, or missing or incorrect mouse software on the hard disk. You must have an operational mouse before you can continue.

1. The first step is to create an adjustment. This is done in the **ADJUST MANAGER** option. Using the mouse, move the arrow to **ADJUST MANAGER**. Note that when the arrow enters the **ADJUST MANAGER** button the border of the button gets dark to indicate that it is active. Press the left button on the mouse (hereinafter, pressing the mouse button will be

referred to as "clicking"). The **ADJUST MANAGER** menu should appear, as shown in Figure 2.4.

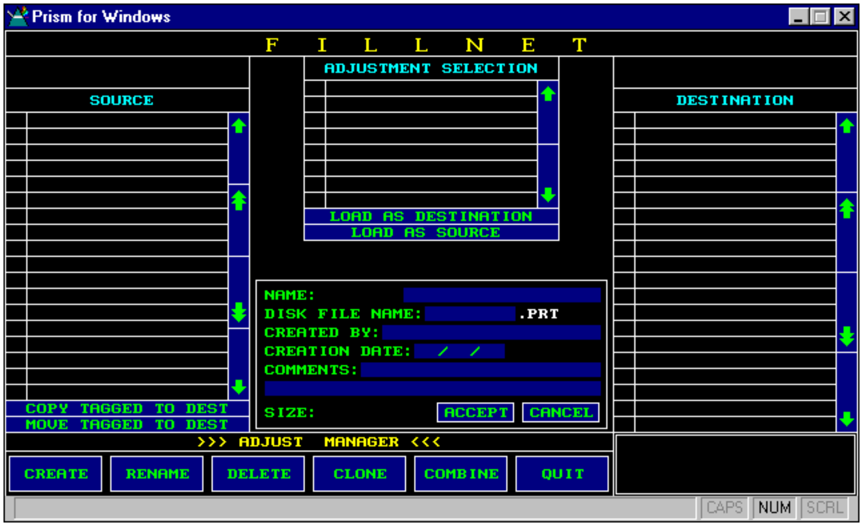

Figure 2.4: ADJUST MANAGER Menu

The **ADJUST MANAGER** menu gives you the following options:

CREATE - The starting point - allows you to create an adjustment file

RENAME - Allows the tagged adjustment to be renamed.

DELETE - Allows the tagged adjustment to be deleted.

CLONE - Allows the tagged adjustment to be copied to a new adjustment.

COMBINE - Allows two adjustments, one loaded as **SOURCE**, the other loaded as **DESTINATION**, to be combined into the destination adjustment. You can also copy portions of one adjustment into another by loading the original adjustment as **SOURCE** and the destination adjustment as **DESTINATION**; then tag the vector(s) from the source adjustment under the **SOURCE** window that you wish to copy into the destination adjustment by clicking on the box next to the vector(s). Finally, select either the **COPY TAGGED TO DEST**. or **MOVE TAGGED TO DEST**. button at the bottom of the window. The selected vector(s) should show up in the destination adjustment in the **DESTINATION** window.

QUIT - Returns control to the main menu

2. Click on the **CREATE** button. The adjustment information box in the lower center of the screen is now active and all of the other buttons outside this box

are inactive. This box includes the following fields for the user to type in information:

NAME - the descriptive name for the adjustment project

DISK FILE - the DOS disk file name for the adjustment

CREATED BY - the user's name or ID (optional)

CREATION DATE - the date the adjustment was created (optional)

COMMENTS - any comments the user wants to enter regarding the adjustment (optional)

ACCEPT - Click on this button to accept the entries or modifications made to the above fields during a **CREATE**, **RENAME**, or **CLONE** operation.

CANCEL - Click on this button to ignore any entries or modifications made to the above fields and cancel the **CREATE**, **RENAME**, or **CLONE** operation.

Move the cursor to the **NAME** field and type in a descriptive name for the adjustment. Press **ENTER** or move the arrow to the **DISK FILE** field, then type in a descriptive name for the DOS disk file that **FILLNET** will automatically create. If you wish, enter appropriate information in the **CREATED BY**, **CREATION DATE**, and **COMMENTS** fields. Click on **ACCEPT** when you are satisfied with the entries. You will see the created adjustment appear in the upper center window under **ADJUSTMENT SELECTION**. There should be a check mark next to it to indicate that it is the tagged or currently selected adjustment.

3. Once you have created an adjustment, click on **QUIT** to exit the **ADJUST MANAGER** screen and return to the main menu.
4. The next step is to import the vectors via the O-files from PRISM for the network you wish to adjust. This is done using the **IMPORT** option.

5. Click on the **IMPORT** button. The **IMPORT** menu should appear, as shown in Figure 2.5

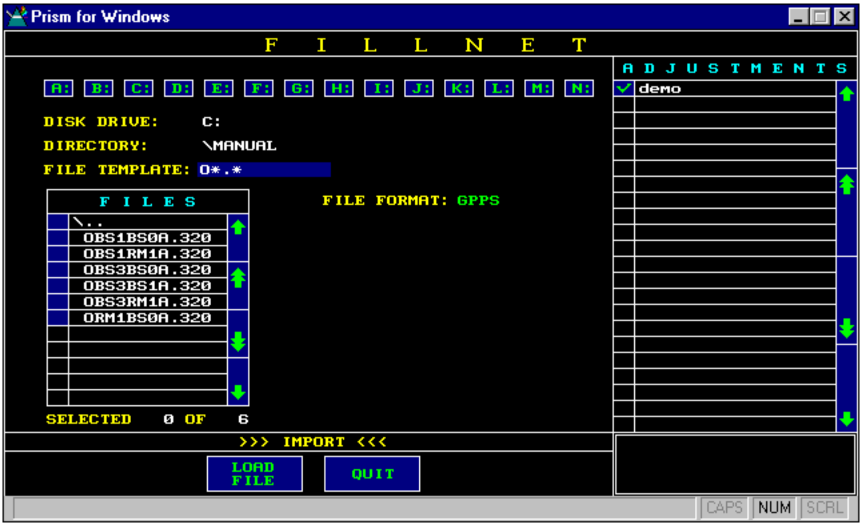

Figure 2.5: IMPORT option

The adjustment you created should appear under the **ADJUSTMENT** window on the right-hand portion of the screen. If the adjustment is not tagged (doesn't have a check mark next to it), tag it by clicking on the box next to the adjustment name.

If necessary, change the drive by clicking on the drive letter in the upper right-hand corner of the screen to the drive where the O-files from PRISM are located. Once you have the appropriate drive, you can use the **FILES** window to move around the directories to enter in the appropriate directory. Once you are at the appropriate path, the O-files should be listed under the **FILES** window. You can use the arrow keys or mouse to see the rest of the O-files if they are not all shown in the **FILES** window.

6. Tag the O-files you wish to import by clicking on the box next to the O-file. A tagged O-file should have a check mark next to it. You can hold the mouse button down and drag the arrow over several file names to select a block of files. Re-clicking on a file untags that file.

7. Once you have tagged all the files you wish to import, click on **LOAD FILE** to load them into the adjustment. You should see the message

   "**loading file**"

   as the computer loads the files, along with a flashing horizontal bar which shows the completion of each file. When loading is complete, the message

   "**OPERATION COMPLETED**

   press button to continue..."

   should appear. Note that if the imported stations are not within the continental US or Alaska, or if you do not have the GEOID96 files in the FILLNET directory, the following message will appear:

   "**OPERATION COMPLETED, GEOID HEIGHT WAS NOT COMPUTED   press button to continue**"

   If you got the above message, click on the left mouse button to return to the **IMPORT** menu, otherwise click on **QUIT** to return to the **MAIN** menu.

8. Next, edit the data and set a station as fixed for use in the adjustment. This is done in the **EDIT SITE** option, as follows.

9. Click on the **EDIT SITE** option. The **EDIT POINTS** menu, Figure 2.6 should appear.

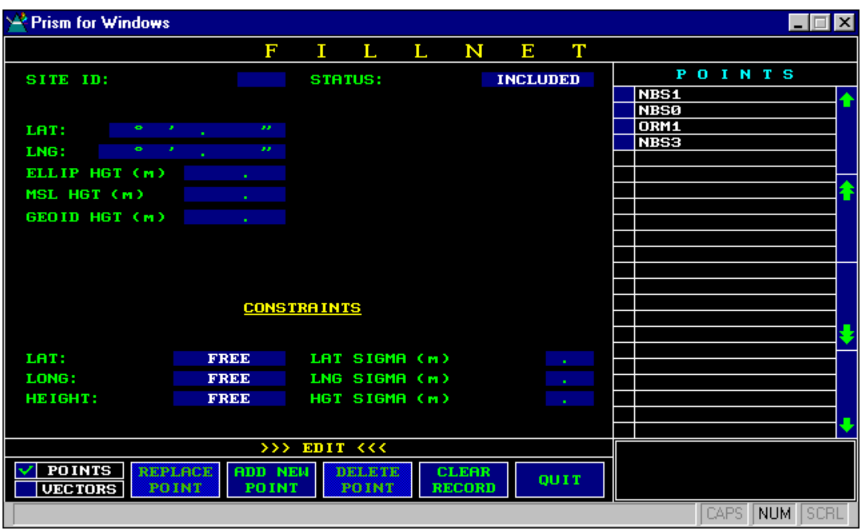

Figure 2.6: Edit Points Menu

10. Click on the station under the **POINTS** window you wish to hold fixed. The data associated with that point will appear in the fields to the left. If necessary, enter in the correct latitude, longitude, and height. In the mid-lower left-hand corner of the screen, under the **CONSTRAINTS** heading, toggle the **LAT**., **LONG**., and **HEIGHT**. fields from **FREE** to **FIXED** by clicking on each field.
11. Once you are satisfied with the modifications you have made to the station, click on **REPLACE POINT** to record the changes. Note that **[FFF]** appears next to the station.

    Note that if you do not set a station as fixed, FILLNET will hold the first station fixed for a free adjustment. This is usually acceptable because, in general, the first station on the list is the station used as the known station for PRISM processing.
12. Next, click on the **VECTORS** box in the lower left corner. The **EDIT VECTORS** menu, Figure 2.7 will appear.

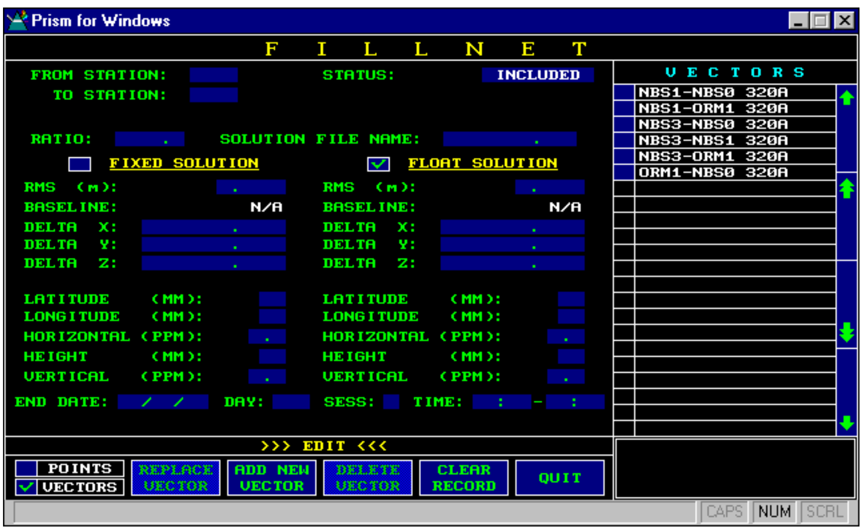

Figure 2.7: EDIT VECTORS Menu

Note that the vectors appear under the **VECTORS** window on the right-hand side of the screen. Some of the vectors may have an **[F]** next to them to indicate that the float solution is tagged. You may later wish to switch all of these to the fixed solution and readjust them. To do this, tag the float solution vector by clicking on the box next to the vector. The vector information will appear on the screen. Click on the box next to the fixed solution (if one is available) and then click on **REPLACE VECTOR**. The **[F]** symbol should disappear. Click on **QUIT** to return to the **MAIN** menu.

13. The next step is verify and/or modify the setup parameters. This is done in the **SETUP** option, as follows.
14. Click on the **SETUP** button. The **SETUP** screen should appear, as shown in Figure 2.8.

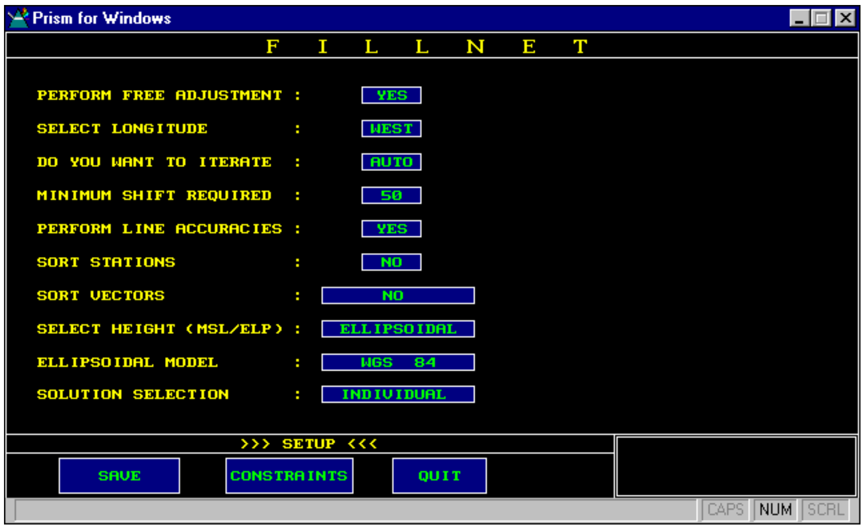

Figure 2.8: SETUP Option

The selections are (defaults are shown in boldface):

PERFORM FREE ADJUSTMENT	**YES**/NO
SELECT LONGITUDE	**WEST**/EAST
DO YOU WANT TO ITERATE	**AUTO**/NO/YES
MINIMUM SHIFT REQUIRED	**50**/0/10/20/30/40/60/70/80/90
PERFORM LINE ACCURACIES	**YES**/NO
SORT STATIONS	**NO**/YES
SORT VECTORS	**NO**/ALPHABETICAL/ BY LENGTH
SELECT HEIGHT(MSL/ELP)	ELLIPSOIDAL/MSL/MSL+GEOID HT

ELLIPSOIDAL MODEL	**WGS 84**/GRS80/INTL/WGS72/ CLARKE 1866/ATS77/NWL90/
BESSEL	KRASSOVSKY/EVEREST/
CLARKE1880	AUSTRALIA NT**SOLUTION**
SELECTION	**INDIVIDUAL**/ALL FLOAT/ALL FIX

In most cases for the initial free adjustment, the default selections are appropriate. To perform a constrained adjustment, click on the box next to **PERFORM FREE ADJUSTMENT** field to toggle it from **YES** to **NO**.

Be aware that the following ellipsoidal models are also available:

GRS80	BESSEL
INTERNATIONAL	KRASSOVSKY
WGS72	EVEREST
CLARKE 1866	CLARKE 1880
ATS77	AUSTRALIA Nt.
NWL9D	

In the **SOLUTION SELECTION** option, if you choose **INDIVIDUAL** the default is used. If you choose **ALL FLOAT** or **ALL FIX**, the input file is modified so that all of the selected solutions are float or fixed, respectively, assuming that a float or fix solution exists.

15. Click on the **CONSTRAINTS** button. The **CONSTRAINTS** menu, Figure 2.9 will appear.

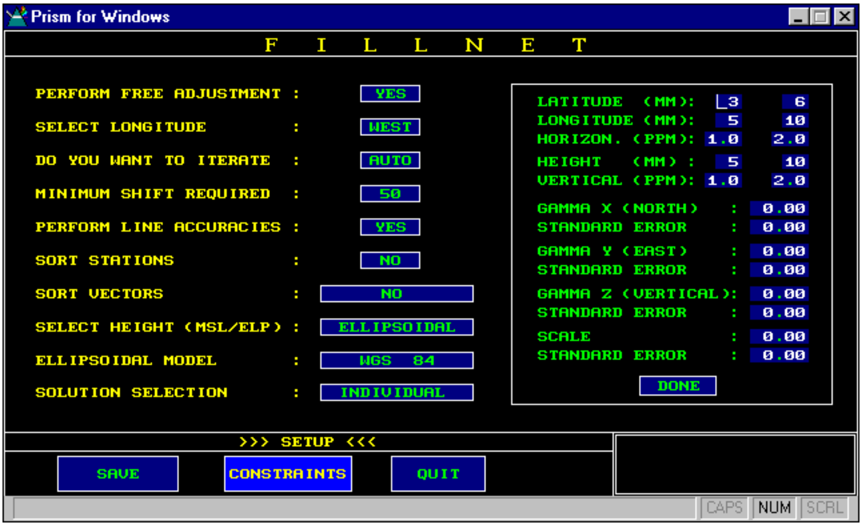

Figure 2.9: Constraints menu

Look at the default constraints, which is described in Table 2.2/

Table 2.2: Default Constraint Descriptions

Parameter	Fixed Solution	Float Solution
latitude	3mm	6mm
longitude	5mm	10mm
horizontal	1ppm	2ppm
height	5mm	10mm
vertical	1ppm	2ppm

Note that the error model (*a priori* errors) should be set to reflect the intended accuracy of the adjustment. In most cases for the initial free adjustment, the default selections are appropriate. For constrained adjustments you may need to increase the *a priori* error.

16. Click on **DONE** to accept the default constraints, and SAVE to accept the rest of the setup parameters. The message

    "**OPTIONS SAVED   press button to continue**"

    will appear.

    Press the mouse button, and click on **QUIT** to return to the **MAIN** menu.
17. Now you are ready to perform a free adjustment. This is done in the **AUTOMATIC** option, as follows.
18. Click on the **AUTOMATIC** button. The **AUTOMATIC** screen, Figure 2.10, will appear.

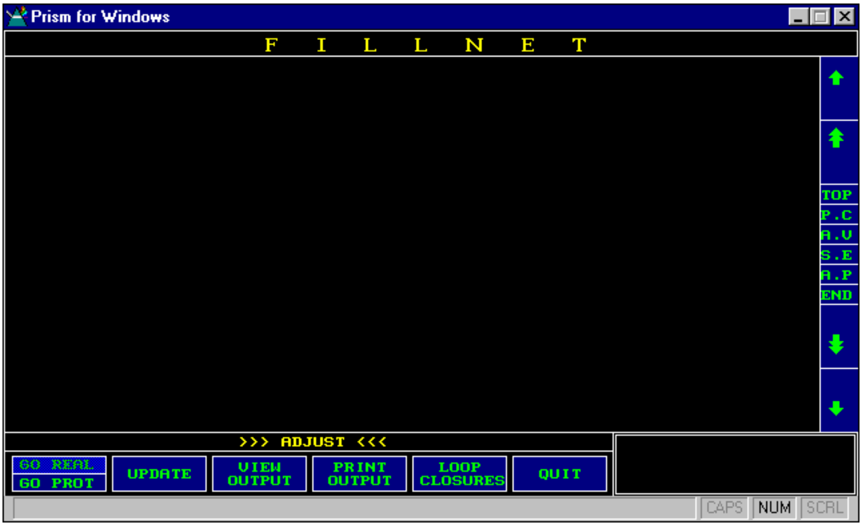

Figure 2.10: AUTOMATIC (ADJUST) Menu

Click on **GO PROT** to perform the adjustment. The message "**ADJUSTMENT IN PROGRESS**" will appear momentarily, and then the output results, as shown in Figure 2.11.

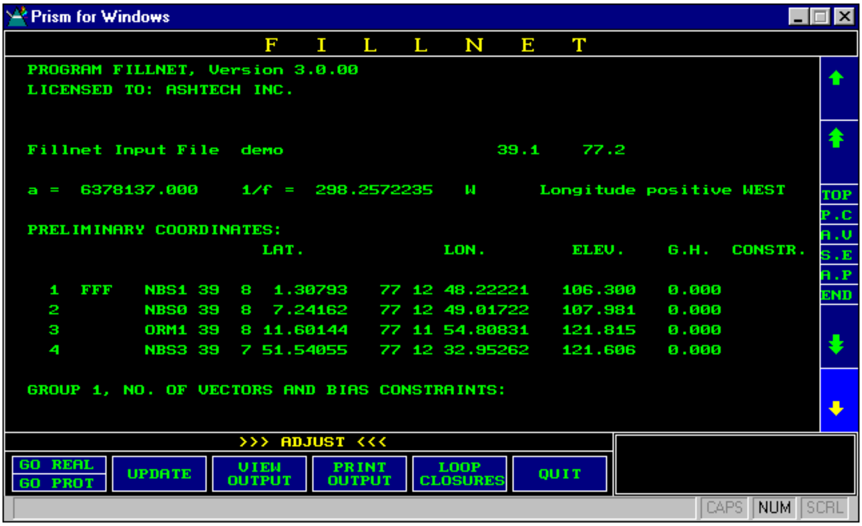

Figure 2.11: Preliminary Coordinates

19. With the adjustment finished and the output on the screen, you are ready to analyze the results. At this point you can also do loop closure analysis by clicking on the **LOOP CLOSURES** button. You can scroll to the adjusted positions portion of the output by clicking on the **A.P.** button bar at the right of the screen; similarly, the **S.E.** button will bring the standard errors into view, and so on. If you are satisfied with the adjustment and the adjusted

coordinates, you can use the **UPDATE** button to replace your initial coordinates with the adjusted coordinates.

Appendix C shows an example of a typical output. Figure 2.12 shows the typical procedure used for a FILLNET adjustment.

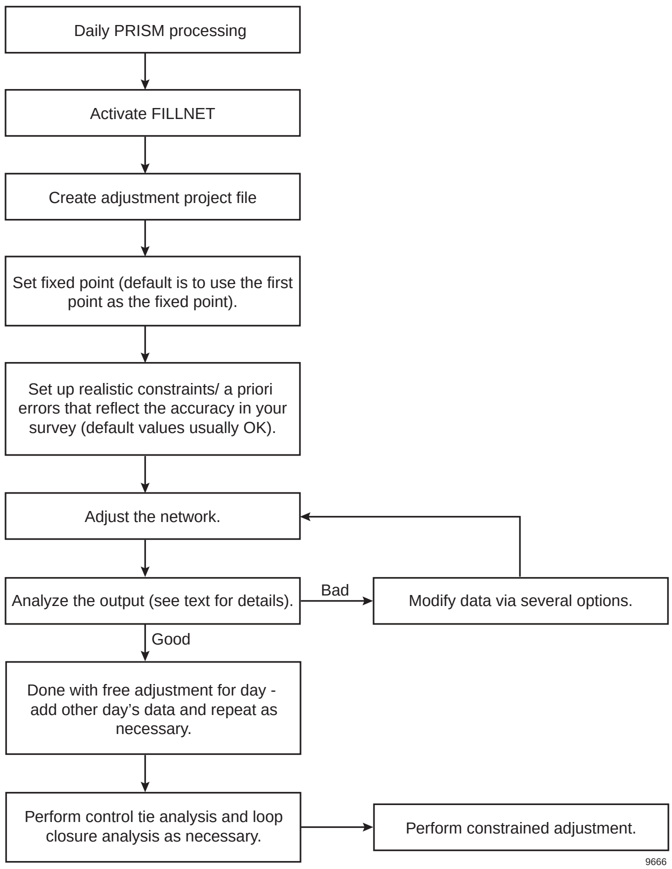

Figure 2.12: Typical Procedure for FILLNET Adjustment

The following two sections discuss how to analyze the results and take you through an example adjustment.

Analyzing Results and Troubleshooting

Analysis

After you have performed the adjustment by pressing GO in the **AUTOMATIC** screen, you should have the output shown in Figure 2.10 on Page 24.

The next step is to analyze the results. First check the value of the Standard Error of Unit Weight (S.E.). Locate this portion of the output by pressing the **S.E.** button in the right-hand bar of the **AUTOMATIC** screen. After you press the **S.E.** button, your screen should look similar to Figure 3.1:

Figure 3.1: Standard Error (SE) Portion of Output Display

- If the **S.E.** is significantly greater than 1, it indicates that either there is defective data or that the constraints are too restrictive. The defective data could be due to a problem baseline(s), or could occur if the entire survey was not observed properly to get the desired accuracy. The next step is to look at the adjusted vectors (**A.V.**) to isolate the problem baseline(s).

- If the **S.E.** is less than or equal to 1, the initial results for the adjustment look good. However, it is still important to check the adjusted vectors (**A.V.**) for any outliers.
- If the **S.E.** is significantly less than 1, the *a priori* errors may be too optimistic. Try to improve results and isolate hidden outliers by lowering *a priori* errors again to within reasonable limits, readjusting the network, and reanalyzing the results.

The next step is to look at the residuals associated with the adjusted vectors. The easiest way to locate this portion of the output is by pressing the **A.V.** button in the right-hand bar of the **AUTOMATIC** screen. After you press the **A.V.** button, your screen should look similar to Figure 3.2.

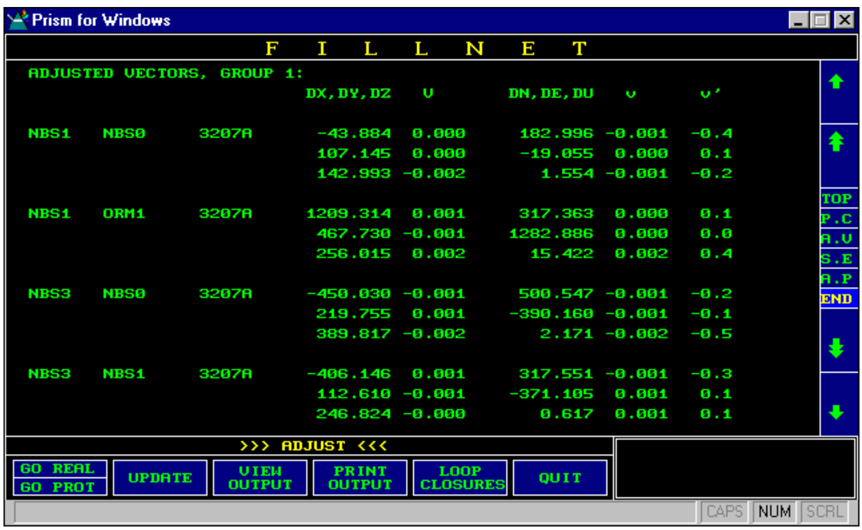

Figure 3.2: Adjusted Vectors Portion of Output Display

You can use the down arrow key to scroll through the vectors. You are interested in looking at the residuals (v) and the normalized residuals (v'), the two most right-hand columns. As you scroll through the adjusted residuals, check the v to verify that it is within the allowable error for your survey, and the v' to see if there are any vectors with a high v' as compared with the other vectors, or if any vector has a v' over 3.0. A vector with a v' over 3.0 means simply that the residual is 3 times larger than the assigned standard error. Any vector that has a v outside of the allowable error, or a v' greater than 3 or a v' that is abnormally high with respect to the other vectors is considered to be an outlier or a possible problem vector. If you notice that all of the outliers appear to go to a particular station, the station may be suspect. Check the station accuracies in the output. Ideally, you want all of the residuals to be low and consistent, recognizing that they will increase slightly with increasing baseline length.

If your S.E. is less than or equal to one, and the residuals associated with the vectors are within the constraints noted above, check the station accuracies, the line accuracies, and the adjusted positions (A.P.). If all of these are acceptable and within the accuracy of your survey, it is probably a good adjustment.

Otherwise you have to modify the data to deal with the problem vector(s) or station, readjust the adjustment, and re-analyze the results. The following section discusses several techniques for dealing with a problem vector(s). Usually, you want to work with the worst-case problem vector first.

Troubleshooting

This section suggests possible approaches to troubleshooting a bad adjustment.

If the O-files had both fixed and float solutions available, try using the alternative solution and reprocess. To tag the alternative solution, click on **QUIT** to return to the main menu, and then click on the **EDIT SITE** button. Figure 2.6 on Page 19 shows **EDIT POINTS** menu screen. In the lower left-hand corner, click on **VECTORS** to bring the **EDIT VECTORS** menu up (Figure 2.7 on Page 20) and then tag the appropriate vector. The vector information should appear on the screen. Click on the box next to the alternative solution, and then click on **REPLACE VECTOR**. Click on **QUIT** to return to the main menu and then re-adjust the adjustment in **AUTOMATIC**.

If there is plenty of redundancy in the network, and there is only one or two outliers, try excluding the bad vector from the adjustment. **Be aware that this may weaken the network, and may be unacceptable**. To exclude a vector, click on **QUIT** to return to the main menu, and then click on the **EDIT SITE** button. In the lower left-hand corner, click on **VECTORS** to bring the **EDIT VECTORS** menu up and then tag the appropriate vector. The vector information should appear on the screen. Click on the **STATUS** field to toggle it from included to excluded, and then click on **REPLACE VECTOR**. Click on **QUIT** to return to the main menu and then re-adjust the adjustment in **AUTOMATIC**.

If you feel that the overall constraints for the adjustment are too restrictive, you can loosen them. To loosen the constraints, click on **QUIT** to return to the main menu and then click on the **SETUP** button. Figure 2.8 on Page 21 shows the **SETUP** menu screen. Click on the **CONSTRAINTS** button to get the constraints parameter box. Enter in the appropriate values for the constraints, and then click on **DONE** and then **SAVE**. Once you have saved the constraint values, click on **QUIT** to return to the main menu and then re-adjust the adjustment in **AUTOMATIC**.

If you suspect the vector solution to be bad, go back to WinPrism and analyze the O-file and associated plot file. Modify the input parameters for WinPrism as necessary and reprocess. If you are then satisfied with the O-file solution, go back to FILLNET and first delete the bad vector from the adjustment. This is done in the **EDIT SITE / EDIT VECTORS** screen. Then, re-import the O-file into the adjustment re-adjust. Please refer to the Ashtech WinPrism Manual for details.

If you aren't able to improve the O-file solution to your satisfaction, nor want to exclude the vector because it will weaken the network too much, it is possible to de-weight the vector (i.e. loosen the constraints on a particular vector). To do this, click on **EDIT SITE** at the main menu, and then on **VECTORS** in the lower left corner of the screen. Tag the appropriate vector and the associated vector should appear on the screen. Enter in the appropriate constraint values in the **LAT, LONG, HOR. PPM, HT.,** and **VERT. PPM** fields under the tagged solution. Click on **REPLACE VECTOR** to accept the changes, and then on quit to return to the **MAIN** menu. Re-adjust the adjustment in **AUTOMATIC**.

If all of the problem vectors appear to involve a particular station, try re-evaluation the station in WinPrism. A common mistake is to use an incorrect antenna height for a particular station in processing. Please refer to the Ashtech WinPrism Manual for details.

A Demonstration Using Sample Files Included with Fillnet

The following procedure illustrates the steps in a typical vector adjustment procedure, using sample files that are part of the FILLNET program. The recommended procedure is to perform a free adjustment to test the internal consistency of the network, then a constrained adjustment to conform the network to local control.

1. Start FILLNET as described in Chapter 2, **Getting Started**. Wait for the **MAIN** menu to appear. In the **MAIN** menu, click on the **ADJUST**

MANAGER icon. The **ADJUST MANAGER** menu,Figure 3.3, will appear.

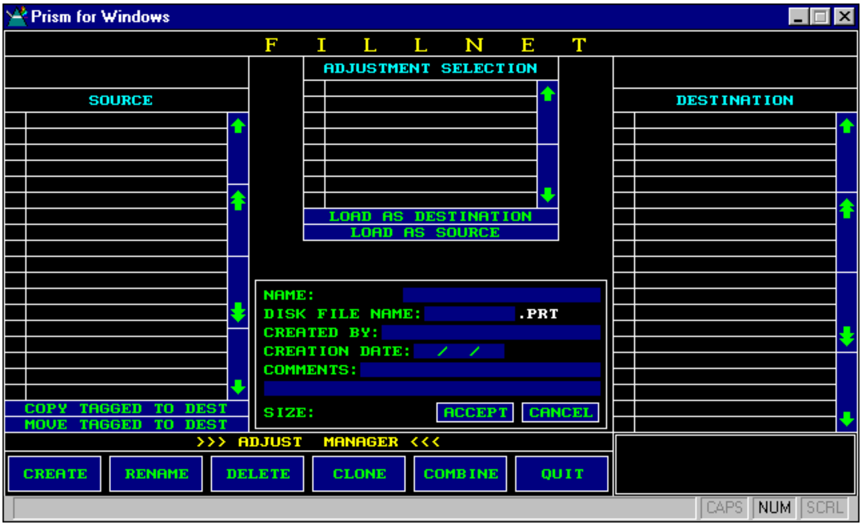

Figure 3.3: ADJUST MANAGER Menu

Click on **CREATE**.

2. In the **NAME** block, type a descriptive name for the adjustment you are creating. For this exercise, call it **DEMONSTRATION** and type

demonstration <ENTER>

The cursor will drop to the **DISK FILE NAME** block. Type in a base name for the disk files that FILLNET will create. For this exercise, call it **DEMO** and type

demo <**enter**>

Remember, this name must be 8 characters or less, per with DOS limitations, and will have a different extension automatically supplied by FILLNET.

3. Move the arrow to **ACCEPT** and click the mouse button. The word "**DEMONSTRATION**" will appear in the **ADJUSTMENT SELECTION** area. There should be a check mark next to the file name, showing that it has been selected.

4. Click on **QUIT**. The **MAIN MENU** will appear. Note that "**DEMONSTRATION**" is now listed in the **ADJUSTMENTS** area at the right edge of the display, accompanied by a check mark.

5. On the **MAIN MENU**, click on **IMPORT**. The **IMPORT** menu, Figure 3.4, will appear. The word **DEMONSTRATION** will be in the **ADJUSTMENTS** area on the right side of the display. There will be a list of the sample O-files in the **FILES** area at the left side of the display; these files will be used to do the adjustment.

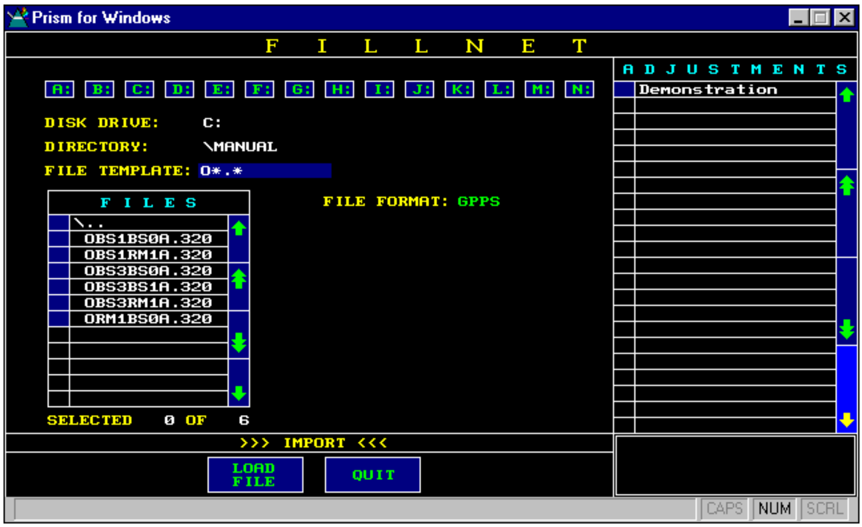

Figure 3.4: IMPORT Menu

6. Move the arrow to the vertical row of small squares at the left edge of the **FILES** area on the left side of the display. Click on all 12 of the files in the list, using the down arrow to access the files not initially shown.

Make sure there is a check mark in the square to the left of each file, indicating that the file has been tagged, and that the line below the file list indicates 12 of 12 have been selected. Move the arrow to the **ADJUSTMENTS** area on the right side of the display and click on the small square at the left of **DEMONSTRATION**, if it is not already tagged.

Click on **LOAD FILE**. The message

"**loading file**"

will appear at the bottom of the display, with a horizontal bar which shows the completion of each file. After a few seconds, the following message will appear:

"operation completed!"

If FILLNET cannot find the GEOID96 data files (*.GEO) in the WinPrism directory, the following message will appear:

> "**OPERATION COMPLETED, GEIOD HEIGHT WAS NOT COMPUTED press button to continue**"

In the **FILES READ** area there will be a number indicating the number of files that were loaded; this number should match the number of files that were selected.

7. Press the mouse button. **LOAD FILE** and **QUIT** will appear at the bottom of the display.
8. Click on **QUIT**. The **MAIN MENU** will appear. The demonstration file should be tagged, as indicated by a check mark in the small box at the left of the file name.
9. Click on **EDIT SITE**. The **EDIT POINTS** menu, Figure 3.5, will appear. In the **POINTS** area at the right side of the display you will see a list of points from the files you just loaded.

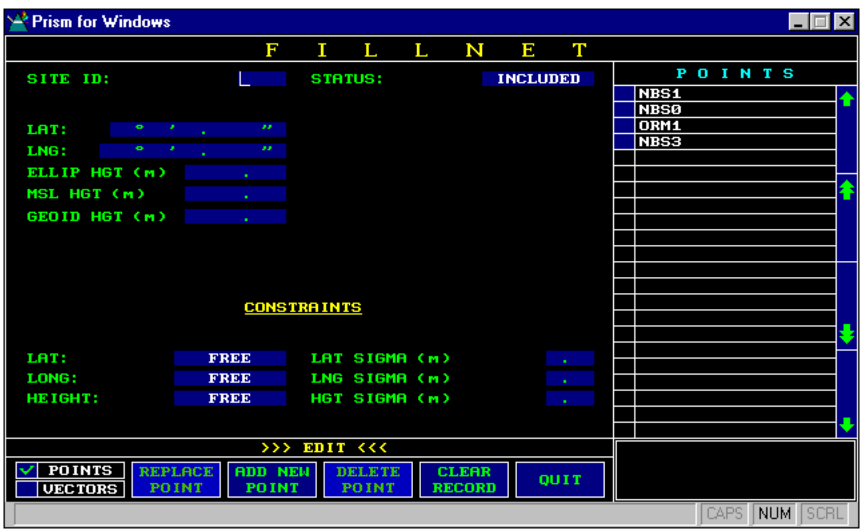

Figure 3.5: EDIT POINTS Menu

10. Click on the small square at the left of the point called 0001. The information associated with this point should show up in the fields on the screen to the left of the **POINTS** window. Set the position to:

```
LAT: 39° 8′1.30793″N
LONG:77°12′48.22221″W
ELLIP. HGT. 106.300
```

11. Change the constraints of LAT, LONG, and ELLIP. HGT. to **FIXED** by clicking on the appropriate fields.

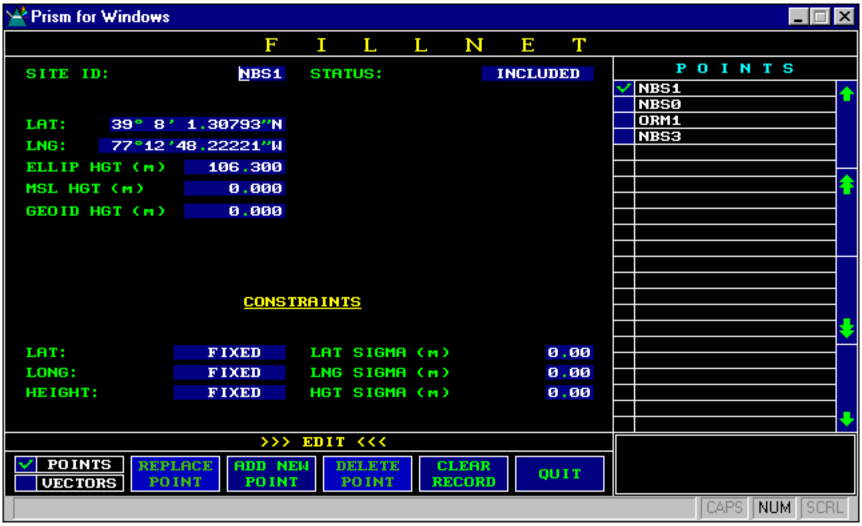

Figure 3.6: Edit Points screen with positions fixed

12. Record the changes you just made by clicking on **REPLACE** POINT. The message

    "OPERATION COMPLETED! press button to continue"

    will appear. Note that **[FFF]** appears to the right of the marked point 0001 in the **POINTS** area, to indicate your selection of **FIXED** for the selected point.

13. Press the mouse button, then click on **QUIT**. The **MAIN** menu will appear.

14. Click on **SETUP**. The **SETUP** menu, Figure 3.7, will appear.

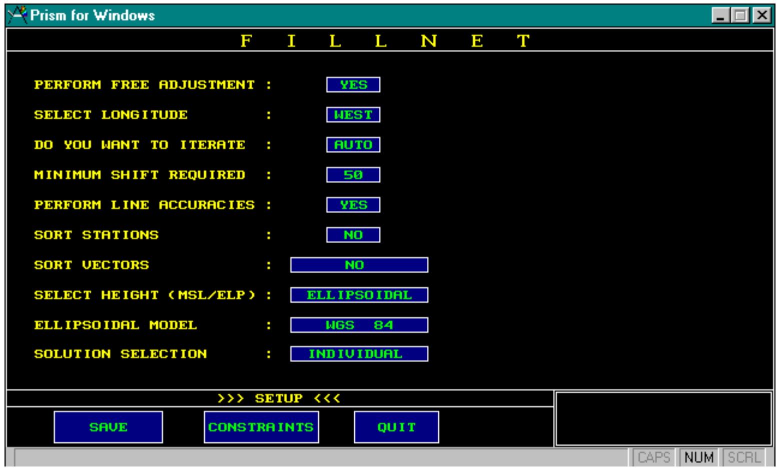

Figure 3.7: Setup Menu Screen

The default selections are:

PERFORM FREE ADJUSTMENT	YES
SELECT LONGITUDE	WEST
DO YOU WANT TO ITERATE	AUTO
PERFORM LINE ACCURACIES	YES
SORT STATIONS	NO
SORT VECTORS	NO
SELECT HEIGHT (MSL/ELP)	ELLIPSOIDAL
ELLIOSOIDAL MODEL	WGS84
SOLUTION SELECTION	INDIVIDUAL

15. Click on **CONSTRAINTS**. The **CONSTRAINTS** menu, Figure 3.8 will appear. Look at the default constraints, which for a free adjustment are:

Table 3.1: Default Constraints

Parameter	Fixed Solution	Float Solution
latitude	3mm	6mm

Table 3.1: Default Constraints

Parameter	Fixed Solution	Float Solution
longitude	5mm	10mm
horizonta	1ppm	2ppm
height	5mm	10mm
vertical	1ppm	2ppm

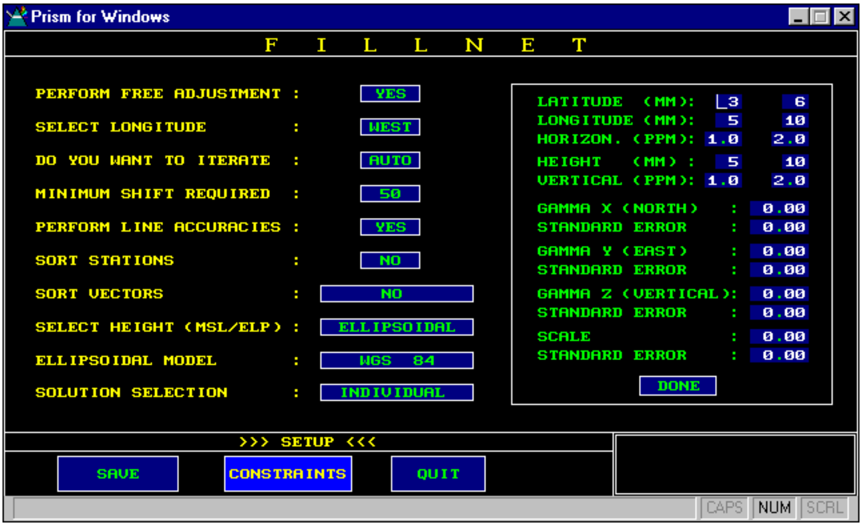

Figure 3.8: CONSTRAINTS Menu

16. For this exericse, leave the default contraint parameter settings as they are and click on **DONE**, then **SAVE**. The message

"OPTIONS SAVED press button to continue"

will appear.

Press the mouse button, then click on **QUIT**. The **MAIN** menu will appear.

17. Click on **AUTOMATIC**. The **AUTOMATIC** menu will appear.
18. Click on **GO REAL** or **GO PROT**, depending upon your memory configuration. The message **ASJUSTMENT IN PROGRESS** will appear, then the preliminary coordinates display, similar to Figure ??.

Appendix C presents a printout of the results for this example.

Note the **FFF** in the first column of the point 0001; this indicates that latitude, longitude, and height were fixed for this point.

19. Click on the **S.E.** (standard error) button. FILLNET displays the **S.E.** portion of the output. **S.E.** gives you an idea of how the adjustment did overall, that is, how well the adjustment fits the error model.

Your screen should now look similar to figure??. In this example, the S.E. = 2.583, which is not good as it does not fit the criteria (**S.E.** should be less than or equal to 1). If the **S.E.** is greater than one, it indicates that there is a problem with the adjustment, or the *a priori* error estimates are too optimistic. Be aware that in either case, you want to look at the adjusted vectors.

20. Click on the **A.V.** (adjusted vector) button at the right edge of the display. The adjusted vector portion of the output will appear, as shown in Figure 3.9.

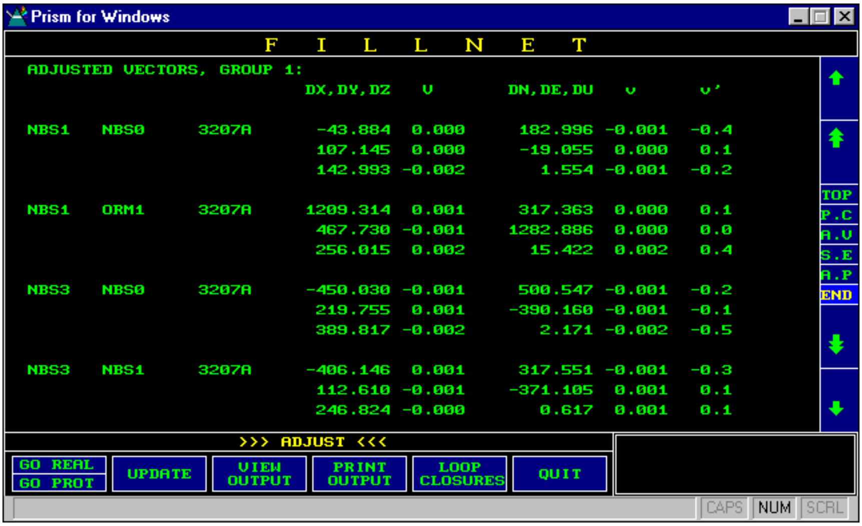

Figure 3.9: Adjusted Vector Display

21. Look for outliers in the residuals in the v' column of the display. To bring more vectors into view, click on the down arrow at the right edge of the display. Note that the normalized residuals of the vector between 0011 and 0002 in session B have the highest value, that is, the worst fit. This is a bad vector and must be dealt with. If you try editing the vector and use the fixed solution, you will find the S.E. is even higher, indicating that the vector must be deleted or deweighted.

22. Return to the **EDIT** screen and exclude this vector, then readjust. The final S.E. should be 0.274, indicating the data is now better than the *a priori* error estimates.

This would conclude a daily free adjustment. When the daily free adjustment is complete it should be added to any previous subtotal adjustment and the new subtotal should be adjusted to confirm that the new data fits the existing data.

When the total project has been completed and all blunders have been removed via the free adjustments, it is then time to fix the control points to their known values and perform a constrained adjustment.

The constrained adjustment is a very important part of the process. It is the stage where we fit our data to the local control network. At this stage, especially if you are adjusting to NAD 27 control values, you may have to increase your *a priori* error estimates. Good adjustments result from realistic error estimates, a standard error of unit weight of one or less, and normalized residuals less than 3.0.

If your S.E. of unit weight is less than one, and you can realistically lower your estimate of error to bring it close to one, do so. If not, leave it. The closer to one the S.E. of unit weight is, the better the statistical outliers will show up in the normalized residuals.

Some Hints on Using Fillnet

Raw position data gathered by the GPS receivers is called a B-file, and cannot be used directly by FILLNET. Instead, the WinPrism software must first convert raw position data to point and vector data in the form Δx, Δy, Δz for each baseline in the network, one solution for each vector. In this form, the data is called an O-file (output file), which FILLNET can pull in using the IMPORT option. Fillnet stores the O-file vector data in the adjustment disk file (the .PRT file). FILLNET then does a least-squares adjustment on the vectors to obtain a best-fit solution. The mathematically intensive least-squares adjustment, not practical until the advent of desktop compters, replaces the traditional compass rule adjustment, with far greater speed and accuracy.

When reading O-files, FILLNET analyzes each vector and decides whether the fixed or float solution is the best solution, then tags it for use in the adjustment. You can manually change which solution is used via the **EDIT SITE** option.

It is good practice to run FILLNET daily for quality control, finding and modifying, reprocessing, or removing data that exceeds reasonably expected values. As the project progresses, the selected daily adjustment can be added to the accumulating project adjustment file for subtotal adjustments each day. At the end of the project, when the final daily adjustment has been added, perform the final free adjustment on that total. Then, fix the control and perform the constrained adjustment, fitting the GPS vectors to the local network.

Hints on Program Execution

If a coordinate is to be held fixed, it will be fixed at exactly the value specified in the **EDIT SITE** option. The shift unknowns for such coordinates are wiped out simply by omitting them in the program.

Any coordinates that are labeled as weighted in the **EDIT SITE** option will also be constrained at the given values, but there is an important difference. Weighted coordinates may, and usually will, change by some amount. The size of the change depends on the standard error chosen for the constraint. It may exceed the standard error value by an amount reflecting the degree of geometric incompatibility with the rest of the network. The feature of constraining coordinates by loose values is useful for a preliminary adjustment of a network in which some fixed coordinates are suspected to be seriously wrong.

These coordinates that are free to change their values (that is, the points that are to be adjusted) can be initially assigned any values within reason. Initial coordinates normally come directly from the o-file solution when imported into Fillnet. Assuming that the coordinates imported from the O-files are reasonable, then an iteration will not be needed in most situations, and Fillnet will automatically iterate if necessary. If you wish to overide the automatic iteration, do so in the **SETUP** option.

Minimum Constraint Adjustments

As generally understood a minimum constraint adjustment is an adjustment in which an arbitrary station is held fixed in lat, long, & ht., and the rest of the station are free to shift. Usually, but not always, the fixed station is a control station. A minimum adjustment (also known as a free adjustment) tests the internal consistency of the network without allowing additional network control to influence the results. A minimum adjustment indicates how well the vectors fit together as a network.

The statistics found in the Fillnet output file are directly dependent upon the a *a priori* errors you input into the adjustment. It it important that the apriori errors reflect the intended accuracy of the survey or network, or the user will get an inaccurate sense of the quality of the adjustment. For many surveys, the default error model is sufficient for an initial adjustment. These *a priori* errors can be changed in the SETUP option.

After performing the initial adjustment, it is useful to inspect the value of the standard error of unit weight (S.E.) in the adjustment output. If the apriori errors (or weights) have been estimated correctly, then this value will be close to unity or one. For further information regarding the significance of the S.E., refer to the Analysis section of this manual.

Control Tie Analysis

If your survey has more than one control point, it is useful to perform a control tie analysis between performing the free adjustment and the constrained adjustment. A control tie analysis indicates the accuracy of your control. **The accuracy of the constrained adjustment is no better than the accuracy of the control points, regardless of the accuracy of the minimum adjustment.** Appendix D describes how to perform a control tie analysis.

Constrained Adjustments

Constrained adjustments use more than the minimum number of fixed coordinates. If this adjustment shows a significant rise in the standard error of unit weight (as it often does), this usually reflects the effects of distortions in the local control. Normally, a constrained network will show more distortion and error than a minimum adjustment.

After performing a control tie analysis and verifying that the control meets or exceeds the intended accuracy of the survey, the control points are now to be held fixed to their published values. This is done in the **EDIT SITE/EDIT POINTS** screen. Remember at this point not only to enter in the proper coordinates, but also to switch the contraints from **FREE** to **FIXED**, and **PRESS REPLACE** point. In addition, you must also change the setting **PERFORM FREE ADJUSTMENT** from **YES** to **NO** in the **SETUP** option.

To allow for network distortions and to make the GPS observations fit the local network as closely as possible, assign additional proprotional *a priori* errors to GPS vectors. This means that long lines will be given less weight than short ones, thus permitting the GPS observations to follow the pattern of distortions.

As in minimum constraint adjustment, an inspection of normalized residuals can also be instructive here. These values should also be inspected for significant differences between the horizontal and the vertical components. If, for example, the normalized residuals for the vertical components are on average much smaller, this means that they have been underweighted, which could reflect the fact that the relative accuracies of spirit leveling are much better than those of fixed horizontal coordinates.

About Bias Unknowns

A bias parameter is defined as the difference between a value given by GPS observation and the corresponding value defined by the local network. There are four such bias parameters in each bias group, always solved for in the constrained adjustment. These are three orientation angles and the scale unknown.

If these bias paramteters are not solved for or if they are constrained to 0, poor results can be expected even from perfect GPS data and perfect fixed control coordinates. It is then of little consolation to say that the adjustment has produced accuracies of one part in so many thousands, thus perhaps meeting the survey criteria, when in fact good data has been spoiled by bad mathematics.

The bias unknowns account for the differences between WGS84 (to which GPS observations are nominally oriented) and whatever local system is used, the latter with horizontal coordinates given as latitudes and longtitudes on some datum and the vertical coordinates perhaps (but not necessarily) expressed as elevations above mean sea level. The local datum usually exhibits regional errors in scale and azimuth, and certainly some geoidal slope with respect to the ellipsoid. *A priori* knowledge of these parameters is not required.

The bias parameters are in the sense *local minus GPS*, meaning that the orientation and the scale of GPS observations are changed to fit the local network. The rotation angles are expressed in the horizon system rather than the XYZ equatorial system, which not only has more immediate meaning to the user but also makes it easy to treat each angle separately in the adjustment, for example when constraining one angle and letting the others be determined by the adjustment.

Table 3.2: Number of Required Constraints

Horiz. Position	Elevation	Angle 1	Angle 2	Angle 3	Scale
2	3	No	No	No	No
2	2	Yes	No	No	No
or		No	Yes	No	No
2	1	Yes	Yes	No	No
1	3	No	No	Yes	Yes
1	2	Yes	No	Yes	Yes
or		No	Yes	Yes	Yes
1	1	Yes	Yes	Yes	Yes
1	0	No solution	No solution	No solution	No solution
0	1	No solution	No solution	No solution	No solution
0	0	No solution	No solution	No solution	No solution

FILLNET supplies the constraints that are missing in the setup and are needed according to Table 1. The constraint values are all 0. This does not mean that the results will be correct, only that the adjustment will run to the end without failing. If two or more horizontal positions and three or more elevations are given, no constraints are required; they would in fact be harmful.

A free adjustment is one in which only one station is fixed in horizontal position and only one in elevation. Then all bias unknowns are constrained to 0. FILLNET asks you if you want a free adjustment. If you specify a free adjustment, the program (1) honors only the first fixed position and only the first fixed elevation, and disregards all others; (2) disregards all coordinate constraints if any have been included in the data set; and (3) constrains all bias unknowns to 0, regardless of the data set entries. When the free option is exercised, all vectors must be in one bias group.

Number of Unknowns in an Adjustment

To determine the number of unknowns, let S equal the number of stations, F the number of coordinates held fixed, and B the number of bias groups. Then the number of unknowns N is given by:

$$N = 3S - F + 4B$$

For example, if the adjustment contains 50 points of which 5 are fixed in latitude and longitude and 6 are fixed in elevation, and if there is one common bias group for all observations, then

$$N = 3(50) - [(5 \text{ points x } 2 \text{ fix}) + (6 \text{ points x } 1 \text{ fix})] + 4(1)$$

$$= 150 - 16 + 4$$

$$= 138$$

The time required for execution depends upon the number of unknowns in the setup and to a lesser extent the number of vectors.

Loop Closures

FILLNET performs loop and open traverse closures on demand (click on **LOOP CLOSURES** in the **AUTOMATIC (ADJUST)** menu. Loop closures are generally unnecessary; however, they may need to be done for bluebooked projects and may be useful in isolating problems in elevation (antenna height) or station occupation (wrong place). See Appendix E for running loop adjustments.

If the elevations are to be meaningful, the adjustment must contain geoid heights.

Building Onto the Network

During the course of a project, we strongly advise that you process your data and run the adjustments daily. This allows you to catch anamolous data and correct problems before the network becomes too cumbersome to analyze. For example, if a combination of the vectors from day 1 and 2 yield a good adjustment, but the addition of vectors from day 3 show problems in the adjustment, it becomes easy to identify the source of the problem.

To add the vectors from two daily adjustments, call up the **ADJUST MANAGER** menu, and clone the first day's adjustment into another adjustment named, for example, 2DAY. Next load the second day's adjustment as the source adjustment, load the cloned adjustment, 2DAY, as the destination adjustment, and then click on **COMBINE**. This will copy the second day adjustment data into the adjustment named 2DAY.

Perform a FILLNET adjustment with 2DAY and see what it looks like. Analyze, reprocess, and readjust as necessary.

Repeat this process until all the vectors of the project have been combined in a final free adjustment and everything fits together; then and only then start constraining control, i.e., fixing the horizontal and vertical positions of the control stations. If you start constraining control too soon, it may become difficult to determine whether there is a data problem or a control problem.

The final project adjustment should always be a constrained adjustment. Even though the GPS measurements may be more precise than the local network, you must adjust your work to fit the local network (e.g., NGS NAD83 control stations) or chaos will result. Simply performing a free adjustment may lead to unacceptable closures when ties are made from another local control station.

Always plan for minimum control for a constrained network. A good rule of thumb is to include sufficient control to number approximately 10% of the total project stations.

Levels of Confidence

All the statistics from FILLNET are reported at 1 sigma, a 68% confidence level. For 95% confidence, the standard errors must be doubled. In a typical case for a given station, the positional standard errors might be 0.015, 0.018, and 0.018, giving 68% confidence that accuracy is within an 18mm radius. For 95% confidence, the spheroid doubles to 3.5cm, so the 2-sigma error ellipse is about 3.5cm, more than sufficient for photo control with 5-foot contours.

Line Accuracies

At the end of the adjustment output file is a list of accuracies. These figures are approximate; they are not mathematically rigorous because the measurements are slope mark-to-mark distance. The square root of the sum of the squares of the XY components is divided by that distance to get horizontal ppm, the vertical component by that distance to get vertical ppm.

Nevertheless, the estimates are close. If you do a loop closure when the display asks, the results should be in the range of 4 to 8 ppm. Below a kilometer, it is difficult to keep ppms less than 10. Ten ppm/kilometer is one cm, and this can be difficult to achieve because of various factors, such as centering error.

FILLNET and the FILLNET Input File

FILLNET processes an ASCII file called FILLNET.IN that is created from the data in the adjustment disk file (the .PRT file) and contains the following records:

Parameter record

Title record

A number of preliminary coordinate records

Section closing record

Bias group header record

A number of vector records

Section closing record (needed only when there is more than one bias group).

Each record is discussed in detail below.

Parameter Record

The parameter record has the following structure:

Table A.1: Parameter Structure

Column	Contents
1-12	Equatorial radius (a)
13-24	Reciprocal of flattening (1/f)
25	Blank
26	Sense of longitude (W for west, E for east)
27	*A priori* transformation from WGS 72
31-46	Setup options flags

Equatorial radius (a) and reciprocal of flattening (1/f) depend upon the ellipsoid:

Table B.2: Ellipsoid Description

Ellipsoid	a	1/f
Clarke 1866	6378206.4	294.9786982

Table B.2: Ellipsoid Description

Ellipsoid	a	1/f
GRS 1980	6378137.0	298.2572221

The utilities can apply *a priori* transformations to vectors to convert vector components from WGS 72 to NAD 83. To specify this, a nonblank character must be put in column 27 of the first input record.

If the adjustment is fully constrained (i.e., all bias unknowns are determined by the geometry), this will have no effect on adjusted positions and heights. Only the bias unknowns will come out slightly different. This option would be used only with GPS data taken prior to January 1987. Since that time, GPS has been on the WGS 84 system.

Title Record

The title record has the following format:

Table B.3: Title Record Format

Column	Contents
1-40	Project name and comments
41-46	Latitude of local origin
47-52	Longitude of local origin

Local origin coordinates are expressed in degrees, with one decimal. This a point, not necessarily a station of the net, somewhere near the middle of the survey area. In the southern hemisphere, use a negative sign with latitude.

Preliminary Coordinates Records

Preliminary coordinates records have the following format:

Table B.4: Preliminary Coordinates Format

Column	Contents
1-3	Three columns denoting coordinates to be held fixed. F in the first column fixes the latitude, F in the second column fixes the longitude, and F in the third column fixes the height. Leave blank for free coordinate. In the example, all three coordinates are held fixed.

Table B.4: Preliminary Coordinates Format

Column	Contents
7-14	Station name, any characters, including blanks.
20	Normally blank. Insert asterisk to delete record.
21	Minus sign to indicate southern hemisphere
22-35	Latitude (DMS)
37-52	Longitude (DMS)
54-62	Elevation (meters)
63-70	Geoid height (meters). Geoid heights must be given for all points, or none.

Degrees and minutes are read as right-justified integers. Column 37 has a minus sign when the sense of longitude is opposite that defined on the parameter record.

The remaining columns are usually left blank. They are used to indicate coordinate constraints in meters, as distinguished from absolute fixing:

72-74	Latitude
75-77	Longitude
78-80	Height

Coordinate values are constrained to the values listed as preliminary but with standard errors as given in these columns. Coordinates so constrained are subject to change.

Preliminary Coordinate Section Closing Record

Preliminary coordinate section closing records have the following format:

Column	Contents
1	Asterisk(*)

The Preliminary Coordinates Records section is closed by a record that contains only an asterisk in column 1.

Header Record for a Bias Group

The header record for a bias group has the following format:

Column	Contents
1-4	Number of vectors in the group

Columns 5 through 15 contain default value codes for *a priori* standard errors of vector components. These can be overridden, in whole or in part, on the record pertaining to the individual vector, as explained in the Vector Data Record discussion below.

Column	Contents
5-6	Millimeters for difference in latitude
7-8	Millimeters for difference in longitude
9-10	Parts per million for both latitude and longitude
12-13	Millimeters for height difference
14-15	Parts per million for height difference

Parts per million have one decimal place implied. The example reads as ±10 mm ±3.0 ppm for latitude; longitude is ±15 mm ±3.0 ppm; height difference is ±5 mm ±2.5 ppm.

Columns 16-55 are usually left blank. These columns can indicate constraints for the four additional unknowns (three rotation angles and scale correction). The rotation angles are with respect to the chosen local origin, positive clockwise around the north, east, and vertical axes, respectively, in seconds. The scale correction is in parts per million. Specific fields are:

Column	Contents
16-20	Constraint value for gamma x (north axis)
21-25	Standard error of x constraint
26-30	Constraint value for gamma y (east axis)
31-35	Standard error of y constraint
36-40	Constraint value for gamma z (vertical axis)
41-45	Standard error of z constraint
46-50	Constraint value for scale
51-55	Standard error of scale constraint

Only those unknowns will be constrained for which a nonzero value is used in the field provided for the standard error. To hold an unknown effectively fixed, place a small value in the standard error field, e.g., 0.01 for angle and 0.05 for scale.

These constraints are not generally used when the unknowns are defined by the geometry. For example, if two stations are held fixed in horizontal positions, this defines the scale and the orientation about the vertical axis. To define the remaining two angles (which express the local tilt of the geoid with respect to the ellipsoid), it is necessary to have three points at which the elevations are known (either fixed or constrained).

The bias constraints could be used to improve the postions of an incompletely constrained subnet within a previously adjusted network. See the discussion of Bias Constraints.

Vector Data Records

Vector data records have the following format:

Column	Contents
5	Number of participating receivers. Column 5, as an option, can indicate the number of stations participating in the session of which the vector is a part. A blank entry is interpreted as 2 stations. This feature is used to deweight vectors used in all combinations (i.e., 3 vectors for a 3-station occupation, 6 vectors for 4 stations, etc.). If the minimum number of vectors is used (i.e., 2 vectors for 3 stations, 3 vectors for 4 stations, etc.), this column should be blank or contain a 2.
6	Type of solution (t=triple, f=float, x=fixed)
7-14	Name of the standpoint (the FROM station)
22-29	Name of forepoint (the TO station)
30-36	Session code or comment
37-47	Delta X
48-58	Delta Y
59-69	Delta Z
71-80	S.E. codes, if any. S.E. codes entered here override default values placed on the header card. The meanings are the same as those of default codes; however, no blank space is used to separate horizontal and vertical components.

During an adjustment, it is often necessary to delete one or more vectors. This is done by clicking on an icon in one of the FILLNET menus.

Bias Group Section Closing Record

Bias group section closing records have the following format:

Column	Contents
1	Asterisk (*)

Close a section of vector data records with this record - an asterisk in column 1. This record is needed only when there is more than one bias group or when line accuracy selections are included below.

If there is another bias group in the project, start it with a second header record and follow with vector data. The maximum number of bias groups in a project is five. In each such group the four additional unknowns must be defined either by the geometry or by explicit constraints.

Accuracies over selected lines are specified as follows:

Column	Contents
7-14	Name of the standpoint (the FROM station)
22-29	Name of forepoint (the TO station)

FILLNET Adjustment Output File

Following is an example of a FILLNET adjustment file.

```
PROGRAM FILLNET, VERSION 3.0.00

LICENSED TO: ASHTECH INC.

FILLNET INPUT FILE  DEMONSTRATION          42.9    71.6

A =  6378137.000    1/F =  298.2572235   W      LONGITUDE POSITIVE WEST

PRELIMINARY COORDINATES:

                  LAT.             LON.        ELEV.    G.H.  CONSTR.

  1        0003 42 53 42.35910   71 34  0.09984    69.341   0.000

  2  FFF   0001 42 54 15.01017   71 34 20.85306    58.705   0.000

  3        0002 42 52 27.20927   71 34 15.11110    53.731   0.000

  4        0011 42 53 44.53519   71 34 44.62818    53.215   0.000

  5        0012 42 53 41.86173   71 34 43.48294    54.198   0.000

  6        0013 42 53 45.33796   71 34  2.54459    67.256   0.000

  7        0006 42 53 58.11089   71 34 57.88947    63.855   0.000


GROUP 1, NO. OF VECTORS AND BIAS CONSTRAINTS:


 12     0.000  0.001    0.000  0.001    0.000  0.001    0.000  0.001


VECTORS:

                DX         DY         DZ      LENGTH   ERROR CODES


0003   0001    -665.990    509.251    730.864   1112.224  3 51.0   51.0  4

0003   0002     172.163  -1594.044  -1709.841   2343.965  3 51.0   51.0  4

0003   0011    -976.717   -264.808     38.216   1012.699  3 51.0   51.0  4

0003   0012    -934.048   -310.518    -21.555    984.546  3 51.0   51.0  4

0003   0013     -72.894     43.268     65.924    107.385  3 51.0   51.0  4
```

```
 0006   0001     683.783    605.946    378.502    988.936  3 51.0  51.0  4
 0006   0003    1349.776     96.689   -352.358   1398.356  3 51.0  51.0  4
 0006   0013    1276.882    139.957   -286.433   1316.077  3 51.0  51.0  4
 0011   0002    1149.031  -1329.130  -1748.050   2478.414  6102.0 102.0  4
 0012   0002    1106.208  -1283.524  -1688.289   2391.955  3 51.0  51.0  4
 0012   0011     -42.669     45.711     59.770     86.502  3 51.0  51.0  4
 0013   0001    -593.094    465.981    664.939   1005.506  3 51.0  51.0  4
```

```
SHIFTS:
    1  -0.020  -0.006   0.012
    2   0.000   0.000   0.000
    3  -0.012   0.008  -0.006
    4  -0.034  -0.066   0.022
    5  -0.016   0.003   0.003
    6  -0.020  -0.011   0.012
    7  -0.021  -0.006   0.014
```

```
ADJUSTED VECTORS, GROUP 1:
                         DX,DY,DZ   V      DN,DE,DU   v      v'
 0003  0001   2960A    -665.990 -0.000   1007.425 -0.000  -0.1
                        509.252  0.001   -471.197  0.000   0.0
                        730.863 -0.001    -10.458 -0.002  -0.2

 0003  0002   2960B     172.177  0.014  -2319.145  0.004   0.7
                      -1594.033  0.011   -339.780  0.017   2.2
                      -1709.841 -0.000    -16.113 -0.005  -0.6

 0003  0011   2960B    -976.730 -0.013     66.813 -0.003  -0.6
                       -264.816 -0.008  -1010.384 -0.015  -2.0
                         38.216 -0.000    -15.760  0.003   0.4
```

0003	0012	2960B	-934.047	0.001	-15.662	-0.000	-0.0
			-310.519	-0.001	-984.310	0.000	0.0
			-21.554	0.001	-14.810	0.001	0.2
0003	0013	2960A	-72.894	-0.000	91.903	0.001	0.2
			43.268	0.000	-55.510	-0.000	-0.0
			65.924	0.000	-2.055	-0.000	-0.0
0006	0001	2960A	683.785	0.002	521.737	-0.001	-0.3
			605.943	-0.003	840.092	0.001	0.1
			378.504	0.002	-5.421	0.004	0.6
0006	0003	2960A	1349.775	-0.001	-485.688	0.001	0.1
			96.691	0.002	1311.290	-0.000	-0.0
			-352.359	-0.001	5.037	-0.002	-0.2
0006	0013	2960A	1276.881	-0.001	-393.785	0.001	0.1
			139.959	0.002	1255.779	-0.001	-0.1
			-286.434	-0.001	2.982	-0.003	-0.4
0011	0002	2960B	1148.907	-0.124	-2385.958	-0.034	-3.1
			-1329.217	-0.087	670.604	-0.145	-9.2
			-1748.057	-0.007	-0.353	0.027	1.7
0012	0002	2960B	1106.225	0.017	-2303.483	0.004	0.8
			-1283.514	0.010	644.530	0.019	2.4
			-1688.287	0.002	-1.303	-0.002	-0.2
0012	0011	2960B	-42.682	-0.013	82.475	-0.003	-0.6
			45.703	-0.008	-26.074	-0.015	-2.1

```
                         59.770 -0.000     -0.950  0.003   0.4


 0013  0001    2960A    -593.096 -0.002    915.522  0.001   0.3
                         465.983  0.002   -415.687 -0.001  -0.1
                         664.938 -0.001     -8.404 -0.003  -0.4


S.E. OF UNIT WEIGHT =     2.583


NUMBER OF -
   OBS. EQUATIONS              40
   UNKNOWNS                    22
   DEGREES OF FREEDOM          18
   ITERATIONS                   0


GROUP  1 ROT. ANGLES (SEC.) AND SCALE DIFF. (PPM):


 HOR. SYSTEM          0.000   0.000   0.000   0.000
 STD. ERRORS          0.003   0.003   0.003   0.003
 XYZ SYSTEM           0.000   0.000   0.000


ADJUSTED POSITIONS:
              LAT.          LON.       ELEV.   STD. ERRORS (M)
   1  0003    42 53 42.35845   71 34  0.10011    69.353 0.008 0.013 0.013
   2  0001    42 54 15.01017   71 34 20.85306    58.705 0.000 0.000 0.000
   3  0002    42 52 27.20889   71 34 15.11077    53.725 0.013 0.020 0.020
   4  0011    42 53 44.53409   71 34 44.63107    53.237 0.012 0.019 0.019
   5  0012    42 53 41.86121   71 34 43.48279    54.201 0.012 0.019 0.019
   6  0013    42 53 45.33733   71 34  2.54507    67.268 0.008 0.013 0.013
   7  0006    42 53 58.11022   71 34 57.88972    63.869 0.008 0.013 0.013
```

ACCURACIES (M):

		D. LAT.	D. LON.	VERT.
0003	0001	0.008	0.013	0.013
0003	0002	0.010	0.015	0.015
0003	0011	0.009	0.014	0.014
0003	0012	0.008	0.013	0.013
0003	0013	0.008	0.013	0.013
0006	0001	0.008	0.013	0.013
0006	0003	0.008	0.013	0.013
0006	0013	0.008	0.013	0.013
0011	0002	0.012	0.017	0.017
0012	0002	0.010	0.015	0.015
0012	0011	0.009	0.014	0.014
0013	0001	0.008	0.013	0.013

```
************************************************************
****                                                    ****
****              ESTIMATES OF PRECISION                ****
****                                                    ****
****    BASED ON THE VECTOR ACCURACIES PRODUCED BY      ****
****                     FILLNET                        ****
****                                                    ****
****   THIS IS A REASONABLE ESTIMATE OF THE ACCURACIES  ****
****      OF THE VECTORS IN THE NETWORK AT 1 SIGMA.     ****
****                                                    ****
************************************************************
```

VECTOR		LENGTH	PPM(H)	RATIO(H)	PPM(V)	RATIO(V)
0003	0001	1112.223	13.7	1: 72861	11.7	1: 85556
0003	0002	2343.959	7.7	1: 130016	6.4	1: 156264

FILLNET Adjustment

0003	0011	1012.713	16.4	1:	60841	13.8	1:	72337
0003	0012	984.546	15.5	1:	64492	13.2	1:	75734
0003	0013	107.386	142.2	1:	7034	121.1	1:	8260
0006	0001	988.936	15.4	1:	64786	13.1	1:	76072
0006	0003	1398.356	10.9	1:	91609	9.3	1:	107566
0006	0013	1316.076	11.6	1:	86219	9.9	1:	101237
0011	0002	2478.408	8.4	1:	119105	6.9	1:	145789
0012	0002	2391.956	7.5	1:	132682	6.3	1:	159464
0012	0011	86.504	192.4	1:	5197	161.8	1:	6179
0013	0001	1005.508	15.2	1:	65871	12.9	1:	77347

Control Tie Analysis

Use the following procedure for a control tie analysis.

1. Compute the difference in the published latitude(PLT) vs computed latitude (CLT) and published longitude(PLG) versus computed longitude (CLG) for station 1:

   PLT1 - CLT1 = d LAT1

   PLG1 - CLG1 = d LONG1

2. Compute difference in published latitude(PLT) vs computed latitude (CLT) and published longitude(PLG) vs computed longitude (CLG) for station 2:

   PLT2 - CLT2 = d LAT2

   PLG2 - CLG2 = d LONG2

3. Compute the misclosure in latitude (MISLAT) and longitude (MISLNG):

   MISLAT = d LAT2 - d LAT1

   MISLNG = d LONG2 - d LONG1

4. Convert the misclosure to meters:

   MISLAT (m) = MISLAT (") * 30

   MISLNG (m) = MISLNG (") * 30 * COS(LAT)

5. Compute the linear misclosure:

   MISLIN = SQRT(MISLAT2 - MISLAT2)

6. Compute the accuracy:

   ACC (ppm) = 1000000 * MISLIN / length of the baseline

   ACC (1:X) = length of the baseline / MISLIN

Running Loop Closures

The LOOP CLOSURES button in the ADJUST screen performs loop (and open traverse) closures. Loop closures are generally unnecessary. However, they may need to be done for bluebooked projects and may be useful in isolating elevation (antenna height) problems of station occupation (wrong place) problems.

If the elevations are to be meaningful, the adjustment must contain geoid heights.

To run the LOOP CLOSURE, enter the **AUTOMATIC** option and click on the **LOOP CLOSURE** button.

Enter the name of the file to contain the loop closures:

OUTPUT FILE (file name or <ENTER>)

If you press <ENTER> without specifying a file name, S_HOOTER creates a file called DEFAULT.

The next prompt is for a list of vectors:

DO YOU WANT A LIST OF VECTORS? (Y/N)

If you answer N for No, S_HOOTER will skip to the starting station prompt below, otherwise it will ask:

DO YOU WANT A PRINTOUT? (Y/N)

If you answer Y, S_HOOTER sends a serially numbered vector list to your printer, and also displays the list on the screen. The serial numbers in this list are required for identifying the connecting vectors in a traverse or loop below.

Next, S_HOOTER asks for the station starting name:

STARTING STATION NAME:

When you type in the station name, followed by <ENTER>, S_HOOTER asks for the line (vector) numbers to use in the loop or traverse:

LINE NUMBERS (end with /):

The list of line numbers must be terminated with a slash (/).

Listed below is a typical loop closure output.

STARTING STATION NAME: C025

LINE	FROM	TO	DX	DY	DZ	LENGTH
25	FC025	_RED 1570A	37057.888	-21278.262	-9326.825	43738.326

28	F_RED	C106	1570A	-42006.781	56040.949	55356.375	89271.977
16	F_AST	C106	1570A	-28288.868	-6601.753	-25576.747	38704.175
14	F_AST	0039	1570A	-28288.868	-6601.753	-25576.747	38704.175
19	F0039	C025	1570A	33237.737	-28160.886	-20452.847	48125.893

STATION	LATITUDE	LONGITUDE	ELEV.	GH
C025	37 20 32.58277	121 42 57.60872	451.616	-32.146
_RED	37 33 3.41210	122 05 43.60655	24.707	-31.946
R003	37 28 38.36888	121 33 21.31313	1213.269	-32.024
R004	37 23 18.33532	122 02 13.76370	-11.753	-32.222
R001	37 21 14.06598	121 54 25.20233	-15.004	-32.184
R001	37 20 32.58204	121 42 57.60569	451.607	-32.146

TRAVERSE LENGTH = 162.066 KILOMETERS

MISCLOSURES (LAT., LON., ELEV., METERS): -0.022 -0.075 -0.009

LOOP MISCLOSURE = 0.5 PPM

This closure is displayed on your screen and put into the specified output file.

If geoid heights are not entered in the input file, you will see the message indicated by shading:

STARTING STATION NAME: C025

LINE	FROM	TO		DX	DY	DZ	LENGTH
25	FC025	_RED	1570A	37057.888	-21278.262	-9326.825	43738.326
28	F_RED	C106	1570A	-42006.781	56040.949	55356.375	89271.977

16	F_AST	C106	1570A	-28288.868	-6601.753	-25576.747	38704.175
14	F_AST	0039	1570A	-28288.868	-6601.753	-25576.747	38704.175
19	F0039	C025	1570A	33237.737	-28160.886	-20452.847	48125.893

STATION	LATITUDE	LONGITUDE	ELEV.	GH
C025	37 20 32.58277	121 42 57.60872	451.616	-32.146
_RED	37 33 3.41210	122 05 43.60655	24.707	-31.946
R003	37 28 38.36888	121 33 21.31313	1213.269	-32.024
R004	37 23 18.33532	122 02 13.76370	-11.753	-32.222
R001	37 21 14.06598	121 54 25.20233	-15.004	-32.184
R001	37 20 32.58204	121 42 57.60569	451.607	-32.146

TRAVERSE LENGTH = 162.066 KILOMETERS

MISCLOSURES (LAT., LON., ELEV., METERS): -0.022 -0.075 -0.009

LOOP MISCLOSURE = 0.5 PPM

Since geoid heights are not given, the computed elevations may be seriously in error.

Press any key to continue...

Compare the difference in elevations due to geoid heights between the two closed loops. The MISCLOSURE information is identical even though the elevations vary. This would NOT be the case with an OPEN TRAVERSE.

When you press any key, you will see the prompt:

MORE? (Y/N)

Answering <Y> clears the screen and prompts for a new starting station name. Answering <N> exits LOOP CLOSURE (S_HOOTER) and takes you back to the AUTOMATIC menu screen.

Common GPS Acronyms

ALT	Altitude
ALMM	Almanac
AFT	After
AGE	Age of Data
ANT	Antenna
ASCII	American Standard Code for Information Interchange
AZM	Azimuth
BEF	Before
BIN	Binary Index (file)
BM	Bench Mark
BP	Barometric Pressure
C/A	Coarse/Acquisition
	Clear/Access
COG	Course Over Ground
CTD	Course To Destination
DGPS	Differential GPS
DIFF	Differential
DMS	Degrees, Minutes, Seconds
DOP	Dilution Of Precision
DOS	Disk Operating System
DTD	Distance To Destination
EDOP	Elevation Dilution Of Precision
ELEV	Elevation
ELIP	Ellipsoid
ELLIP	Ellipsoid
ELP	Ellipsoid
ELV	Elevation
EMI	Electromagnetic Interference
ENU	East, North, Up
EPHM	Ephemeris
FCC	Federal Communications Commission
FREQ	Frequency

GH	Geoid Height
GLL	Latitude/Longitude for Position
GMST	Greenwich Mean Sidereal Time
GMT	Greenwich Mean Time
GPS	Global Positioning System
GPSIC	GPS Information Center
	7323 Telegraph Road
	Alexandria VA 22310-3998
	703-866-3806
HDOP	Horizontal Dilution Of Position
HEL	Health
HI	Height of Instrument
HTDOP	Horizontal/Time Dilution Of Precision
ID	Identification
	Integrated Doppler
LAT	Latitude
LCD	Liquid Crystal Display
LNA	Low-Noise Amplifier
LNG	Longitude
LON	Longitude
MMDD	Date format - Month, Date
MSG	RTCM Message
MSL	Mean Sea Level
N	Geodetic Undulation
NAD	North American Datum
NMEA	National Marine Electronics Assoc.
NV	Non-Volatile
PDOP	Position Dilution of Precision
PE	Precise Ephemeris
POS	Position
RAM	Random-Access Memory
RF	Radio Frequency
RFI	Radio Frequency Interference
RH	Relative Humidity

RMS	Root Mean Square
RTCM	Radio Technical Commission for Maritime Services P.O. Box 19087 Washington DC 20036-9087
SE	Site Editor Standard Error
SESS	Session
SOG	Speed Over Ground
SS	Static Survey
SV	Satellite Visibility Space Vehicle
T-DRY	Temperature - Dry (Celsius)
T-WET	Temperature - Wet (Celsius)
TDOP	Time Dilution Of Precision
UT	Universal Time
UTC	Universal Time Coordinated
VDC	Volts Direct Current
VDOP	Vertical Dilution of Precision
WGS	World Geodetic System
WGS-84	Reference Ellipsoid
WP	Waypoint

The U.S. Coast Guard Navigation Information Service

7323 Telegraph Road, Alexandria VA 22310-3998

Tel 703-313-5900   Fax 703-313-5920

Overview

Since February 1989, the US Coast Guard has developed the requirements and plans for the Civil GPS Service (CGS) and has begun to implement these services. The four CGS functions recognized by the Coast Guard are listed below:

- Provide a GPS Operational Advisory Broadcast (OAB)

- Process applications for the civil use of GPS PPS (Precise Positioning Service)
- Provide precise GPS satellite ephemeris data
- Provide a government interface for civil GPS users

Two agencies perform these functions:

- The GPS Information Center - provides the OAB and precise ephemerides
- The PPS Program Office - processes civil applications to PPS access

The primary source of information for the OAB is the GPS control center at Falcon Air Force Base in Colorado Springs, Colorado. The OAB originates at GPSIC in Alexandria VA and is broadcast during normal working hours, 8AM to 4PM EST, Monday through Friday, except Federal holidays. An answering machine records messages after hours, and calls are returned the next working day. OAB information is updated only during normal working hours, but advisory services are accessible 24 hours, 7 days. OAB presents the following information:

- Status - Current constellation health and availability
- Outages - Recent and future satellite down time
- Almanac - Current projected orbit data for GPS coverage and visibility predictions
- Other - General GPS information and some user documentation

Satellite visibility and coverage predictions are not offered by GPSIC. These services are available from commercial sources or commercially available software.

GPSIC Voice Recording

This is a 90-second tape message which contains current satellite status and outage information. The recording is available 24 hours 7 days and can be heard by dialing 703-866-3826. The recording is updated at least daily during normal GPSIC working hours.

WWV/WWVH Voice Broadcasts

These short-wave voice broadcasts contain current GPS status and outage information in a 45-second message. The message is broadcast at minutes 14 and 15 past each hour on WWV and at minutes 43 and 44 past the hour on WWVH. The information is updated at least daily during normal GPSIC working hours. WWV and WWVH operate at 5.0, 10.0, and 15.0 MHz.

US Coast Guard Broadcast to Mariners

GPS status, future outages, and safety advisories are transmitted on the VHF marine radio band. The information is updated weekly and whenever satellite outages occur.

GPSIC Compute Bulletin Board Service (BBS)

GPSIC operates BBS that lists status, outage, almanac, and other GPS information. The BBS is available to any user free of charge, except for normal telephone fees. To access the BBS, the user will need a computer, a modem, and communication software. Users obtain a User ID password on line during the first session. The following information will be found useful in connecting to the GPSIC BBS. p62

Call 703-866-3890* for connections at 300 bps/Bell103, 1200 bps/Bell 212A, 2400 bps/CCITT V.22bis, no MNP capability (common US specs, Supramodem 2400).

Call 703-866-3893* for connections at 1200 bps/CCITT V.22bis, 1200 bps/CCITT V.22, 1200 bps/Bell 212A, 2400 bps/CCITT V.22bis, 4800 bps/CCITT V.32, 9600 bps/CCITT V.32 and MNP capabilities level 2,3,4,5, none (DigiCom Systems 9624).

Communications parameters at both numbers:

Asynchronous No parity

8 data bits Full duplex

1 stop bit (10-bit word)

* FTS subscribers: 398-3890/3894 Autovan access in not available.

The BBS ignores the 8th bit of data, restricting the character set to the lower 128 ASCII values. The BBS also checks for ANSI graphics capability, and employs some ANSI graphics if the user's equipment can display them. All users get the same information, but non-ANSI users will not see color images.

Defense Mapping Agency ANMS

The Defense Mapping Agency's Navigation Information Network, Automated Notice to Mariners System is a computer database that contains GPS status, outage, almanac, and other information. GPSIC updates the information at least daily. The information is contained in query number 85.

Users must register with DMA. To obtain a user ID and information booklet, contact:

Defense Mapping Agency

Attention: Navigation Department

4600 Sangamore Road

Bethesda Maryland 20816-5003

301-227-3296

DMA Broadcast Warnings

GPSIC provides GPS status, future outages, and safety advisories through the DMA HYDROLANT, HYDROPAC, and NAVAREA warning systems. These warnings are updated weekly and whenever satellite outages occur.

DMA Weekly Notice to Mariners

DMA publishes weekly navigation warnings and notices to mariners in a weekly publication "Notices to Mariners." This publication automatically includes active GPS status and outage information generated by both broadcast and NAVAREA warnings.

Distributed by:

Director, DMA

Customer Service Division

Attention: CSIE

Bethesda Maryland 20315-0010

NAVTEX Text Broadcast

The Coast Guard Local Notice to Mariners and DMA Broadcast Warnings also include text broadcast that contains the same information as the voice broadcasts. NAVTEX data is broadcast in English at 518 KHz from 16 transmitters worldwide. GPS status and outage information is available on NAVTEX.

Reference Documents

Two excellent reference books on GPS theory are:

Wells: *Guide to GPS Positioning* ISBN 0-920-114-73-3

Available from Canadian GPS Associates

Box 5378, Postal Station F Ottawa, Ontario Canada K2C 3J1

King, Masters, Rizos, Stolz, Collins: *Surveying with GPS* ISBN 0-85839-042-6

Available from School of Surveying, University of New South Wales

P.O. Box 1 Kensington, NSW, 2033, Australia

Heavy mathematical treatment:

Leick: *GPS Satellite Surveying* ISBN 0-471-81990-5

Wiley Interscience 605 3rd Avenue New York NY 10158-0012

Excellent overview of geodesy:

Smith: *Basic Geodesy - An Introduction to the History and Concepts* of Modern Geodesy without Mathematics ISBN 0-910845-33-6

Landmark Enterprises, 10324 Newton Way, Rancho Cordova CA 95670

NMEA Standards

NMEA Standard 0183: Standard for Interfacing Marine Electronic Navigational Devices

National Marine Electronics Association

7074 Bembe Beach Road

Annapolis Maryland 21403

Sources of GPS Information

NOAA, National Geodetic Survey

N-NGS12-SSMC3 Rm. 9202

1315 East West Highway

Silver Spring Maryland 20910 301-713-3242

Institute of Navigation

1800 Diagonal Road #480

Alexandria Virginia 22314 703-683-7101